

Data Scraping and Cleaning

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Part 1: Data scraping and preparation

Step 1: Scrape your competitor's data (10 pts)

```
weather_url <- "https://www.spaceweatherlive.com/en/solar-activity/top-50-solar-flares"

# retrieve the table
weather_tab <- weather_url %>%
  read_html() %>%
  html_node('table') %>%
  html_table()

# rename columns
colnames(weather_tab) <- c('rank', 'flare_classification', 'date', 'flare_region', 'start_time',
                          'maximum_time', 'end_time', 'movie')

head(weather_tab)
```

##	rank	flare_classification	date	flare_region	start_time	maximum_time
## 1	1	X28+	2003/11/04	486	19:29	19:53
## 2	2	X20+	2001/04/02	9393	21:32	21:51
## 3	3	X17.2+	2003/10/28	486	09:51	11:10
## 4	4	X17+	2005/09/07	808	17:17	17:40
## 5	5	X14.4	2001/04/15	9415	13:19	13:50
## 6	6	X10	2003/10/29	486	20:37	20:49
##	end_time	movie				
## 1	20:06	MovieView archive				
## 2	22:03	MovieView archive				
## 3	11:24	MovieView archive				
## 4	18:03	MovieView archive				
## 5	13:55	MovieView archive				
## 6	21:01	MovieView archive				

Step 2: Tidy the top 50 solar flare data (10 pts)

```
# drop last column
weather_tab <- select(weather_tab, -'movie')

# combine the date and times
weather_tab <- weather_tab %>%
```

```

mutate(start_time = paste(date, start_time, sep = ' ')) %>%
mutate(maximum_time = paste(date, maximum_time, sep = ' ')) %>%
mutate(end_time = paste(date, end_time, sep = ' '))

# convert the combined columns into datetime objects
weather_tab <- weather_tab %>%
  mutate(start_time = make_datetime(
    year = strtoi(str_sub(start_time, start = 1L, end = 4L), base = 10L),
    month = strtoi(str_sub(start_time, 6L, 7L), base = 10L),
    day = strtoi(str_sub(start_time, 9L, 10L), base = 10L),
    hour = strtoi(str_sub(start_time, 12L, 13L), base = 10L),
    min = strtoi(str_sub(start_time, 15L, 16L), base = 10L),
    sec = 0)) %>%
  mutate(end_time = make_datetime(
    year = strtoi(str_sub(end_time, start = 1L, end = 4L), base = 10L),
    month = strtoi(str_sub(end_time, 6L, 7L), base = 10L),
    day = strtoi(str_sub(end_time, 9L, 10L), base = 10L),
    hour = strtoi(str_sub(end_time, 12L, 13L), base = 10L),
    min = strtoi(str_sub(end_time, 15L, 16L), base = 10L),
    sec = 0)) %>%
  mutate(maximum_time = make_datetime(
    year = strtoi(str_sub(maximum_time, start = 1L, end = 4L), base = 10L),
    month = strtoi(str_sub(maximum_time, 6L, 7L), base = 10L),
    day = strtoi(str_sub(maximum_time, 9L, 10L), base = 10L),
    hour = strtoi(str_sub(maximum_time, 12L, 13L), base = 10L),
    min = strtoi(str_sub(maximum_time, 15L, 16L), base = 10L),
    sec = 0)) %>%
  select(rank, flare_classification, flare_region, start_datetime = start_time, maximum_datetime = maximum_time, end_datetime = end_time)

head(weather_tab)

```

```

##   rank flare_classification flare_region      start_datetime
## 1    1                X28+         486 2003-11-04 19:29:00
## 2    2                X20+        9393 2001-04-02 21:32:00
## 3    3             X17.2+         486 2003-10-28 09:51:00
## 4    4                X17+         808 2005-09-07 17:17:00
## 5    5             X14.4        9415 2001-04-15 13:19:00
## 6    6                X10         486 2003-10-29 20:37:00
##           maximum_datetime      end_datetime
## 1 2003-11-04 19:53:00 2003-11-04 20:06:00
## 2 2001-04-02 21:51:00 2001-04-02 22:03:00
## 3 2003-10-28 11:10:00 2003-10-28 11:24:00
## 4 2005-09-07 17:40:00 2005-09-07 18:03:00
## 5 2001-04-15 13:50:00 2001-04-15 13:55:00
## 6 2003-10-29 20:49:00 2003-10-29 21:01:00

