Lecture 5, Regular Expressions

36-350

10 September 2014

In Our Last Thrilling Episode

- Characters and strings
- Matching strings, splitting on strings, counting strings
- We need a ways to compute with *patterns* of strings

Agenda

- Patterns of strings: regular expressions
- Grammar of regular expressions
- Splitting, searching, replacing
- Capture groups

Why We Need String Patterns

Split entries in a data file separate by commas:

```
strsplit(some_text, split=",")
```

Split entries in a data file separated by one space:

```
strsplit(some_text, split= " ")
```

=== Split entries in a data file separated by a comma, then a space:

```
strsplit(text, split=", ")
```

Split entries in a data file separated by a comma, then *optionally* some spaces:

```
???????
```

Regular Expressions

- We need a language for telling R about patterns of strings
- The most basic such language is that of **regular expressions**
- Regular expressions **match** sets of strings
- Start with string constants, and build up by allowing "*this* and then *that*", "either *this* or *that*", "repeat *this*"
- These rules get expressed in a **grammar**, with special symbols

Grammar of Regular Expressions

- Every string is a valid regexp
  `fly` matches end of `fruitfly`, `why walk when you can fly`
  does not match `time flies like an arrow; fruit flies like a banana; a banana flies poorly`
- OR of two regexps is a regexp, write with `|`
  `fly|flies`
- **Concatenation** of two regexps is a regexp
  `time|fruit fly|flies`
- Parentheses create groups: `(time|fruit) (fly|flies)`

Escaping, Ranges

- **Escape** special characters with a leading `\` to match them
- Use braces `[]` to indicate character ranges
  `[a-z]`, `[0-9]`, many pre-named ones like `[:punct:]` for punctuation marks
- **Negate** a character range with a leading `^`
  `[^aeiou]` = anything except a lower-case vowel
- The period `.` stands for any character, no brackets needed

Quantifiers in Regexps

How often? - `+` after a regexp means "1 or more times" - `*` means "0 or more times" - `?` means "0 or 1 times" (optional, once) - `{n}` means "exactly n times" - `{n,}` means "n or more times" - `{n,m}` means "between n and m times (inclusive)"
some redundancy, e.g., can fake `+` with `*`

Quantifier Scope

- By default, quantifiers are "greedy", match as many repetitions as they can
- Following a quantifier by `?` makes it match as few as possible
  `\[.+\]` matches all of `[i][j]`, but `\[.+?\]` just matches `[i]`
- By default, quantifiers apply to last character; use parentheses
  `H(TT)+` vs. `(HH|TT)+`

Anchoring

- `$` means a pattern can only match at the beginning of a line or string
- `^` means (outside of braces) the end of a line or string
- `<` and `>` anchor to beginning or ending of words
- `\b` anchors boundary (beginning *or* ending) of words, `\B` anywhere else
- e.g. `[a-z,]$` matches lines ending in a lower-case letter or comma
- e.g., `\B[A-Z]` matches capital letters not at the beginning or ending of a word

Back-References

- Use `\1`, `\2`, etc., to refer to whatever matched the 1st, 2nd, etc. parenthesized sub-expression
- The matching strings are **captures**, **capture-groups** or **captured strings**
- `[HT]+` matches any sequence of heads and tails
- `([HT]+)\1` matches any sequence of heads and tails that exactly repeats

Self-Referentially

- Regular expressions are strings
- ∴ a regexp can be stored in a `character` variable
- regexps can be built up and changed using string-manipulating functions

Splitting on a Regexp

- `strsplit` will take a regexp as its `split` argument
- Splits a string into new strings at each instance of the regexp, just like it would if `split` were a string

=== Last time:

```
al2 <- readLines("http://www.stat.cmu.edu/~cshalizi/statcomp/14/lectures/04/al2.txt")
al2 <- paste(al2, collapse=" ")
al2.words1 <- strsplit(al2, split=" ")
```

=== Weird results (e.g., punctuation marks as parts of wordss)

```
head(sort(table(al2.words1)))
```

```
## al2.words1
##       -    "the    "Woe absorbs  accept achieve
##       1       1       1       1       1       1
```

===

Better:

```
al2.words2 <- strsplit(al2, split="(\\s|[[:punct:]])+")[[1]]
```

===

```
head(sort(table(al2.words2)))
```

```
## al2.words2
## absorbs  accept achieve against  agents     aid
##       1       1       1       1       1       1
```

Closer examination shows there's still a problem:
"men's" → "men", "s"

