Lecture 5: Character Strings, Regular Expressions, and Web Scraping.

STAT GR5206 *Statistical Computing & Introduction to Data Science*

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September 28, 2018

Course Notes

Character Strings and String Operations

Textual Data

Analyzing textual data is common in machine learning and data science.

Textual Data Sources

- Classifying and analyzing tweets from Twitter.
- Answering, does this email belong in the spam filter?
- Processing and comparing survey responses.
- Working with character data such as names, birthdays, or addresses.

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`R` contains many functions for manipulating character data a few of which we study today.

Definition

- A **character** is a symbol in a written language - anything you can enter on a keyboard.
  Examples: 'Q', '*', '+', 'd', 'x', ' ', '{' etc.
- A **string** is a sequence of characters.
  Examples: 'Columbia University', 'cat, squirrel, hedgehog', etc.

Definition

- A **character** is a symbol in a written language - anything you can enter on a keyboard.
  Examples: ‘Q’, ‘*’, ‘+’, ‘d’, ‘x’, ‘ ’, ‘{’ etc.
- A **string** is a sequence of characters.
  Examples: ‘Columbia University’, ‘cat, squirrel, hedgehog’, etc.

- Both are type `character` in `R`.

```
> mode("d")
```

```
[1] "character"
```

```
> mode("cat, squirrel")
```

```
[1] "character"
```

- Both can go into scalars, vectors, matrices, lists, or dataframes.
- In `R` strings are denoted by quotation marks.

Whitespace

As noted above, whitespace ‘ ’ is considered a character and multiple spaces ‘ ’ a string.

```
> mode(" ")
```

```
[1] "character"
```

```
> nchar(" "); nchar("  "); nchar("")
```

```
[1] 1
[1] 2
[1] 0
```

Whitespace

As noted above, whitespace ‘ ’ is considered a character and multiple spaces ‘ ’ a string.

```
> mode(" ")
```

```
[1] "character"
```

```
> nchar(" "); nchar("  "); nchar("")
```

```
[1] 1
[1] 2
[1] 0
```

Special Characters

- Quotes within a string: `\"`
- Tab: `\t`
- New Line: `\n`

Strings as Elements of a Vector

If strings are elements of an object,

- `length()` reports the number of strings in the object, not the number of characters in the string.
- `nchar()` reports the number of character values in a string.
- `nchar()` is vectorized, like most R functions.

Strings as Elements of a Vector

```
> length("cat, squirrel, hedgehog")
```

```
[1] 1
```

```
> length(c("cat", "squirrel", "hedgehog"))
```

```
[1] 3
```

```
> nchar("cat, squirrel, hedgehog") # Not 25
```

```
[1] 23
```

```
> nchar(c("cat", "squirrel", "hedgehog"))
```

```
[1] 3 8 8
```

Printing Strings

- Can be displayed when their name is typed or using `print()`.
- Often want to use `cat()` to print character strings directly.
- `cat()` coerces its argument to strings, so can be useful when printing warnings.

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- Often want to use `cat()` to print character strings directly.
- `cat()` coerces its argument to strings, so can be useful when printing warnings.

```
> print("cat, squirrel")
```

```
[1] "cat, squirrel"
```

```
> cat("cat, squirrel")
```

```
cat, squirrel
```

```
> x <- 6
> y <- 7
> cat("I have", x, "cats and", y, "hedgehogs as pets.")
```

```
I have 6 cats and 7 hedgehogs as pets.
```

Printing Strings

```
> print("cat, \n squirrel")
```

```
[1] "cat, \n squirrel"
```

```
> cat("cat, \nsquirrel")
```

```
cat,
squirrel
```

```
> print("In R, an \"array\" is a multi-dimension matrix.")
```

```
[1] "In R, an \"array\" is a multi-dimension matrix."
```

```
> cat("A group of hedgehogs is called an \"array\".")
```

```
A group of hedgehogs is called an "array".
```

Check Yourself

Task

Use `print()` and `cat()` to print the following in R:

```
"Columbia\tUniversity"
```

How many characters are in the above? Why?