```

Step 3. Scrape the NASA data (15 pts)

```

NASA_url <- "https://cdaw.gsfc.nasa.gov/CME_list/radio/waves_type2.html"

# convert the HTML into a table-like structure
NASA_tab <- NASA_url %>%

```

```

read_html() %>%
html_node('pre') %>%
html_text() %>%
str_sub(802, -99) %>%
strsplit(split = '\n')

# insert the vector of strings into a dataframe
NASA_tab <- data.frame(NASA_tab)
colnames(NASA_tab) <- c('raw_data')

# parse the raw data into separate columns
NASA_tab[, 'start_date'] <- NASA_tab$raw_data %>%
  substr(1, 10) %>%
  str_trim()
NASA_tab[, 'start_time'] <- NASA_tab$raw_data %>%
  substr(12, 17) %>%
  str_trim()
NASA_tab[, 'end_date'] <- NASA_tab$raw_data %>%
  substr(18, 22)
NASA_tab[, 'end_time'] <- NASA_tab$raw_data %>%
  substr(24, 29)
NASA_tab[, 'start_freq'] <- NASA_tab$raw_data %>%
  substr(30, 35) %>%
  str_trim()
NASA_tab[, 'end_freq'] <- NASA_tab$raw_data %>%
  substr(36, 41) %>%
  str_trim()
NASA_tab[, 'location'] <- NASA_tab$raw_data %>%
  substr(42, 49) %>%
  str_trim()
NASA_tab[, 'NOAA'] <- NASA_tab$raw_data %>%
  substr(50, 55) %>%
  str_trim()
NASA_tab[, 'imp'] <- NASA_tab$raw_data %>%
  substr(56, 62) %>%
  str_trim()
NASA_tab[, 'CME_date'] <- NASA_tab$raw_data %>%
  substr(63, 68) %>%
  str_trim()
NASA_tab[, 'CME_time'] <- NASA_tab$raw_data %>%
  substr(69, 74)
NASA_tab[, 'CME_angle'] <- NASA_tab$raw_data %>%
  substr(76, 80) %>%
  str_trim()
NASA_tab[, 'CME_width'] <- NASA_tab$raw_data %>%
  substr(81, 85) %>%
  str_trim()
NASA_tab[, 'CME_speed'] <- NASA_tab$raw_data %>%
  substr(86, 90) %>%
  str_trim()
head(NASA_tab)

```

```

##
## 1 1997/04/01 14:00 04/01 14:15 8000 4000 S25E16 8026 M1.3 04/01 15:18 74 79 312 PHTX raw_data

```

```
## 2 1997/04/07 14:30 04/07 17:30 11000 1000 S28E19 8027 C6.8 04/07 14:27 Halo 360 878 PHTX
## 3 1997/05/12 05:15 05/14 16:00 12000 80 N21W08 8038 C1.3 05/12 05:30 Halo 360 464 PHTX
## 4 1997/05/21 20:20 05/21 22:00 5000 500 N05W12 8040 M1.3 05/21 21:00 263 165 296 PHTX
## 5 1997/09/23 21:53 09/23 22:16 6000 2000 S29E25 8088 C1.4 09/23 22:02 133 155 712 PHTX
## 6 1997/11/03 05:15 11/03 12:00 14000 250 S20W13 8100 C8.6 11/03 05:28 240 109 227 PHTX
## start_date start_time end_date end_time start_freq end_freq location NOAA
## 1 1997/04/01 14:00 04/01 14:15 8000 4000 S25E16 8026
## 2 1997/04/07 14:30 04/07 17:30 11000 1000 S28E19 8027
## 3 1997/05/12 05:15 05/14 16:00 12000 80 N21W08 8038
## 4 1997/05/21 20:20 05/21 22:00 5000 500 N05W12 8040
## 5 1997/09/23 21:53 09/23 22:16 6000 2000 S29E25 8088
## 6 1997/11/03 05:15 11/03 12:00 14000 250 S20W13 8100
## imp CME_date CME_time CME_angle CME_width CME_speed
## 1 M1.3 04/01 15:18 74 79 312
## 2 C6.8 04/07 14:27 Halo 360 878
## 3 C1.3 05/12 05:30 Halo 360 464
## 4 M1.3 05/21 21:00 263 165 296
## 5 C1.4 09/23 22:02 133 155 712
## 6 C8.6 11/03 05:28 240 109 227
```