===

Handle possessives: look for any number of white spaces, *or* at least one puncutation mark followed by at least one space

```
al2.words3 <- strsplit(al2, split="\\s+|([[:punct:]]+[[:space:]]+)")[[1]]
```

grep() and grepl()

`grep()` scans a character vector for matches to a regexp
returns either indices of matches, or matching strings

```
grep(x, pattern, value)
```

Example: scanning data files

ANSS.csv.html catalogs earthquakes of magnitude 6+, 1/1/2002–1/1/2012

===

```
<HTML><HEAD><TITLE>NCEDC_Search_Results</TITLE></HEAD><BODY>Your search parameters are:<ul>
<li>catalog=ANSS
<li>start_time=2002/01/01,00:00:00
<li>end_time=2012/01/01,00:00:00
<li>minimum_magnitude=6.0
<li>maximum_magnitude=10
<li>event_type=E
</ul>
<PRE>
DateTime,Latitude,Longitude,Depth,Magnitude,MagType,NbStations,Gap,Distance,RMS,Source,EventID
2002/01/01 10:39:06.82,-55.2140,-129.0000,10.00,6.00,Mw,78,,,1.07,NEI,2002010140
```

Now: extract *just* the data, not the search parameters and so forth

===

Notice: every line of *data* begins with a date, YYYY/MM/DD

```
anss <- readLines("http://www.stat.cmu.edu/~cshalizi/statcomp/14/lectures/05/ANSS.csv.html", warn=FALSE)
head(grep(x=anss,pattern="^[0-9]{4}/[0-9]{2}/[0-9]{2}"))
```

```
## [1] 11 12 13 14 15 16
```

Getting the value of the matches

```
head(grep(x=anss,pattern="^[0-9]{4}/[0-9]{2}/[0-9]{2}",value=TRUE))
```

```
## [1] "2002/01/01 10:39:06.82,-55.2140,-129.0000,10.00,6.00,Mw,78,,,1.07,NEI,2002010140"
## [2] "2002/01/01 11:29:22.73,6.3030,125.6500,138.10,6.30,Mw,236,,,0.90,NEI,2002010140"
## [3] "2002/01/02 14:50:33.49,-17.9830,178.7440,665.80,6.20,Mw,215,,,1.08,NEI,2002010240"
## [4] "2002/01/02 17:22:48.76,-17.6000,167.8560,21.00,7.20,Mw,427,,,0.90,NEI,2002010240"
## [5] "2002/01/03 07:05:27.67,36.0880,70.6870,129.30,6.20,Mw,431,,,0.87,NEI,2002010340"
## [6] "2002/01/03 10:17:36.30,-17.6640,168.0040,10.00,6.60,Mw,386,,,1.14,NEI,2002010340"
```

Storing a regexp in a variable

```
initial_date <- "^[0-9]{4}/[0-9]{2}/[0-9]{2}"
all.equal(grep(x=anss,pattern="^[0-9]{4}/[0-9]{2}/[0-9]{2}"),
   grep(x=anss,pattern=initial_date))
```

```
## [1] TRUE
```

Finding *non*-matches

The `invert` option:

```
grep(x=anss,pattern=initial_date,invert=TRUE,value=TRUE)
```

```
##  [1] "<HTML><HEAD><TITLE>NCEDC_Search_Results</TITLE></HEAD><BODY>Your search parameters are:<ul>"
##  [2] "<li>catalog=ANSS"
##  [3] "<li>start_time=2002/01/01,00:00:00"
##  [4] "<li>end_time=2012/01/01,00:00:00"
##  [5] "<li>minimum_magnitude=6.0"
##  [6] "<li>maximum_magnitude=10"
##  [7] "<li>event_type=E"
##  [8] "</ul>"
##  [9] "<PRE>"
## [10] "DateTime,Latitude,Longitude,Depth,Magnitude,MagType,NbStations,Gap,Distance,RMS,Source,EventID
## [11] "</PRE>"
## [12] "</BODY></HTML>"
```

grepl()

When you just want a Boolean vector saying where the matches are:

```
grepl(x=anss,pattern=initial_date)[1:20]
```

```
##  [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE  TRUE
## [12]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
```

More information about the matches

- `regexpr()` returns location of first match in the target string, plus attributes like length of matching substring
- `gregexpr()` returns a list of this for all matches
- A location of `-1` means no match
- Neither returns the *text* of the match

Getting the matching text

- `regmatches()` takes the output of `regexpr()` or `gregexpr()` and a string, and returns the matching strings
- Why separate `regexpr()` from `regmatches`?
  - Lets us do things like count the number or length of matches with less work
  - Lets us see what text in one file corresponds to matching locations in another file