Substrings

- A **substring** is a smaller string taken from a larger string, but it is itself still a string.
- Note that we can't use regular subsetting options like `[[]]` or `[]` because a string isn't a vector or list.
- The `substr()` function can extract or change values of parts of strings.

Substrings

The call `substr(string, start = , stop = )` returns the substring from character position `start` to `stop` ii the given `string`.

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```
> phrase <- "Christmas Bonus"
> substr(phrase, start = 8, stop = 12)
```

```
[1] "as Bo"
```

```
> substr(phrase, start = 13, stop = 13) <- "g"
> phrase
```

```
[1] "Christmas Bogus"
```

Substrings

substr() vectorizes

```
> fav_animals <- c("cat", "squirrel", "hedgehog")
> substr(fav_animals, start = 1, stop = 2)
```

```
[1] "ca" "sq" "he"
```

```
> substr(fav_animals, nchar(fav_animals)-1,
+         nchar(fav_animals))
```

```
[1] "at" "el" "og"
```

```
> substr(fav_animals, start = 4, stop = 4)
```

```
[1] ""  "i" "g"
```

Dividing Strings into Vectors

`strsplit(string, split =)` divides its input string at the appearances of the pattern passed to `split`.

```
> todo <- "Lecture, Lab, Homework"
> strsplit(todo, split = ",")
```

```
[[1]]
[1] "Lecture"   " Lab"       " Homework"
```

```
> strsplit(todo, split = ", ")
```

```
[[1]]
[1] "Lecture"  "Lab"       "Homework"
```

Dividing Strings into Vectors

`strsplit(string, split =)` divides its input `string` at the appearances of the pattern passed to `split`.

```
> todo <- "Lecture, Lab, Homework"
> strsplit(todo, split = ",")
```

```
[[1]]
[1] "Lecture"    " Lab"       " Homework"
```

```
> strsplit(todo, split = ", ")
```

```
[[1]]
[1] "Lecture"   "Lab"       "Homework"
```

Note that the output of `strsplit()` is a list. Why?

Dividing Strings into Vectors

```
> todo <- "Lecture, Lab, Homework"
> strsplit(c(todo, "Midterm, Final"), split = ",")
```

```
[[1]]
[1] "Lecture"    " Lab"       " Homework"

[[2]]
[1] "Midterm" " Final"
```

The pattern is recycled over the elements of an input vector.

Check Yourself

Tasks

- Make a vector of three elements which are "Columbia", "slumber party", and "sugarplum". Make a call to `substr()` that returns the "lum" from each element of the vector. The output should be

  ```
  "lum" "lum" "lum"
  ```

- Use `strsplit()` on the vector you created splitting on "lum". Output should be a list of length three.

Building Strings from Multiple Parts

paste() combines strings into one long string and is very flexible.

```
> paste("cat", "squirrel", "hedgehog")
```

```
[1] "cat squirrel hedgehog"
```

```
> paste("cat", "squirrel", "hedgehog", sep = ", ")
```

```
[1] "cat, squirrel, hedgehog"
```

```
> paste(c("cat", "squirrel", "hedgehog"), 1:3)
```

```
[1] "cat 1"      "squirrel 2" "hedgehog 3"
```

```
> paste(c("cat", "squirrel", "hedgehog"), 1:2)
```

```
[1] "cat 1"      "squirrel 2" "hedgehog 1"
```

Building Strings from Multiple Parts

```
> paste(c("cat", "squirrel", "hedgehog"), "(", 1:3, ")")
```

```
[1] "cat ( 1 )"      "squirrel ( 2 )" "hedgehog ( 3 )"
```

```
> paste(c("cat", "squirrel", "hedgehog"), "(", 1:3, ")",
+       sep = "")
```

```
[1] "cat(1)"      "squirrel(2)" "hedgehog(3)"
```

```
> paste(c("cat", "squirrel", "hedgehog"), " (", 1:3, ")",
+       sep = "")
```

```
[1] "cat (1)"      "squirrel (2)" "hedgehog (3)"
```

Exercise

What happens when you pass a vector to the sep argument?

Condensing Multiple Strings

The `paste()` function can also condense multiple strings using the `collapse` argument.