Step 4: Tidy the NASA the table (15 pts)

```
# Remove empty values
NASA_tab$start_freq[startsWith(NASA_tab$start_freq, '?')] <- NA
NASA_tab$end_freq[startsWith(NASA_tab$end_freq, '?')] <- NA
NASA_tab$location[grepl('.*[bB][aA][cC][kK].*', NASA_tab$location)] <- NA
NASA_tab$NOAA[startsWith(NASA_tab$NOAA, '-')] <- NA
NASA_tab$imp[startsWith(NASA_tab$imp, '-')]
  | grepl('.*[fF][iI][lL][aA].*', NASA_tab$imp)] <- NA
NASA_tab$CME_date[startsWith(NASA_tab$CME_date, '-')] <- NA
NASA_tab$CME_time[startsWith(NASA_tab$CME_time, '-')] <- NA
NASA_tab$CME_angle[startsWith(NASA_tab$CME_angle, '-')] <- NA
NASA_tab$CME_width[startsWith(NASA_tab$CME_width, '-')] <- NA
NASA_tab$CME_speed[startsWith(NASA_tab$CME_speed, '-')] <- NA

# Tidying the data
NASA_tab <- NASA_tab %>%
  mutate(start_time = paste(start_date, start_time, sep = ' ')) %>%
  mutate(end_time = paste(paste(substr(start_date, 1, 4), end_date, sep='/'),
    end_time, sep = ' ')) %>%
  mutate(CME_time = paste(paste(substr(start_date, 1, 4), CME_date, sep='/'),
    CME_time, sep = ' ')) %>%
  select(-raw_data, -start_date, -end_date, -CME_date)

# convert the combined columns into datetime objects
NASA_tab <- NASA_tab %>%
  mutate(start_time = make_datetime(year = strtoi(substr(start_time, 1, 4), base = 10),
    month = strtoi(substr(start_time, 6, 7), base=10),
    day = strtoi(substr(start_time, 9, 10), base=10),
    hour = strtoi(substr(start_time, 12, 13), base=10),
    min = strtoi(substr(start_time, 15, 16), base=10),
    sec = 0)) %>%
  mutate(end_time = make_datetime(year = strtoi(substr(end_time, 1, 4), base=10),
```

```

        month = strtoi(substr(end_time, 6, 7), base=10),
        day = strtoi(substr(end_time, 9, 10), base=10),
        hour = strtoi(substr(end_time, 12, 13), base=10),
        min = strtoi(substr(end_time, 15, 16), base=10),
        sec = 0)) %>%
mutate(CME_time = make_datetime(year = strtoi(substr(CME_time, 1, 4), base=10),
        month = strtoi(substr(CME_time, 6, 7), base=10),
        day = strtoi(substr(CME_time, 9, 10), base=10),
        hour = strtoi(substr(CME_time, 13, 14), base=10),
        min = strtoi(substr(CME_time, 16, 17), base=10),
        sec = 0)) %>%
select(start_datetime = start_time, end_datetime = end_time, start_freq, end_freq, location, NOAA,
        imp, CME_datetime = CME_time, CME_angle, CME_width, CME_speed)

# removing Halo from CME_angle and > symbols from CME_width
# creating lower_bound and Halo columns
NASA_tab <- NASA_tab %>%
  mutate(Halo = (CME_angle == 'Halo'), lower_bound = startsWith(CME_width, '>')) %>%
  mutate(CME_width = ifelse(startsWith(CME_width, ">"), str_sub(CME_width, 2, -1), CME_width)) %>%
  mutate(CME_angle = ifelse(CME_angle == 'Halo', NA, CME_angle))

# converting columns to appropriate datatypes
NASA_tab <- NASA_tab %>%
  mutate(start_freq = ifelse(is.na(start_freq), NA, strtoi(start_freq, base=10))) %>%
  mutate(end_freq = ifelse(is.na(end_freq), NA, strtoi(end_freq, base=10))) %>%
  mutate(NOAA = ifelse(is.na(NOAA), NA, strtoi(NOAA, base=10))) %>%
  mutate(CME_angle = ifelse(is.na(CME_angle), NA, strtoi(CME_angle, base=10))) %>%
  mutate(CME_width = ifelse(is.na(CME_width), NA, strtoi(CME_width))) %>%
  mutate(CME_speed = ifelse(is.na(CME_speed), NA, strtoi(CME_speed)))

head(NASA_tab)

