Histograms

Intro to Stats, Spring 2017

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Learning Objectives

- Visualizing quantitative variables
- Function `hist()`

Intro to Descriptive Statistics

The first part of the course has to do with **Descriptive Statistics**. The main idea is to make a "large" or "complicated" dataset more compact and easier to understand by using three major tools:

- summary and frequency tables
- charts and graphics
- key numeric summaries

Describing and summarizing data can be done in many different ways. An important consideration involves distinguishing variables between quantitative and qualitative ones. Depending on the type of variable, you will use certain types of visual displays and calculate specific types of numeric values. Keep in mind that not all graphics are valid for all classes of variables. And not all arithmetic operations will make sense on all types of variables.

In this and subsequent scripts I will cover more concepts than what the textbook (FPP) discusses. The book focuses on:

- Histograms
- Measures of center: average and median
- Measures of spread: standard deviation

I will talk about:

- Frequency tables
- Histograms and density curves
- Measures of center: average and median
- Measures of spread: standard deviation
- Percentiles and quartiles
- The *five-number* summary and boxplots

More NBA Data

We are going to consider data of basketball players from the NBA. The data is from the season 2015-2016 and it is available in the file `nba_players.csv` (see the folder `data` in the course's github repository).

Reading CSV Tables

The first step involves importing the data in R. Because the data is already in a tabular format (stored in a CSV file), you can use the function `read.csv()`. What you need is to pass the URL address of the file:

```
# assembling the URL of the CSV file
# (otherwise it won't fit within the margins of this document)
repo = 'https://raw.githubusercontent.com/ucb-introstat/introstat-spring-2017/'
datafile = 'master/data/nba_players.csv'
url = paste0(repo, datafile)

# read in data set
nba = read.csv(url)
```

If you get an error message, make sure that you have the right URL address, check the correct use of single or double quotes, and verify the names of the functions.

Technical Note: by default, `read.csv()` automatically converts any columns containing character strings as R factors.

The object `nba` is a data frame. Usually, after you import a data frame in R, you may want to use a handful of functions to inspect its properties and basic structure:

- `str(nba)`: display overall structure of the table
- `dim(nba)`: dimensions (i.e. size) of the table
- `head(nba, n = 5)`: show first `n` rows
- `tail(nba, n = 5)`: show last `n` rows
- `names(nba)`: column names
- `colnames(nba)`: sames as `names(nba)`
- `summary(nba)`: descriptive summary of variables in `nba`

```
# dimensions (num rows and columns)
dim(nba)
```

```
## [1] 528  39
```

```
# names of first 10 columns
names(nba[ ,1:10])
```

```
##  [1] "player"            "player_num"        "position"
##  [4] "height"            "weight"            "birthdate"
##  [7] "country"           "experience"        "college"
## [10] "team_stat_ranking"
```

```
# basic summary of first 3 columns
summary(nba[ ,1:3])
```

```
##                player      player_num              position
##  James Ennis      :  3   Min.   : 0.00   center        : 96
##  Kris Humphries   :  3   1st Qu.: 6.00   point guard   :112
##  Alex Stepheson   :  2   Median :13.00   power forward :112
##  Anderson Varejao:  2   Mean   :17.55   shooting guard:107
##  Andre Miller     :  2   3rd Qu.:25.00   small forward :101
##  Beno Udrih       :  2   Max.   :99.00
##  (Other)          :514
```

Frequency tables

As we mention before, an important consideration has to do with identifying the type of variables: quantitative -vs- qualitative.

An example of a qualitative variable is `position`. This variable contains the position of each player. When you inspect a qualitative variable, you typically start by computing a **frequency table**. A frequency table shows the frequencies or counts of each category. In R, we have the function `table()` to obtain this type of table.

