Reproducible Research: Activity Monitoring

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Contents

`{r setup, include=FALSE} knitr::opts_chunk$set(echo = TRUE)`

Introduction

Excerpts from the original repo from which this was forked

It is now possible to collect a large amount of data about personal movement using activity monitoring devices such as a Fitbit, Nike Fuelband, or Jawbone Up. These type of devices are part of the "quantified self" movement – a group of enthusiasts who take measurements about themselves regularly to improve their health, to find patterns in their behavior, or because they are tech geeks. But these data remain under-utilized both because the raw data are hard to obtain and there is a lack of statistical methods and software for processing and interpreting the data.

This project makes use of data from a personal activity monitoring device which collects data at five-minute intervals through out the day.

The data consists of two months of data from an anonymous individual collected during the months of October and November, 2012 and include the number of steps taken in five-minute intervals each day.

Variable name	Description
steps	Number of steps taking in a five-minute interval (missing values are coded as `NA`)
date	The date on which the measurement was taken, in YYYY-MM-DD format
interval	Identifier for the five-minute interval in which measurement was taken

The following are the questions to be addressed:

- What is mean total number of steps taken per day?
- What is the average daily activity pattern?
- Are there differences in activity patterns between weekdays and weekends?

1 Boring admin stuff

1.1 Install the needed libraries

```r
if (!require("ggplot2")) {
    message("Installing ggplot2")
    install.packages("ggplot2")
}
```

```
## Loading required package: ggplot2
```

```r
if (!require("knitr")) {
  message("Installing knitr")
  install.packages("knitr")
}
```

```
## Loading required package: knitr
```

```r
if (!require("scales")) {
  message("Installing scales")
  install.packages("scales")
}
```

```
## Loading required package: scales
```

```r
if (!require("numform")) {
  message("Installing numform")
  install.packages("numform")
}
```

```
## Loading required package: numform
```

```r
if (!require("timeDate")) {
  message("Installing timeDate")
  install.packages("timeDate")
}
```

```
## Loading required package: timeDate
```

```r
if (!require("dplyr")) {
  message("Installing dplyr")
  install.packages("dplyr")
}
```

```
## Loading required package: dplyr
```

```
##
## Attaching package: 'dplyr'
```

```
## The following object is masked from 'package:numform':
##
##     collapse
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

1.2 Download the zipped dataset if not yet present

```r
if (!file.exists("activity.zip")) {
          message("Downloading dataset")
          download.file("https://d396qusza40orc.cloudfront.net/repdata%2Fdata%2Factivity.zip",
                        destfile = "activity.zip",
                        method   = "internal",
                        mode     = "wb")
     }
```

1.3 Unzip the dataset if not yet present

```r
if (!file.exists("activity.csv")) {
          message("Extracting dataset")
          unzip("activity.zip",
                overwrite = FALSE)
     }
```

1.4 Read in the data

```r
# Shouldn't need error checking here
activity <- read.csv("activity.csv")
```

1.5 Load the libraries

```r
library(ggplot2)
library(knitr)
library(scales)
library(numform)
library(timeDate)
library(dplyr)
```

2 Now let's get cooking

2.1 What is mean total number of steps taken per day?

Compute the total number, mean, and median steps per day. Build a `dayStats` dataframe by starting with the aggregate of `steps`, `by = list(date)`, and `FUN = sum`, then merging with aggregates with `FUN = mean` and `FUN = median`.

As an aside, take note of the use of the superassignment (`<<-`) instead of the usual assignment operator (`<-`). This is because the `with(){}` creates its own scope.