```
> paste(c("cat", "squirrel", "hedgehog"), " (", 1:3, ")",
+       sep = "", collapse = "; ")
```

```
[1] "cat (1); squirrel (2); hedgehog (3)"
```

Check Yourself

Task

Use `paste()` with its first input being `c("Columbia", "slumber party", "sugarplum")` along with the `sep` and `collapse` arguments to create the following string:

`"Columbia [3-5]; slumber party [2-4]; sugarplum [7-9]".`

Searching Strings

Honor Code Example

The file `"HonorCode.txt"` contains Columbia University's Honor Code:

"Students should be aware that academic dishonesty (for example, plagiarism, cheating on an examination, or dishonesty in dealing with a faculty member or other University official) or the threat of violence or harassment are particularly serious offenses and will be dealt with severely under Dean's Discipline..."

Searching Strings

Code example.

Searching Strings

Honor Code Example

```
> HC <- readLines("HonorCode2.txt")
> length(HC)
```

```
[1] 43
```

```
> head(HC, 5)
```

```
[1] "Students should be aware that academic dishonesty (for e
[2] "examination, or dishonesty in dealing with a faculty mem
[3] "the threat of violence or harassment are particularly se
[4] "with severely under Dean's Discipline."
[5] ""
```

HC is a vector with one element per line of text in the Honor Code.

Searching Strings

The `grep(pattern, x)` function searches for a specified substring given by `pattern` in a vector `x` of strings.

Honor Code Example

```
> grep("students", HC)
```

```
[1]  6 15 23 30
```

```
> grep("Students", HC)
```

```
[1]  1 19 33
```

```
> head(grepl("students", HC), 15)
```

```
 [1] FALSE FALSE FALSE FALSE FALSE  TRUE FALSE FALSE FALSE
[10] FALSE FALSE FALSE FALSE FALSE  TRUE
```

Searching Strings

Honor Code Example

```
> grep("students", HC)
```

```
[1]  6 15 23 30
```

```
> HC[grep("students", HC)]
```

```
[1] "Graduate students are expected to exhibit the high level
[2] "In practical terms, students must not cheat on examinati
[3] "Graduate students are responsible for proper citation an
[4] "All incoming doctoral and master's students in the Arts a
```

Searching Strings

Using functions we've learned today, let's make `HC` a vector with each element a word of the Honor Code (instead of a line of text). Of course, could do this with `scan()`.

Honor Code Example

```
> HC <- paste(HC, collapse = " ") # One long string
> HC.words <- strsplit(HC, split = " ")[[1]] # List output
> head(HC.words, 10)
```

```
 [1] "Students"     "should"       "be"           "aware"
 [5] "that"         "academic"     "dishonesty"   "(for"
 [9] "example,"     "plagiarism,"
```

We can count words using `table()`.

Honor Code Example

```
> word_count <- table(HC.words)
> word_count <- sort(word_count, decreasing = TRUE)
> head(word_count, 10)
```

```
HC.words
  and    of    or   the    to    in          from     a    is
   23    17    16    13    11    10     8     6     5     5
```

Searching Strings

We can count words using `table()`.

Honor Code Example

```
> word_count <- table(HC.words)
> word_count <- sort(word_count, decreasing = TRUE)
> head(word_count, 10)
```

```
HC.words
 and   of   or  the   to   in        from    a   is
  23   17   16   13   11   10     8     6    5    5
```

This is much more simple than the strategy we used a few weeks ago to produce the same result!

Searching Strings

Honor Code Example

```
> word_count <- table(HC.words)
> word_count <- sort(word_count, decreasing = TRUE)
> head(word_count, 10)
```

```
HC.words
 and   of   or  the   to   in       from    a   is
  23   17   16   13   11   10    8     6    5    5
```

Some undesireable things are happening here...

- The null string `""` is the seventh most common word.
- Punctuation and capitalization are messing up our counts. (`"students"` vs. `"Students"` before).

Searching Strings

Honor Code Example

```
> head(word_count, 10)
```

```
HC.words
 and    of    or  the    to   in         from     a    is
  23    17    16   13    11   10      8     6      5     5
```

Some undesirable things are happening here...