To obtain the frequencies of the positions simply type:

```
freq_position = table(nba$position)
freq_position
```

```
##
##         center    point guard  power forward shooting guard  small forward
##             96            112            112            107            101
```

Often, it is convenient to express the frequencies as proportions or percentages, also referred to as **relative frequencies**.

```
prop_position = freq_position / sum(freq_position)
prop_position
```

```
##
##         center    point guard  power forward shooting guard  small forward
##      0.1818182      0.2121212      0.2121212      0.2026515      0.1912879
```

If you want to express the proportions as percentages, multiply `prop_position` times 100:

```
perc_position = 100 * prop_position
perc_position
```

```
##
##         center    point guard  power forward shooting guard  small forward
##       18.18182       21.21212       21.21212       20.26515       19.12879
```

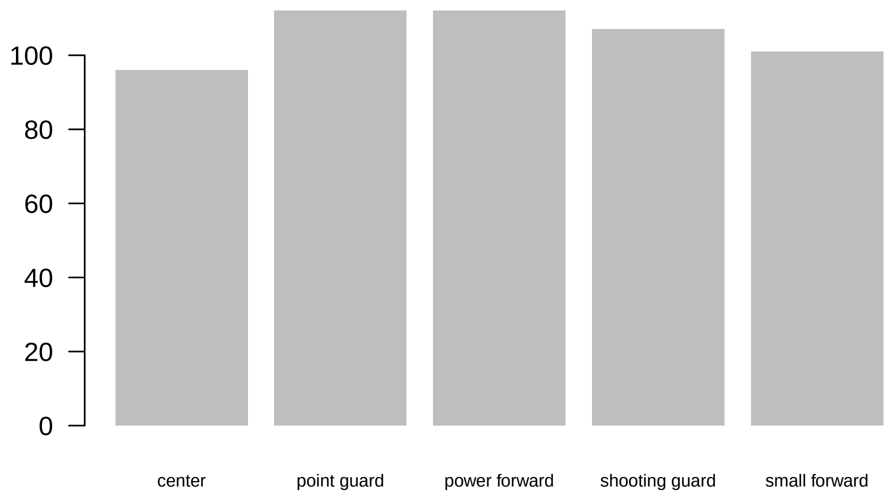
Bar-Charts and Pie-Charts

Having obtained the frequencies and/or proportions of the categories of a qualitative variable, we can proceed our exploration with some visual displays. There are two most common graphics that are used to visualize frequencies:

- bar-charts
- pie-charts

To create a bar-chart in R you can use the `barplot()` function. This function requires a numeric vector or a table of frequencies:

```r
barplot(freq_position, las = 1, border = NA, cex.names = 0.7)
```

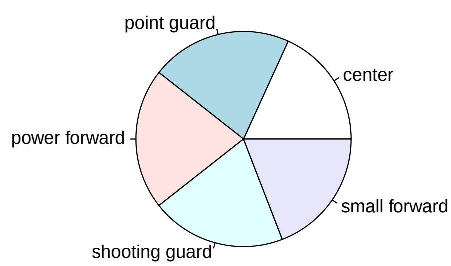


The use of `barplot()` includes the arguments `las`, `border`, and `cex.names`:

- `las = 1`: displays the frequencies perpendicular to the y-axis
- `border = NA`: removes the black border around bars
- `cex.names = 0.7`: reduces the sizes of the category labels (so they all fit in the plot)

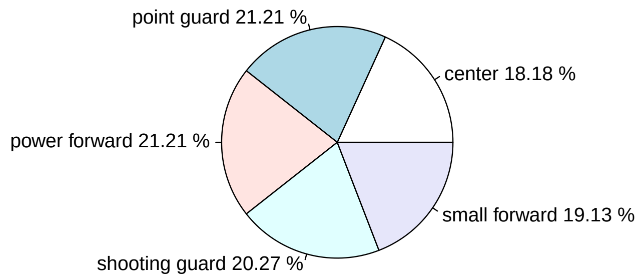
Pie Chart. The other common type of chart to see frequencies is a pie-chart. R provides the function `pie()` to produce these charts:

```r
pie(freq_position)
```



If you want to display the frequencies, you can do something like this:

```r
pie(freq_position,
    labels = paste(levels(nba$position), round(perc_position, 2), "%"))
```



Your Turn

Obtain a frequency table of the variable `team`, and plot a bar-chart of such frequencies.