```r
with(data = activity,{
     dayStats <<- aggregate(steps, by = list(date), FUN = sum)
```

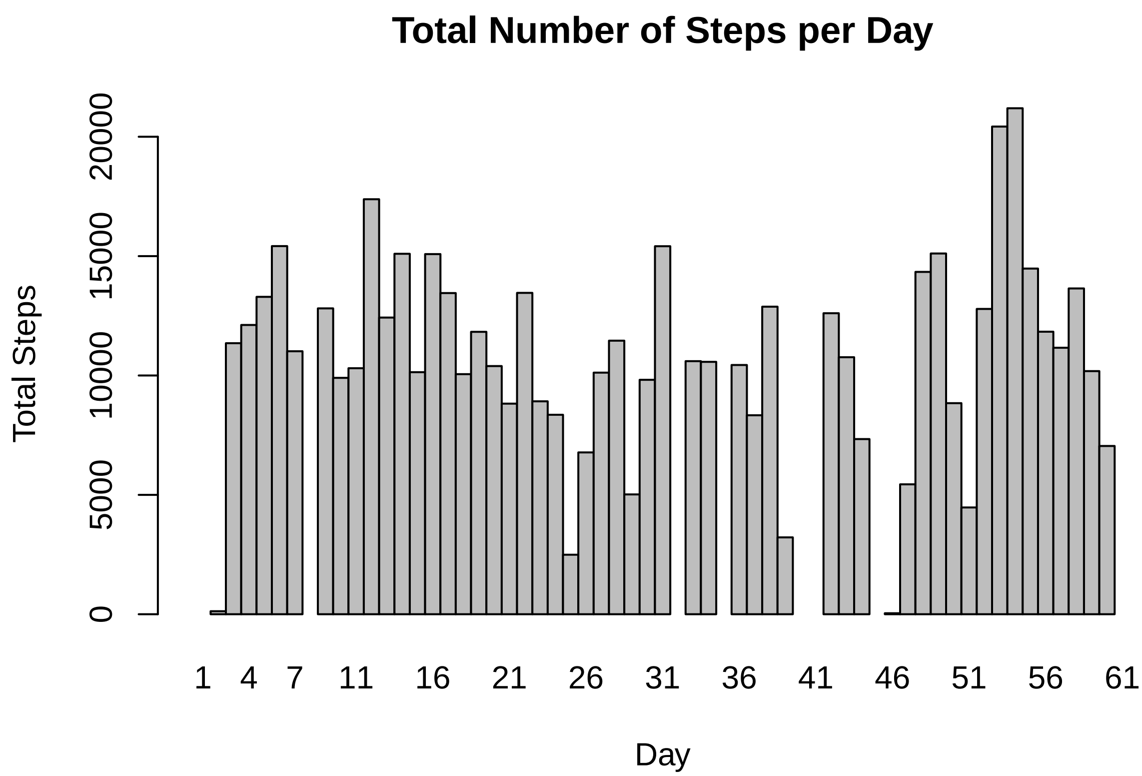
```
    dayStats <<- merge(dayStats,
                       aggregate(steps, by = list(date), FUN = mean), by = "Group.1")
    dayStats <<- merge(dayStats,
                       aggregate(steps, by = list(date), FUN = median), by = "Group.1")
})
```

Give the columns meaningful names

```
colnames(dayStats) <- c("date", "totalSteps", "meanSteps", "medianSteps")
```

Plot total number of steps taken each day, telling `barplot()` to remove spaces between bars. Also, using `(as.Date(date) - as.Date(dayStats[1, 1]) + 1)` as `names.arg` so labels on x axis are day numbers, not the dates. This is so the plot is neater.

```
with(dayStats,
     barplot(space = 0, totalSteps,
             main  = "Total Number of Steps per Day",
             xlab  = "Day", ylab = "Total Steps",
             names.arg = (as.Date(date) - as.Date(dayStats[1, 1]) + 1)))
```