```
> tail(word_count, 10)
```

```
HC.words
   vital   which   words    work   work;  works.   world
       1       1       1       1       1       1       1
   write Writing    your
       1       1       1
```

Check Yourself

Task

Use `grep()` to search over `names(word_count)` to find the number of words in the word count vector that have semi-colons in them. Hint:`";"` should be one of your arguments to grep. Using your result print the words that `grep()` finds.

Functions for Character Data

Next

We want to search for text patterns instead of text constants. We can do this with regular expressions.

Summary

- `nchar()`: Finds the length of a string.
- `substring()`: Extracts substrings and substitutes.
- `strsplit()`: Turns strings into vectors.
- `paste()`: Turns vectors into a string.
- `grep()`: Search for patterns in a string.

Regular Expressions

Why Do We Need Regular Expressions

```
> fav_animals <- "cat,squirrel, hedgehog,   octopus"
```

Why Do We Need Regular Expressions

```
> fav_animals <- "cat,squirrel, hedgehog,   octopus"
```

```
> strsplit(fav_animals, split = ",")
```

```
[[1]]
[1] "cat"        "squirrel"   " hedgehog"  "   octopus"
```

Why Do We Need Regular Expressions

```
> fav_animals <- "cat,squirrel, hedgehog,   octopus"
```

```
> strsplit(fav_animals, split = ",")
```

```
[[1]]
[1] "cat"          "squirrel"    " hedgehog"   "   octopus"
```

```
> strsplit(fav_animals, split = " ")
```

```
[[1]]
[1] "cat,squirrel," "hedgehog,"      ""
[4] ""              "octopus"
```

Why Do We Need Regular Expressions

```
> fav_animals <- "cat,squirrel, hedgehog,   octopus"
```

```
> strsplit(fav_animals, split = ", ")
```

```
[[1]]
[1] "cat,squirrel" "hedgehog"     "  octopus"
```

Why Do We Need Regular Expressions

```
> fav_animals <- "cat,squirrel, hedgehog,   octopus"
```

```
> strsplit(fav_animals, split = ", ")
```

```
[[1]]
[1] "cat,squirrel" "hedgehog"     "  octopus"
```

Need to split the entries by a commma and *optionally* some space.

Why Do We Need Regular Expressions

It's not just annoying we can't do these things, there are a lot of examples where we have to do such manipulations.

- When scraping data from a webpage, will need to get rid of formatting instructions buried in the source of the webpage.
- Names may be preceded by titles such as Mr., Mrs., or Dr. that we aren't interested in using.

Regular Expressions

- **Regular expressions** are a method of expressing patterns in character strings.
- Used to match sets of strings or patterns of strings in `R`.
- Can express ideas like match "*this* and then *that*", "either *this* or *that*", "*this* repeated some number of times".
- **Regular expressions** are rules expressed in a grammar with special symbols.

Rules for Regular Expressions

1. Every string is a regular expression.
   - `"cat"` matches `"categorize"` and `"dogs and cats"`.
   - `"cat"` does not match `"Dog is man's best friend"` and `"work doggedly"`.

Rules for Regular Expressions

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   - `"cat"` does not match `"Dog is man's best friend"` and `"work doggedly"`.
2. Can represent `OR` with a vertical bar `|`.
   - `"cat|dog|Dog"` matches all of the above.

Rules for Regular Expressions

1. Every string is a regular expression.
   - `"cat"` matches `"categorize"` and `"dogs and cats"`.
   - `"cat"` does not match `"Dog is man's best friend"` and `"work doggedly"`.
2. Can represent `OR` with a vertical bar `|`.
   - `"cat|dog|Dog"` matches all of the above.
3. Precede special characters like `|` with a backslash \ to match exactly.
   - `"A\|b"` matches `"P(A|b)"`.
   - `"A|b"` matches twice in `"Alabama"` and twice in `"blueberry"`.

Rules for Regular Expressions

When I say 'matches', I mean in R:

```
> grep("cat|dog", c("categorize", "work doggedly"))
```

```
[1] 1 2
```

```
> grep("A|b", c("Alabama", "blueberry", "work doggedly"))
```

```
[1] 1 2
```

Rules for Regular Expressions

1. Indicate sets of characters with brackets `[]`.
   - `"[a-z]"` matches any lower case letters.
   - `"[:punct:]"` matches all punctuation marks.
2. The caret ^ negates a character range when in the leading position.
   - `"[^aeiou]"` matches any characters except lower-case vowels.
3. The period `.` stands for any character and doesn't need brackets.
   - `"c..s"` matches `"cats"`, `"class"`, `"c88s"`, `"c  s"`, etc.

Rules for Regular Expressions

Quantifiers can be used to tell “how often” an expression occurs.

Quantifier	Description (Match if the expression is ...)
`+`	Repeated one or more times.
`*`	Repeated zero or more times.
`?`	Repeated zero or one times.
`{n}`	Repeated exactly `n` times.
`{n, }`	Repeated `n` or more times.
`{n, m}`	Repeated between `n` and `m` times.

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Notes

- Quantifiers apply to the last character before they appear.
- Any valid expression can be enclosed in parentheses for grouping.

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`?`	Repeated zero or one times.
`{n}`	Repeated exactly `n` times.
`{n, }`	Repeated `n` or more times.
`{n, m}`	Repeated between `n` and `m` times.

Examples

- `"[0-9][0-9][a-zA-z]+"` matches strings with two digits followed by one or more letters.
- `"(abc){3}"` matches three consecutive occurrences of `"abc"`.
- `"abc{3}"` matches `"abccc"`.

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`+`	Repeated one or more times.
`*`	Repeated zero or more times.
`?`	Repeated zero or one times.
`{n}`	Repeated exactly `n` times.
`{n, }`	Repeated `n` or more times.
`{n, m}`	Repeated between `n` and `m` times.

Examples

- `"M[rs][rs]?\.?"` matches `"Mr"`, `"Ms"`, `"Mrs"`, `"Mr."`, `"Ms."`, `"Mrs."`.
- The above also matches `"Mrr"`, `"Msr"`, `"Mss"`, `"Mrr."`, `"Msr."`, `"Mss."` (and nothing else).

Rules for Regular Expressions

1. The dollar sign $ means that a pattern only matches at the end of a line.
   - `"[a-z,]$"` matches strings ending in lower-case letters or a comma.
2. The caret ^ outside of brackets means that a pattern only matches at the beginning of a line.
   - `"^[^A-Z]"` matches strings not beginning with capital letters.

Regular Expressions in `R`

- Many `R` functions we've already seen take regular expressions as their arguments.
    - `strsplit()` can use a regular expression to divide a string into a vector.
    - `grep()` can search for patterns represented by regular expressions in a string.

Regular Expressions in R

Honor Code Example

Without regular expressions we get weird results when we try to count words:

```
> head(word_count, 10)
```

```
HC.words
 and    of    or   the    to    in        from     a    is
  23    17    16    13    11    10     8     6     5     5
```

```
> tail(word_count, 10)
```

```
HC.words
   vital    which    words     work    work;   works.    world
       1        1        1        1        1        1        1
   write  Writing     your
       1        1        1
```

Regular Expressions in R

Honor Code Example

```
> HC <- readLines("HonorCode2.txt")
> length(HC)
```

```
[1] 43
```

```
> head(HC, 5)
```

```
[1] "Students should be aware that academic dishonesty (for e
[2] "examination, or dishonesty in dealing with a faculty mem
[3] "the threat of violence or harassment are particularly se
[4] "with severely under Dean's Discipline."
[5] ""
```

HC is a vector with one element per line of text in the Honor Code.

Regular Expressions in R

Honor Code Example

```
> HC <- paste(HC, collapse = " ") # One long string
> HC.words <- strsplit(HC, split=" ")[[1]] # Last Time
> HC.words <- strsplit(HC, split="(\\s|[[:punct:]])+")[[1]]
> head(HC.words, 10)
```