Looking at Quantitative Variables

Most of the variables in the data set `nba` are of quantitative nature. One possibility to visually inspect those variables is to *categorize* them and then use a bar-chart or a pie-chart. Another possibility is to use a couple of displays specifically dedicated to quantitative variables:

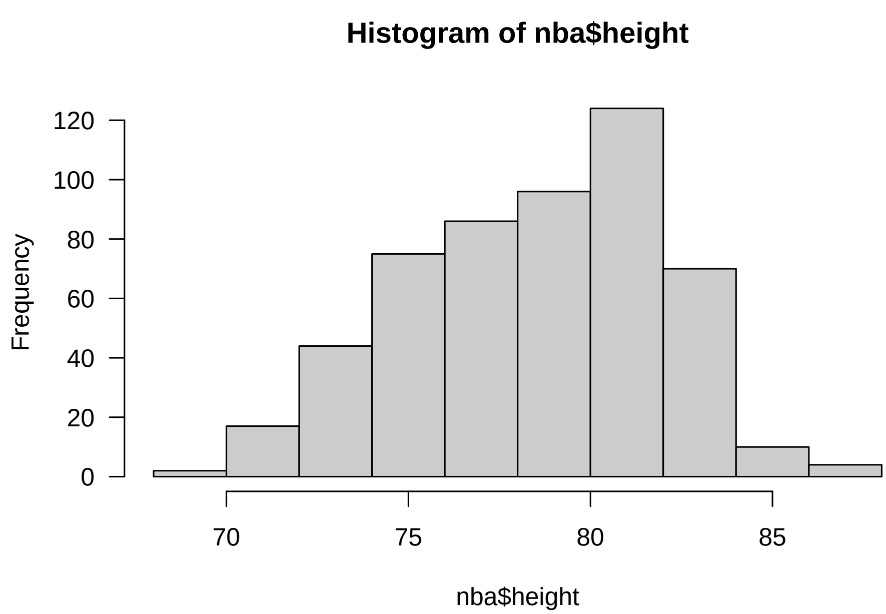
- histograms
- box-and-whisker plots (aka boxplots)

Histograms

A histogram is a type of plot that shows the **distribution** of numerical data. To produce histograms, R provides the function `hist()`. The default action of `hist()` is to plot a histogram, but you can also store its output in an R object. Inspecting such an object will let you see the different components used to plot the histogram.

Let's apply `hist()` on the column `height` (in inches) and save its output in the object `height_hist`:

```
height_hist = hist(nba$height, las = 1, col = 'gray80')
```



As you can tell, a histogram is very similar to a bar-chart. The common feature is the use of bars and the use of an axis to display some sort of frequency measure. However, a histogram is NOT a bar-chart. There are special attributes in a histogram that makes it different from a bar-chart.

In a histogram, the bars are adjacent (no gaps between bars). Moreover, the bars cannot be rearranged in a different order. Unlike bar-charts, what matters in a histogram is not the length of the bars but their areas. The area of a bar in a histogram should be equal to the proportion of the bin.

Because we stored the output produced by `hist()` in the object `height_hist`, we can type this object to see what output is contained in it:

```
height_hist
```

```
## $breaks
##  [1] 68 70 72 74 76 78 80 82 84 86 88
##
## $counts
##  [1]   2  17  44  75  86  96 124  70  10   4
##
## $density
##  [1] 0.001893939 0.016098485 0.041666667 0.071022727 0.081439394
##  [6] 0.090909091 0.117424242 0.066287879 0.009469697 0.003787879
##
## $mids
##  [1] 69 71 73 75 77 79 81 83 85 87
##
## $xname
## [1] "nba$height"
##
## $equidist
## [1] TRUE
##
## attr(,"class")
## [1] "histogram"
```