```
dev.copy(png, "plots/01-totalSteps.png")
```

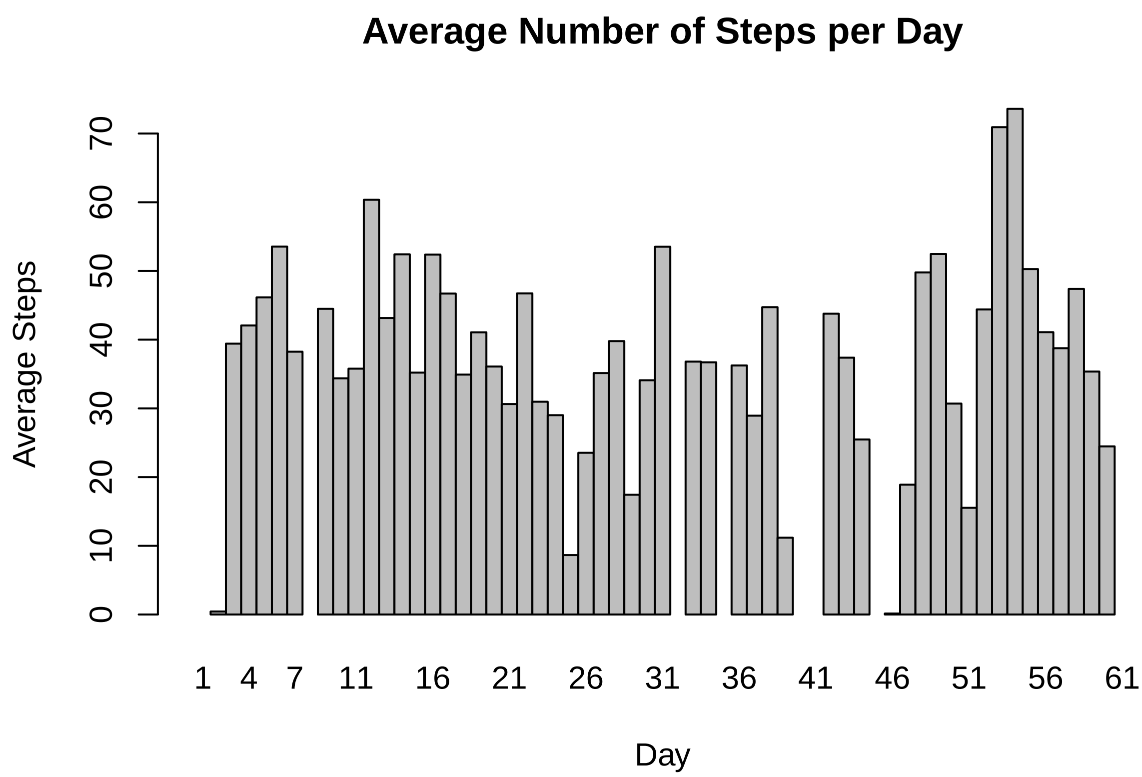
```
## png
##   3
```

```
dev.off()
```

```
## pdf
##   2
```

Plot mean of number of steps per day.

```
with(dayStats,
     barplot(space = 0, meanSteps,
             main  = "Average Number of Steps per Day",
             xlab  = "Day", ylab = "Average Steps",
             names.arg = (as.Date(date) - as.Date(dayStats[1, 1]) + 1)))
```




```
dev.copy(png, "plots/02-meanSteps.png")
```

```
## png
##   3
```

```
dev.off()
```

```
## pdf
##   2
```

And here's the dataframe of average number of steps per day:

```
knitr::kable(dayStats[, c(1, 3)],
      col.names = c("date", "mean"))
```

date	mean
2012-10-01	NA
2012-10-02	0.4375000
2012-10-03	39.4166667
2012-10-04	42.0694444
2012-10-05	46.1597222

date	mean
2012-10-06	53.5416667
2012-10-07	38.2465278
2012-10-08	NA
2012-10-09	44.4826389
2012-10-10	34.3750000
2012-10-11	35.7777778
2012-10-12	60.3541667
2012-10-13	43.1458333
2012-10-14	52.4236111
2012-10-15	35.2048611
2012-10-16	52.3750000
2012-10-17	46.7083333
2012-10-18	34.9166667
2012-10-19	41.0729167
2012-10-20	36.0937500
2012-10-21	30.6284722
2012-10-22	46.7361111
2012-10-23	30.9652778
2012-10-24	29.0104167
2012-10-25	8.6527778
2012-10-26	23.5347222
2012-10-27	35.1354167
2012-10-28	39.7847222
2012-10-29	17.4236111
2012-10-30	34.0937500
2012-10-31	53.5208333
2012-11-01	NA
2012-11-02	36.8055556
2012-11-03	36.7048611
2012-11-04	NA
2012-11-05	36.2465278
2012-11-06	28.9375000
2012-11-07	44.7326389
2012-11-08	11.1770833
2012-11-09	NA
2012-11-10	NA
2012-11-11	43.7777778
2012-11-12	37.3784722
2012-11-13	25.4722222
2012-11-14	NA
2012-11-15	0.1423611
2012-11-16	18.8923611
2012-11-17	49.7881944
2012-11-18	52.4652778
2012-11-19	30.6979167
2012-11-20	15.5277778
2012-11-21	44.3993056
2012-11-22	70.9270833
2012-11-23	73.5902778
2012-11-24	50.2708333
2012-11-25	41.0902778
2012-11-26	38.7569444

date	mean
2012-11-27	47.3819444
2012-11-28	35.3576389
2012-11-29	24.4687500
2012-11-30	NA

The `summary()` function will also give us the mean and median, plus other stats:

```
knitr::kable(summary(dayStats))
```

date	totalSteps	meanSteps	medianSteps
2012-10-01: 1	Min. : 41	Min. : 0.1424	Min. :0
2012-10-02: 1	1st Qu.: 8841	1st Qu.:30.6979	1st Qu.:0
2012-10-03: 1	Median :10765	Median :37.3785	Median :0
2012-10-04: 1	Mean :10766	Mean :37.3826	Mean :0
2012-10-05: 1	3rd Qu.:13294	3rd Qu.:46.1597	3rd Qu.:0
2012-10-06: 1	Max. :21194	Max. :73.5903	Max. :0
(Other) :55	NA's :8	NA's :8	NA's :8

`medianSteps` is zero because of the large number of zeroes in that column, mostly from `interval` = c(0, 530). `NA`s may also account for that. Since the median is zero, there's no point in drawing a boring plot with a vertical line at `y = 0`, save for blanks for columns with only `NA`s.

2.2 What is the average daily activity pattern?

Create a dataframe with steps per interval, and plot the line.

Define a function that will take an integer – in this case, the interval – and convert it to a `time` string.

```
int2Time <- function(hhmm) {
     # separate the integer into its minute and hour components
     # assumes an integer of the form hhmm, where hh and mm are the hour
     # (between 0-23) and minute (between 0-59) components, respectively, of the
     # time.
     # Does not do parameter validation
     startHr  <- hhmm %/% 100
     startMin <- hhmm %% 100
     # and put them back together
     return(paste0(substring(paste0("0", startHr), nchar(startHr)),
                   ":",
                   substring(paste0("0", startMin), nchar(startMin))))
}
```

Since the steps from interval 0 to interval 600 are mostly zero, I'm betting that the measurements start midnight. If they don't, I'm screwed. Or not, maybe just have to make adjustments in the conversions.

What I'm fairly sure of is that the intervals are of the form `hhmm`, where `hh` and `mm` are the hour and minute components, respectively, of the interval. As evidence, let's examine a the subset of `intervalSteps` where the `interval` is an exact multiple of 100 or congruent to 55 modulo 100:

```
knitr::kable(head(subset(activity, interval %% 100 %in% c(0, 55))))
```

	steps	date	interval
1	NA	2012-10-01	0

	steps	date	interval
12	NA	2012-10-01	55
13	NA	2012-10-01	100
24	NA	2012-10-01	155
25	NA	2012-10-01	200
36	NA	2012-10-01	255

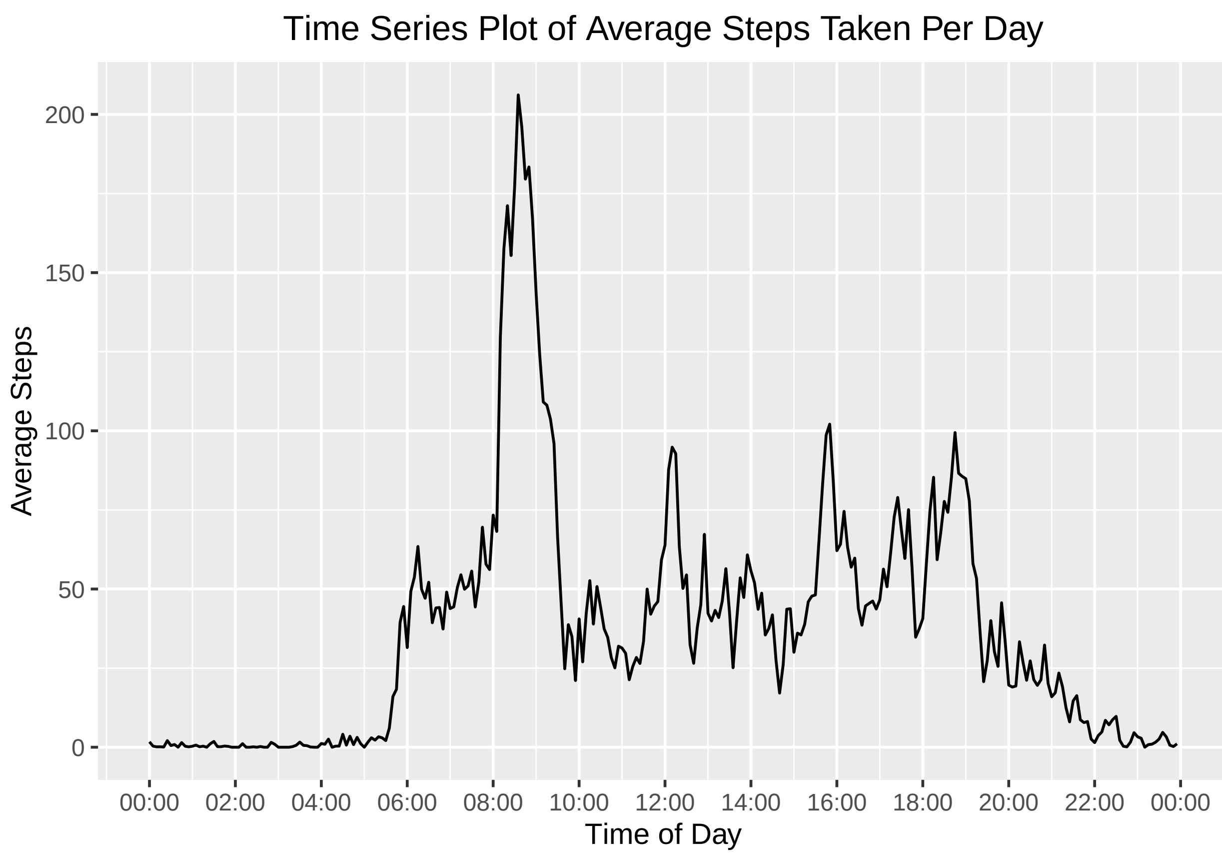
Note that two succeeding rows number are congruent to 0 mod 12 and 1 mod 12, respectively. Why 12? Intervals are five minutes apart. One hour is 60 minutes, and sixty divided by 5 is 12. Then, the next column jumps to the next hundred.

However, the more interesting pattern to look at is `intervalSteps[c(12, 13),]` or, in general, `intervalSteps[x, (x + 1), ]` where `x >= 12`. Note that `intervalSteps[c(x, x + 1), ]$interval = (i1, i2)`, and `i1` is congruent to 55 mod 100, i2 is congruent to 0 mod 100.

That out of the way, let's get back to the questions at hand.

Average the number of steps over each five-minute interval and plot the time series.