```
 [1] "Students"    "should"      "be"          "aware"
 [5] "that"        "academic"    "dishonesty"  "for"
 [9] "example"     "plagiarism"
```

- Splits at blocks of *only* whitespace and/or punctuation.
- Regular expression is enclosed in quotation marks.
- `"\s"` is a special character like `"\n"` or `"\t"`.

Honor Code Example

In the previous we have the following problem: `university's` splits to `university` and `s`.

Exercise

Check that `split = "\\s+|([[:punct:]]+[[:space:]]+)"` gives us what we want: *either* any number of white spaces *or* at least one punctuation mark followed by at least one space.

`help(regexp)`

Earthquakes Example

- Recall that the `grep()` functions search a character string for a specified pattern.
- Now we can use regular expressions to specify that pattern.
- We're going to practice using some data from the web.

Earthquakes Example

Code Example.

Earthquakes Example

```
> quakes <- readLines("NCEDC_Search_Results.html",
+                     warn = FALSE)
> head(quakes)
```

```
[1] "<HTML><HEAD><TITLE>NCEDC_Search_Results</TITLE></HEAD><BODY>Yo
[2] "<li>catalog=ANSS"
[3] "<li>start_time=2002/01/01,00:00:00"
[4] "<li>end_time=2016/01/01,00:00:00"
[5] "<li>minimum_magnitude=6.0"
[6] "<li>maximum_magnitude=10"
```

We suppress a superfluous warning about end-of-line character in the `readLines()` call.

Earthquakes Example

```
> tail(quakes)
```

```
[1] "2015/12/19 02:10:53.36 -18.3819  169.3857  10.00  6.00
[2] "2015/12/20 18:47:35.53   3.6384  117.6310   6.93  6.10
[3] "2015/12/24 19:44:03.13 -55.7550 -123.1158  12.28  6.20
[4] "2015/12/25 19:14:47.17  36.4872   71.1308 206.00  6.30
[5] "</PRE>"
[6] "</BODY></HTML>"
```

Every earthquake of magnitude 6 on the Richter scale from January 1, 2002 until January 1, 2016.

Earthquakes Example

```
> quakes[8:15]
```

```
[1] "</ul>"
[2] "<PRE>"
[3] "Date        Time            Lat        Lon  Depth   Mag Magt  N
[4] "--------------------------------------------------------------
[5] "2002/01/01 10:39:06.82 -55.2140 -129.0000  10.00  6.00    Mw
[6] "2002/01/01 11:29:22.73   6.3030  125.6500 138.10  6.30    Mw  2
[7] "2002/01/02 14:50:33.49 -17.9830  178.7440 665.80  6.20    Mw  2
[8] "2002/01/02 17:22:48.76 -17.6000  167.8560  21.00  7.20    Mw  4
```

Earthquakes Example

```
> quakes[8:15]
```

```
[1] "</ul>"
[2] "<PRE>"
[3] "Date       Time            Lat        Lon   Depth    Mag Magt  N
[4] "-----------------------------------------------------------------
[5] "2002/01/01 10:39:06.82 -55.2140 -129.0000  10.00  6.00    Mw
[6] "2002/01/01 11:29:22.73   6.3030  125.6500 138.10  6.30    Mw  2
[7] "2002/01/02 14:50:33.49 -17.9830  178.7440 665.80  6.20    Mw  2
[8] "2002/01/02 17:22:48.76 -17.6000  167.8560  21.00  7.20    Mw  4
```

Tasks

- Get rid of the first few lines of HTML formatting code and search parameters.
- Actual data begins on line 12. Headers on line 11.
- Strategy: all data lines begin with a date in format YYYY/MM/DD.

Earthquakes Example

Extracting the Data

```
> date_express <- "^[0-9]{4}/[0-9]{2}/[0-9]{2}"
> head(grep(quakes, pattern = date_express))
```

```
[1] 12 13 14 15 16 17
```

Earthquakes Example

Extracting the Data

```
> date_express <- "^[0-9]{4}/[0-9]{2}/[0-9]{2}"
> head(grep(quakes, pattern = date_express))
```

```
[1] 12 13 14 15 16 17
```

```
> head(grep(quakes, pattern = date_express, value = TRUE))
```

```
[1] "2002/01/01 10:39:06.82 -55.2140 -129.0000  10.00  6.00
[2] "2002/01/01 11:29:22.73   6.3030  125.6500 138.10  6.30
[3] "2002/01/02 14:50:33.49 -17.9830  178.7440 665.80  6.20
[4] "2002/01/02 17:22:48.76 -17.6000  167.8560  21.00  7.20
[5] "2002/01/03 07:05:27.67  36.0880   70.6870 129.30  6.20
[6] "2002/01/03 10:17:36.30 -17.6640  168.0040  10.00  6.60
```

Earthquakes Example

What are we leaving behind?