```

```

##      start_datetime      end_datetime start_freq end_freq location NOAA
## 1 1997-04-01 14:00:00 1997-04-01 14:15:00      8000    4000   S25E16 8026
## 2 1997-04-07 14:30:00 1997-04-07 17:30:00     11000    1000   S28E19 8027
## 3 1997-05-12 05:15:00 1997-05-14 16:00:00     12000      80   N21W08 8038
## 4 1997-05-21 20:20:00 1997-05-21 22:00:00      5000      500   N05W12 8040
## 5 1997-09-23 21:53:00 1997-09-23 22:16:00      6000     2000   S29E25 8088
## 6 1997-11-03 05:15:00 1997-11-03 12:00:00     14000      250   S20W13 8100
##      imp      CME_datetime CME_angle CME_width CME_speed  Halo lower_bound
## 1 M1.3 1997-04-01 15:18:00      74      79      312 FALSE      FALSE
## 2 C6.8 1997-04-07 14:27:00      NA     360      878  TRUE      FALSE
## 3 C1.3 1997-05-12 05:30:00      NA     360      464  TRUE      FALSE
## 4 M1.3 1997-05-21 21:00:00     263     165      296 FALSE      FALSE
## 5 C1.4 1997-09-23 22:02:00     133     155      712 FALSE      FALSE
## 6 C8.6 1997-11-03 05:28:00     240     109      227 FALSE      FALSE

```

Part 2: Analysis

Question 1: Replication (10 pts)

Can you replicate the top 50 solar flare table in SpaceWeatherLive.com exactly using the data obtained from NASA? That is, if you get the top 50 solar flares from the NASA table based on their classification (e.g., X28 is the highest), do you get data for the same 50 solar flare events in the SpaceWeatherLive page? If not, why not?

```
# Replication

options(digits = 5)
NASA_top50 <- NASA_tab %>%
  filter(startsWith(imp, 'X')) %>%
  mutate(rank = as.double(str_sub(imp, start = 2, end = nchar(imp)))) %>%
  arrange(desc(rank)) %>%
  head(50) %>%
  mutate(rank = row_number()) %>%
  select(rank, flare_classification=imp, flare_region = NOAA, start_datetime,
         maximum_datetime=CME_datetime, end_datetime)

head(NASA_top50)
```

```
##   rank flare_classification flare_region      start_datetime
## 1    1                X28.      10486 2003-11-04 20:00:00
## 2    2                X20.       9393 2001-04-02 22:05:00
## 3    3                X17.      10486 2003-10-28 11:10:00
## 4    4                X14.       9415 2001-04-15 14:05:00
## 5    5                X10.      10486 2003-10-29 20:55:00
## 6    6                X9.4       8100 1997-11-06 12:20:00
##           maximum_datetime      end_datetime
## 1 2003-11-04 19:54:00 2003-11-05 00:00:00
## 2 2001-04-02 22:06:00 2001-04-03 02:30:00
## 3 2003-10-28 11:30:00 2003-10-30 00:00:00
## 4 2001-04-15 14:06:00 2001-04-16 13:00:00
## 5 2003-10-29 20:54:00 2003-10-30 00:00:00
## 6 1997-11-06 12:10:00 1997-11-07 08:30:00
```

You cannot get the same solar flares with the NASA table, although you can get a similar one. It appears that the weather table got its information from a different source than the NASA table. Also the NASA table does not record the maximum time, only the CME time. It does appear however that some of the solar flares in the NASA table are the same ones as the ones in the Weather table.

Question 2: Entity Resolution (15 pts)

There are three similarity functions defined in `flare_similarity`.

- `s_classification` compares the classifications of flares based on how far away they are from each other numerically. If they have different classification IDs a zero is returned. I consider it highly unlikely that two flares with different classifications would be the same flare.
- `s_region` compares the categorical regions of each flare. Either these flares were in the same region, or they were not. If so it returns 1, if not it returns 0. Does not account for the fact that some of the regions have very similar region codes, such as the NOAA being 10486 and the region in the spaceweather

table being 486 as there is no way to know whether that was a typo or if these tables are using slightly different regional categories.

- `s_datetime` measures the differences between datetimes and returns an exponential value such that the smaller the difference is, the larger the value that will be returned.