```
intervalSteps <- aggregate(steps ~ interval, data = activity, mean)
intervalSteps$time <- as.POSIXct(int2Time(intervalSteps$interval), format = "%H:%M", tz = "MST")
ggplot(intervalSteps, aes(x = time, y = steps)) +
     geom_line() +
     scale_x_datetime(labels = date_format("%H:%M", tz = "MST"),
                      date_breaks = "2 hours") +
     labs(title = "Time Series Plot of Average Steps Taken Per Day",
          x = "Time of Day", y = "Average Steps") +
     theme(plot.title = element_text(hjust = 0.5))
```




```
dev.copy(png, "plots/04-intervalSteps.png")
```

```
## png
##   3
```

```
dev.off()
```

```
## pdf
##   2
```

So, from the plot, on average there is negligible activity from midnight to around 5:30 in the morning, slowly climbing at around 7:00, and a spike of over 200 steps at around 8:30.

From then on, there is a minimum of 25 to a maximum of 100 steps, and activity dies down starting close to 11:30 PM.

Which 5-minute interval, on average across all the days in the dataset, contains the maximum number of steps?

The starting time and corresponding average number of steps are in `intervalSteps[which.max(intervalSteps$steps), 1]` and `intervalSteps[which.max(intervalSteps$steps), 2]` respectively. I thought I'd include the end time of that interval by adding five minutes.

```
intervalStart <- intervalSteps[which.max(intervalSteps$steps), 1]
intervalEnd   <- intervalSteps[which.max(intervalSteps$steps), 1] + 5
averageSteps  <- intervalSteps[which.max(intervalSteps$steps), 2]
```

The start and end of the interval will be in 24-hour format.

```
sprintf("Maximum number of steps on average taken from %s to %s, number of steps = %f",
        int2Time(intervalStart), int2Time(intervalEnd), averageSteps)
```

```
## [1] "Maximum number of steps on average taken from 08:35 to 08:40, number of steps = 206.169811"
```

2.3 Imputing missing values

First question: how many missing values are there?

```
missing <- is.na(activity$steps)
sprintf("Number of missing steps: %s.", f_comma(sum(missing), mark = ","))
```

```
## [1] "Number of missing steps: 2,304."
```

```
sprintf("Mean: %s.", mean(missing))
```

```
## [1] "Mean: 0.131147540983607."
```

So, do those 2,304 `NA`s make a difference? Let's find out.

Define a helper function `fillNA`.

Parameter	Description
steps	Cell to be converted, if `NA`, to the average number of steps for `interval` (second parameter)
interval	Identifier for the five-minute interval from which to get the mean number of steps. The function will match `intervalSteps$interval` with the parameter `interval`, and return the average steps if the `steps` parameter is `NA`

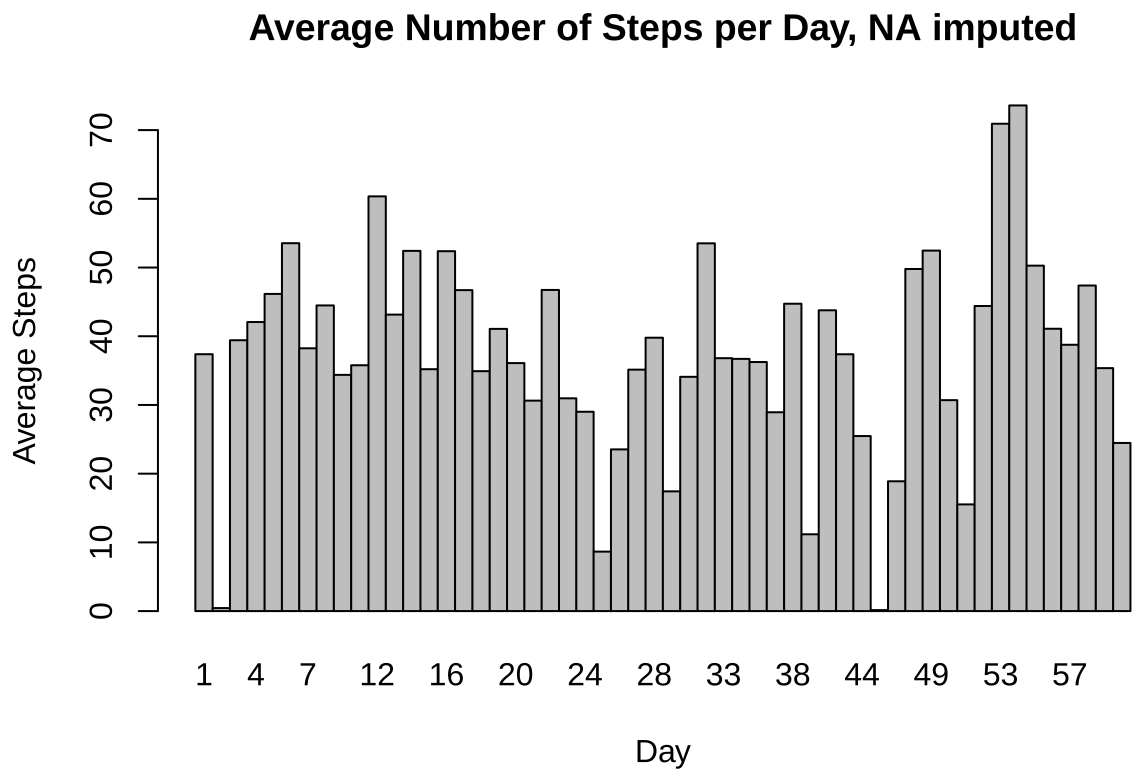
```
fillNA <- function(steps, interval) {
  return(ifelse
         (!is.na(steps), steps,
           intervalSteps[intervalSteps$interval == interval, "steps"]))
}
```

Make a copy of `activity`, then use `mutate()` to create a `steps` column using `fillNA`. Although the `mutate()` is applied to `activity`, the result is assigned to `adjActivity`, so the former is still intact.