```
> grep(quakes, pattern = date_express,
+       invert = TRUE, value = TRUE)
```

```
 [1] "<HTML><HEAD><TITLE>NCEDC_Search_Results</TITLE></HEAD><BODY>Y
 [2] "<li>catalog=ANSS"
 [3] "<li>start_time=2002/01/01,00:00:00"
 [4] "<li>end_time=2016/01/01,00:00:00"
 [5] "<li>minimum_magnitude=6.0"
 [6] "<li>maximum_magnitude=10"
 [7] "<li>event_type=E"
 [8] "</ul>"
 [9] "<PRE>"
[10] "Date       Time             Lat       Lon  Depth   Mag Magt
[11] "-------------------------------------------------------------
[12] "</PRE>"
[13] "</BODY></HTML>"
```

Check Yourself

Task

- We just extracted the lines we need by noting that they all begin with a date. The lines we need also seem to all end in an event i.d. which is a 12 digit code. Use this idea with `grep()` to extract the lines of actual data.
- This won't work – we leave behind some data lines. What happened?
- How else could we search for the data using regular expressions?

More Commands in the `grep()` Family

All return information about where regular expressions are matched *in a string*.

- `grep()` returns a logical indicating a match.
- `regexpr()` returns the location of the first match with attributes like the length of the match.
- `gregexpr()` works similarly to `regexpr()`, but returns *all* matching locations. ‘`g`’ for `global`.
- `regmatches()` takes strings and the output of `regexpr()` or `gregexpr()` and returns the actual matching strings.

More Commands in the grep() Family

Examples

```
> # Is there a match?
> grep("a[a-z]", "Alabama")
```

```
[1] 1
```

```
> # Information about the first match.
> regexpr("a[a-z]", "Alabama")
```

```
[1] 3
attr(,"match.length")
[1] 2
attr(,"useBytes")
[1] TRUE
```

More Commands in the grep() Family

Examples

```
> # Information on all matches.
> gregexpr("a[a-z]", "Alabama")
```

```
[[1]]
[1] 3 5
attr(,"match.length")
[1] 2 2
attr(,"useBytes")
[1] TRUE
```

```
> # What are the matches?
> regmatches("Alabama", gregexpr("a[a-z]", "Alabama"))
```

```
[[1]]
[1] "ab" "am"
```

Earthquakes Example

Let's Extract the (longitude, latitude) Pairs

```
> quakes[11:15]
```

```
[1] "-----------------------------------------------------
[2] "2002/01/01 10:39:06.82 -55.2140 -129.0000  10.00  6.00
[3] "2002/01/01 11:29:22.73   6.3030  125.6500 138.10  6.30
[4] "2002/01/02 14:50:33.49 -17.9830  178.7440 665.80  6.20
[5] "2002/01/02 17:22:48.76 -17.6000  167.8560  21.00  7.20
```

```
> coord_exp <- "-?[0-9]+\\.[0-9]{4}"
> full_exp <- paste(coord_exp, "\\s+", coord_exp, sep = "")
```

Earthquakes Example

Let's Extract the (longitude, latitude) Pairs

```
> quakes[11:15]
```

```
[1] "--------------------------------------------------------
[2] "2002/01/01 10:39:06.82 -55.2140 -129.0000  10.00  6.00
[3] "2002/01/01 11:29:22.73   6.3030  125.6500 138.10  6.30
[4] "2002/01/02 14:50:33.49 -17.9830  178.7440 665.80  6.20
[5] "2002/01/02 17:22:48.76 -17.6000  167.8560  21.00  7.20
```