- `breaks`: breaking (cutting) points of class intervals
- `counts`: number of observations in each bin
- `density`: density
- `mids`: mid-point of class intervals
- `xname`: name of object (variable) that is plotted
- `equidist`: are bins of equal width?
- `attr`: class attribute (an object of class histogram)

`hist()` produces a histogram using predefined settings. By default, it will determine the number of bins or class intervals automatically. Like most histograms produced by statistical software, the default bins are of equal size. Also, the class-intervals are right-closed (i.e. the right endpoint is included). In the example above this means that the bins are:

- (68-70]
- (70-72]
- (72-74]
- (74-76]
- (76-78]
- (78-80]
- (80-82]
- (82-84]
- (84-86]
- (86-88]

Steps to plot a histogram

To make a histogram, the first step is to "bin" the range of values—that is, divide the entire range of values into a series of class intervals—and then count how many values fall into each class-interval. The resulting number of counts in a bin will give be associated to a bar in a histogram.

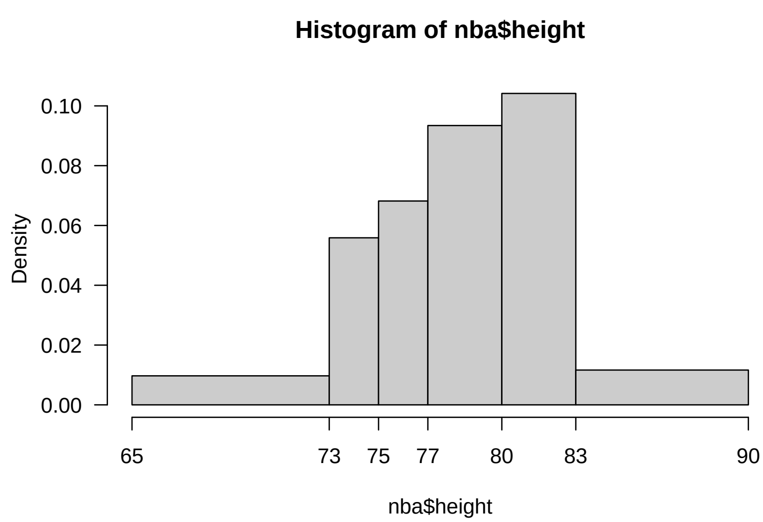
FPP Textbook Histograms

I want to highlight the difference of the histograms displayed in the textbook (FPP) with the histograms that you usually obtain with virtually all software programs. FPP is one of the very few introductory statistics book that shows histograms with bins of unequal sizes. In real life, you won't probably see many FPP-like histograms. In fact, I don't remember seeing a histogram of unequal bin-widths published in a scientific journal.

Interestingly, though, you can use `hist()` to produce FPP-style histograms in R. To do so, you must use the `breaks` argument to provide a vector of intervals. Let's see how to produce a histogram with the following class-intervals:

- (65-73]
- (73-75]
- (75-77]
- (77-80]
- (80-83]
- (83-90]

```
# right-closed interval with unequal bins
height_hist2 = hist(
  x = nba$height,
  breaks = c(65, 73, 75, 77, 80, 83, 90),  # vector of class intervals
  col = 'gray80',
  las = 1,
  axes = FALSE)
# x-axis with tick-marks that match the bins
axis(side = 1, at = c(65, 73, 75, 77, 80, 83, 90))
# y-axis
axis(side = 2, las = 1)
```



Note that we are turning off the display of the axes when using `hist()`. In order to "manually" plot the axes, we call the function `axis()`. The y-axis is plotted with the argument `side = 2`. In turn, the x-axis is plotted with the argument `side = 1`, indicating the position of the tick marks `at = c(65, 73, 75, 77, 80, 83, 90)`.