```
adjActivity <- activity %>%
  mutate(steps = fillNA(steps, interval))
```

Set up the plot, then plot it.

```
adjSteps <- aggregate(steps ~ date, data = adjActivity, mean)
with(adjSteps,
     barplot(space = 0, steps,
             main  = "Average Number of Steps per Day, NA imputed",
             xlab  = "Day", ylab = "Average Steps",
             names.arg = (as.Date(date) - as.Date(date[1]) + 1)))
```

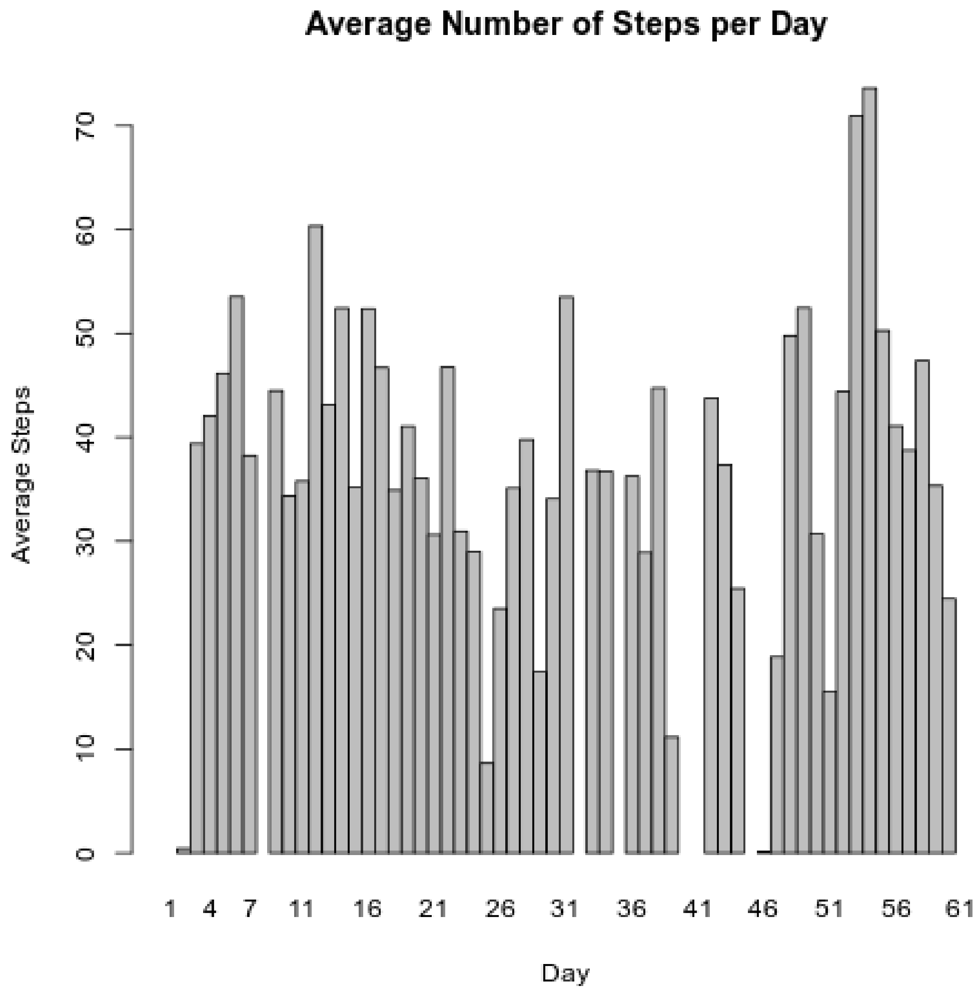