The threshold is set to 1.01 so that if something is in the same region it won't automatically be resolved to an entity in the NASA data.

```
flare_similarity <- function(E1, E2) {
  # Similarity Functions

  s_classification <- function(e1, e2) {
    if(substr(e1, 1, 1) == substr(e2, 1, 1)) {
      s1 <- ifelse(endsWith(e1, "+"), as.double(str_sub(e1, 2, -2)), as.double(str_sub(e1, 2, -1)))
      s2 <- ifelse(endsWith(e2, "+"), as.double(str_sub(e2, 2, -2)), as.double(str_sub(e2, 2, -1)))
      exp( -((s1 - s2)^2))
    } else 0
  }

  s_region <- function(e1, e2) {
    ifelse(e1 == e2, 1, 0)
  }

  s_datetime <- function(e1, e2) {
    exp( -(as.double(e1 - e2)^2))
  }

  # building the matrix
  m <- matrix(nrow = nrow(E1), ncol = nrow(E2))

  for(i in 1:nrow(E1)) {
    for(j in 1:nrow(E2)) {
      if(!(is.na(E1$flare_classification[i]) || is.na(E2$imp[j])))
        m[i, j] <- s_classification(E1$flare_classification[i], E2$imp[j])
      if(!(is.na(E1$flare_region[i]) || is.na(E2$NOAA[j])))
        m[i, j] <- m[i, j] + s_region(E1$flare_region[i], E2$NOAA[j])
      if(!(is.na(E1$start_datetime[i]) || is.na(E2$start_datetime[j])))
        m[i, j] <- m[i, j] + s_datetime(E1$start_datetime[i], E2$start_datetime[j])
      if(!(is.na(E1$maximum_datetime[i]) || is.na(E2$CME_datetime[j])))
        m[i, j] <- m[i, j] + s_datetime(E1$maximum_datetime[i], E2$CME_datetime[j])
      if(!(is.na(E1$end_datetime[i]) || is.na(E2$end_datetime[j])))
        m[i, j] <- m[i, j] + s_datetime(E1$end_datetime[i], E2$end_datetime[j])
    }
  }
  m
}

# returns a vector of the index in E2 that e1 in E1 corresponds to
flare_match <- function(E1, E2) {
  sim_matrix <- flare_similarity(E1, E2)
  matches <- vector()
  index = vector(length=nrow(sim_matrix))

  for(i in 1:nrow(sim_matrix)) {
```

```

matches <- append(matches, max(sim_matrix[i,], na.rm=TRUE))
index[i] <- ifelse(matches[i] < 1.01, NA, which(sim_matrix[i,] == max(sim_matrix[i,],
na.rm=TRUE)))
}
index
}

weather_tab[, 'index'] <- flare_match(weather_tab, NASA_tab)

head(weather_tab)

```

```

##   rank flare_classification flare_region      start_datetime
## 1    1                X28+           486 2003-11-04 19:29:00
## 2    2                X20+          9393 2001-04-02 21:32:00
## 3    3             X17.2+           486 2003-10-28 09:51:00
## 4    4                X17+           808 2005-09-07 17:17:00
## 5    5             X14.4          9415 2001-04-15 13:19:00
## 6    6                X10           486 2003-10-29 20:37:00
##   maximum_datetime      end_datetime index
## 1 2003-11-04 19:53:00 2003-11-04 20:06:00  241
## 2 2001-04-02 21:51:00 2001-04-02 22:03:00  118
## 3 2003-10-28 11:10:00 2003-10-28 11:24:00  234
## 4 2005-09-07 17:40:00 2005-09-07 18:03:00   NA
## 5 2001-04-15 13:50:00 2001-04-15 13:55:00  127
## 6 2003-10-29 20:49:00 2003-10-29 21:01:00   NA

```

Question 3: Analysis (10 pts)

This plot analyzes the amount of Halo CMEs in top 50 flares that were resolvable.

```

graph_tab <- filter(weather_tab, !is.na(index))

for( i in 1:nrow(graph_tab)) {
  graph_tab[i, 'Halo'] <- NASA_tab$Halo[graph_tab$index[i]]
}

graph_tab %>%
  group_by(Halo) %>%
  summarize(true = sum(Halo), false = sum(!Halo)) %>%
  ggplot(aes(x = Halo, y = true + false )) + geom_bar(stat = "identity")

```