Notice also that when the bins are of unequal size, `hist()` produces what the FPP book refers to as a histogram with a **density scale**. This means that the vertical axis does not show the frequency or count anymore. Instead, the height of the bars are expressed in a scale such that the area of the bars represent percentages.

```
# bin widths
widths = height_hist2$breaks[2:7] - height_hist2$breaks[1:6]

# percentages: (bin widths) * (bar heights)
widths * height_hist2$density
```

```
## [1] 0.07765152 0.11174242 0.13636364 0.28030303 0.31250000 0.08143939
```

```
# sum of percentages must equal 1
sum(widths * height_hist2$density)
```

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

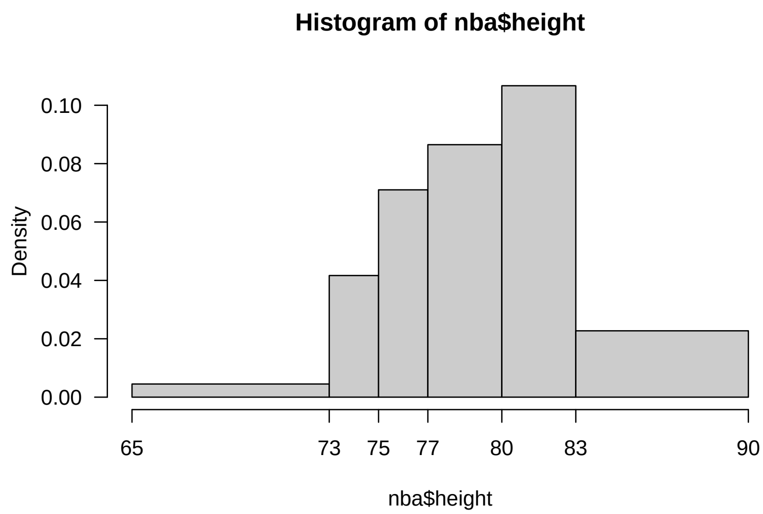
Histogram with right open (left-closed) intervals

An alternative histogram can be produced if we specify right-open intervals:

- [65-73)
- [73-75)
- [75-77)
- [77-80)
- [80-83)
- [83-90)

To plot a histogram with the previous bins, you must specify the argument `right = FALSE`:

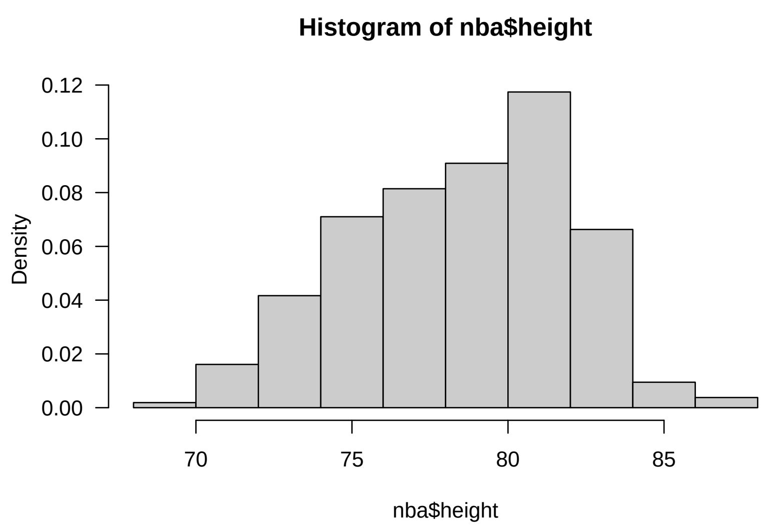
```
# left-closed bins
left_closed = hist(
  x = nba$height,
  breaks = c(65, 73, 75, 77, 80, 83, 90),
  right = FALSE,
  col = 'gray80',
  las = 1,
  axes = FALSE)
# x-axis
axis(side = 1, at = c(65, 73, 75, 77, 80, 83, 90))
# y-axis
axis(side = 2, las = 1)
```