```
dev.copy(png, "plots/05-imputedSteps.png")
```

```
## png
##   3
```

Compare that with the plot of Average Number of Steps per Day, without imputing `NA`s:

```
knitr::include_graphics("plots/02-meanSteps.png")
```



Without the imputed data, average steps for days 1, 8, 32, 35, 40, 41, 45, and 61 are zero because of the `NA` steps for those days. Imputing creates data points that look reasonable, consistent in height with the other data points.

Meanwhile, the heights for the other days don't show any appreciable change.

2.4 Are there differences in activity patterns between weekdays and weekends?

Create a new Boolean column that determines whether the day is a weekday or weekend.

```
adjActivity$is.Weekday <- timeDate::isWeekday(adjActivity$date)
```

Take the mean number of steps per interval broken down into `is.Weekday` and `!is.Weekday`

```
stepsPerInterval <- aggregate(steps ~ interval + is.Weekday, data = adjActivity, mean)
```

Use the `interval` column to create a `time` column.

```
stepsPerInterval$time <- as.POSIXct(int2Time(intervalSteps$interval), format = "%H:%M", tz = "MST")
```

Map the `is.Weekday` column to the more readable "Weekend" and "Weekday", then create the plot.

```r
is.Weekday.labs <- as_labeller(c("FALSE" = "Weekend", "TRUE" = "Weekday"))
ggplot(stepsPerInterval, aes(time, steps, col = factor(is.Weekday))) +
  facet_wrap(.~factor(is.Weekday), dir = "v",
             labeller = is.Weekday.labs) +
  geom_line(show.legend = FALSE) +
  labs(x = "Time of day", y = "Steps") +
  labs(title = "Time Series Plot Comparison of Steps") +
  scale_x_datetime(labels = date_format("%H:%M", tz = "MST"), date_breaks = "2 hours") +
  theme(plot.title = element_text(hjust = 0.5))
```


```r
dev.copy(png, "plots/06-WkDayVsWkEnd.png")
```

```
## png
##   4
```

The plot tells us that on both weekends and weekdays, the subject is on average inactive, possibly asleep, from midnight to 5:30 in the morning. However, inactivity on weekends stretches to about 8:00 AM, whereas the subject starts moving about 5:30 AM on weekdays. Activity on both weekends and weekdays spikes at 9:00 AM, although to a lesser extent for the former.

Oddly, activity from 10:00 AM all the way to 5:30 PM is heavier on weekends, then wanes at 11:00 PM for both weekends and weekdays. The subject is probably at a desk, maybe at school or at work, at those times during weekdays, and outdoors, possibly at the mall, on weekends.

3 Recreating this PDF or HTML

The YAML of this document instructs `knitr` to produce both a PDF and an HTML. From the command line, you can issue the command: `R -e "rmarkdown::render('PA1_template.Rmd')"` no matter your Operating System. You can also render it using the RStudio `Knit` button (where's the fun in that?) or the R console, with the command `rmarkdown::render('PA1_template.Rmd')`.