Example: Extracting earthquake locations

Get the (latitude, longitude) pair for each earthquake:

```
one_geo_coord <- paste("-?[0-9]+\\.[0-9]{4}")
pair_geo_coords <- paste(rep(one_geo_coord,2),collapse=",")
have_coords <- grepl(x=anss,pattern=pair_geo_coords)
coord.matches <- gregexpr(pattern=pair_geo_coords,text=anss[have_coords])
coords <- regmatches(x=anss[have_coords],m=coord.matches)
```

===

```
coord.matches[1]
```

```
## [[1]]
## [1] 24
## attr(,"match.length")
## [1] 18
## attr(,"useBytes")
## [1] TRUE
```

`useBytes`: The default is to assume the ASCII encoding of characters for English, 1 character per byte. Other alphabets need longer encodings and forcing `useBytes=FALSE`

===

```
head(coords)
```

```
## [[1]]
## [1] "-55.2140,-129.0000"
##
## [[2]]
```

```
## [1] "6.3030,125.6500"
##
## [[3]]
## [1] "-17.9830,178.7440"
##
## [[4]]
## [1] "-17.6000,167.8560"
##
## [[5]]
## [1] "36.0880,70.6870"
##
## [[6]]
## [1] "-17.6640,168.0040"
```

Earthquake coordinates (cont'd)

You thought we'd forgotten data frames, didn't you?

```
coords <- do.call(c,coords)  # De-list-ify to vector
coord.pairs <- strsplit(coords,",")  # Break apart latitude and longitude
coord.df <- do.call(rbind, coord.pairs) # De-list-ify to array
coord.df <- apply(coord.df,2,as.numeric) # Character to numeric
coord.df <- as.data.frame(coord.df)
colnames(coord.df) <- c("Latitude","Longitude")
```

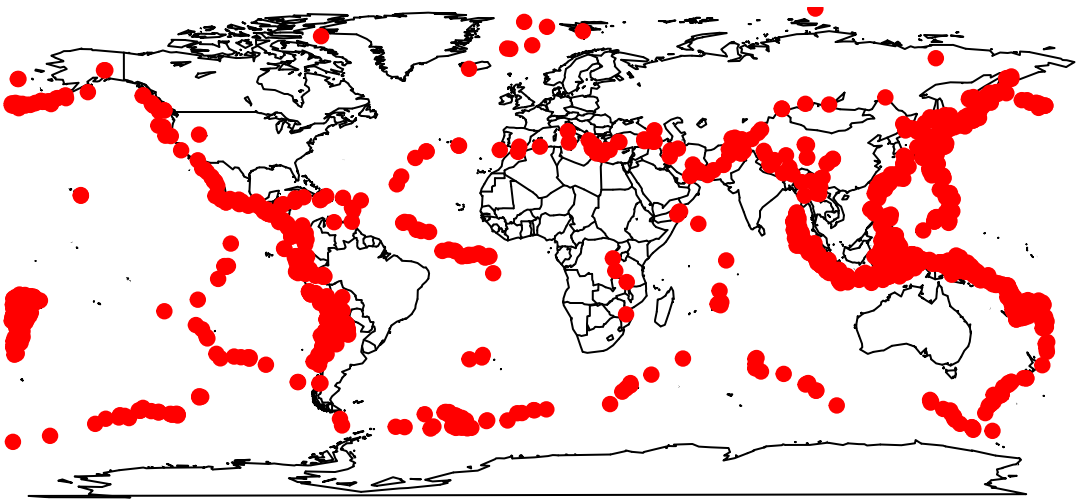
===

```
head(coord.df)
```

```
##   Latitude Longitude
## 1  -55.214   -129.00
## 2    6.303    125.65
## 3  -17.983    178.74
## 4  -17.600    167.86
## 5   36.088     70.69
## 6  -17.664    168.00
```

===

```
library(maps)
map("world")
points(x=coord.df$Longitude, y=coord.df$Latitude, pch=19, col="red")
```



Replacements

Assigning to `regmatches()` changes the matched string, just like `substr()`

`sub()` and `gsub()` work like `regexpr()` and `gregexpr()`, but with an extra `replace` argument

`sub()` produces a new string, assigning to `regmatches()` modifies the original one
Really, assigning to `regmatches()` creates a new string, destroys the old one, and assigns the new string the old name

Summary

- Regexps are text patterns built up from strings by alternation and repetition
- Mastering the syntax of regexps lets us scan text for complicated patterns
- Many string-based functions work with regexps as well
- Special functions exist to scan vectors for matches, to extract regexp matches, and to do substitutions