```
> coord_exp <- "-?[0-9]+\\.[0-9]{4}"
> full_exp <- paste(coord_exp, "\\s+", coord_exp, sep = "")
```

A negative sign zero or one times with digits $0-9$ one or more times followed by a period and four digits.

Earthquakes Example

```
> head(grepl(quakes, pattern = full_exp), 15)
```

```
 [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
[10] FALSE FALSE  TRUE  TRUE  TRUE  TRUE
```

```
> coord_log <- grepl(quakes, pattern = full_exp)
> matches   <- gregexpr(pattern = full_exp,
+                       text = quakes[coord_log])
> head(matches, 1)
```

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

Earthquakes Example

Let's Extract the (longitude, latitude) Pairs

```
> coords <- regmatches(quakes[coord_log], matches)
> head(coords, 4)
```

```
[[1]]
[1] "-55.2140 -129.0000"

[[2]]
[1] "6.3030  125.6500"

[[3]]
[1] "-17.9830  178.7440"

[[4]]
[1] "-17.6000  167.8560"
```

Earthquakes Example

Let's get the data out of a list and put it in a two-column matrix.

Let's Extract the (longitude, latitude) Pairs

```
> coords_split <- sapply(coords, strsplit, split="\\s+")
> head(coords_split, 3)
```

```
[[1]]
[1] "-55.2140"  "-129.0000"

[[2]]
[1] "6.3030"   "125.6500"

[[3]]
[1] "-17.9830" "178.7440"
```

Earthquakes Example

Let's get the data out of a list and put it in a two-column matrix.

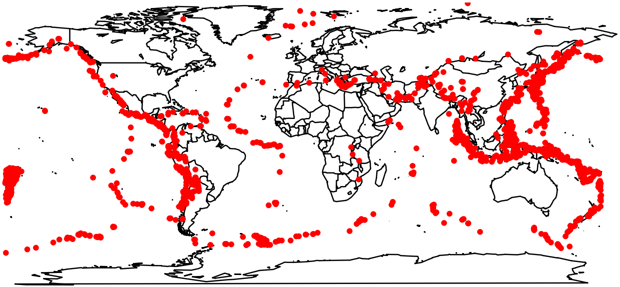
Let's Extract the (longitude, latitude) Pairs

```
> coords_mat <- matrix(unlist(coords_split), ncol = 2,
+                      byrow = TRUE)
> colnames(coords_mat) <- c("Latitude", "Longitude")
> head(coords_mat)
```

```
     Latitude  Longitude
[1,] "-55.2140" "-129.0000"
[2,] "6.3030"   "125.6500"
[3,] "-17.9830" "178.7440"
[4,] "-17.6000" "167.8560"
[5,] "36.0880"  "70.6870"
[6,] "-17.6640" "168.0040"
```

Earthquakes Example

```
> library(maps)
> map("world")
> points(coords_mat[,"Longitude"], coords_mat[,"Latitude"],
+         pch = 19, col = "red", cex = .5)
```



What is Web Scraping?

- We've learned about getting data in and out of `R` when it's structured: `read.table()`, `read.csv()`, etc.
- Often, like the last example, it's not as structured.
  - Could have metadata.
  - Non-tabular arrangement.
- In general this is true of data on the web.

Strategy

Read in line-by-line and split into a nicer format (generally requires a lot of regular expressions).

What is Web Scraping?

- Webpages are generally designed for humans to read.
- Use a computer to extract the information we actually want.
- Iterate the process.

Strategy

Take in unstructured pages, return rigidly-formatted data.

What is Web Scraping?

How do we use the computer extract the information we want?

What is Web Scraping?

How do we use the computer extract the information we want?

- Information is *somewhere* in the page source, usually in the HTML code.
- Often some sort of marker or pointer surrounding the data (again, usually HTML).
- Pick apart the HTML to leave the data using regular expressions.

What is Web Scraping?

How do we pick apart HTML code with regular expressions?

What is Web Scraping?

How do we pick apart HTML code with regular expressions?

- What *exactly* do we want from the page?
- How is the page organized? Where is the information we want located?
    - How does it show up on the webpage?
    - How is that represented in the HTML?
- Write a function to automate the information extraction.
- Now iterate over relevant pages.