Histogram with a density scale

You can also invoke `hist()` with the default equal bins, but showing a density scale by specifying the argument `probability = TRUE`:

```
hist(nba$height, probability = TRUE, las = 1, col = 'gray80')
```



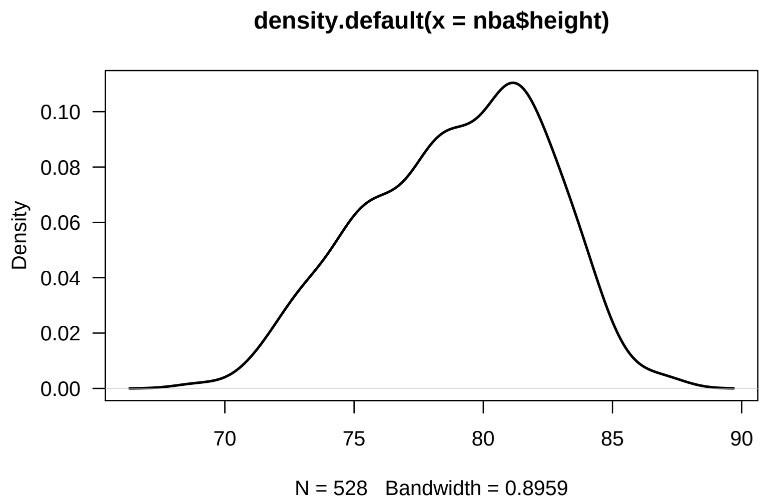
Density Curves

If you take a look at the FPP book, you will see that some histograms are sketched not with bars but with some sort of continuous curve. These figures are drawn as idealized or stylized histograms, just for conceptual purposes.

In practice, you can use statistical software to get similar graphics by obtaining what is known as a *density curve*. The computational procedure behind these type of curves involves estimating a kernel density. Estimating kernel densities is out of the scope of the course, but I will show you how to produce a plot that ressembles the sketched smoothed histograms of the textbook.

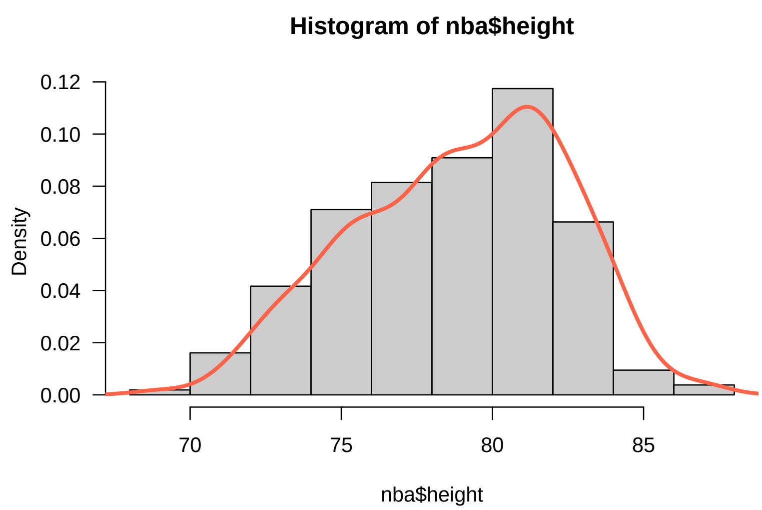
The first step is to use `density()` to obtain the kernel density estimation (KDE). After obtaining the KDE, you can pass it to `plot()` to get a smooth density curve:

```r
height_density = density(nba$height)
plot(height_density, las = 1, lwd = 2)
```



Sometimes it is useful to plot a histogram, and then overlap a density curve. This is achieved in R with the following code:

```r
hist(nba$height, probability = TRUE, las = 1, col = 'gray80')
lines(height_density, lwd = 3, col = "tomato")
```



The density curve is added via the `lines()` function. Note that we are invoking `hist()` using the argument `probability = TRUE` in order to obtain a ensity scale in the y-axis.