**Exploratory Data Analysis I**

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Summarizing
Categorical Data

Summarizing
Numerical Data

# Lecture 2
## Exploratory Data Analysis I
Readings: IntroStat Chapters 2-3; OpenIntro Chapter 2

*STAT 8010 Statistical Methods I*
May 17, 2023

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Clemson University

**1** **Summarizing Categorical Data**


**2** **Summarizing Numerical Data**

# Last Lecture

- Stating the problem, identifying the variable(s) of interest, and gathering data

  - Types of variables and datasets

  - Observational vs. Experimental Studies

  - Methods of sampling

- Summarizing the data

- Analyzing the data

- Reporting and interpreting the results

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- Stating the problem, identifying the variable(s) of interest, and gathering data

  - Types of variables and datasets

  - Observational vs. Experimental Studies

  - Sampling Techniques

- Summarizing the data

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- Reporting and interpreting the results

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# Summarizing Categorical Variables

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# Example: Sport Injuries

The paper *"Profile of sport/leisure injuries treated at emergency rooms of urban hospitals."* by Pelletier et al. 1991 examined the nature and number of sport/leisure injuries treated in hospital emergency rooms in a large metropolitan city. They classified non-contact sports injuries by sport, resulting in the following data set:

| Sport |
|-------|
| Soccer |
| Basketball |
| Others |
| Basketball |
| Touch Football |
| Others |
| Touch Football |
| Volleyball |
| Baseball/softball |
| ⋮ |

**Question:** How to summarize this data set?

# Frequency Table

- A frequency table for **categorical data** is a table that displays the possible categories along with the associated **frequencies** or **relative frequencies**

- The frequency for a particular category is the number of times the category appears in the data set

- The relative frequency for a particular category is the fraction or proportion of the time that the category appears in the data set.

# Frequencies and Relative Frequencies

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```
> table(sport)
sport
Baseball/softball        Basketball            Bicycling  Jogging/running
              11                19                   11               11
          Others            Soccer       Touch Football       Volleyball
              47                24                   38               17
> table(sport) / dim(sport)[1]
sport
Baseball/softball        Basketball            Bicycling  Jogging/running
      0.06179775        0.10674157           0.06179775       0.06179775
          Others            Soccer       Touch Football       Volleyball
      0.26404494        0.13483146           0.21348315       0.09550562
```
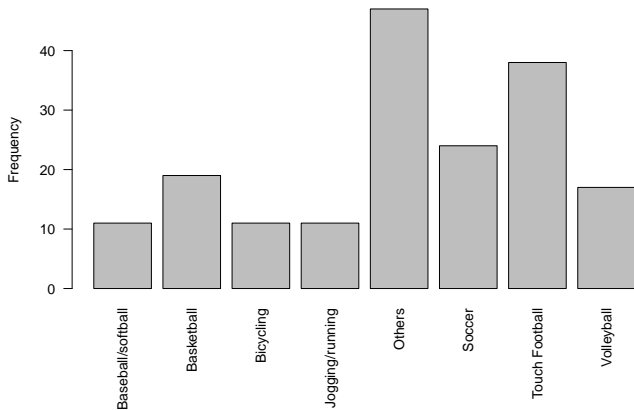
# Frequencies and Relative Frequencies

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```
> table(sport)
sport
Baseball/softball        Basketball          Bicycling   Jogging/running
              11                  19                 11                11
          Others              Soccer     Touch Football        Volleyball
              47                  24                 38                17
> table(sport) / dim(sport)[1]
sport
Baseball/softball        Basketball          Bicycling   Jogging/running
      0.06179775          0.10674157         0.06179775        0.06179775
          Others              Soccer     Touch Football        Volleyball
      0.26404494          0.13483146         0.21348315        0.09550562
```
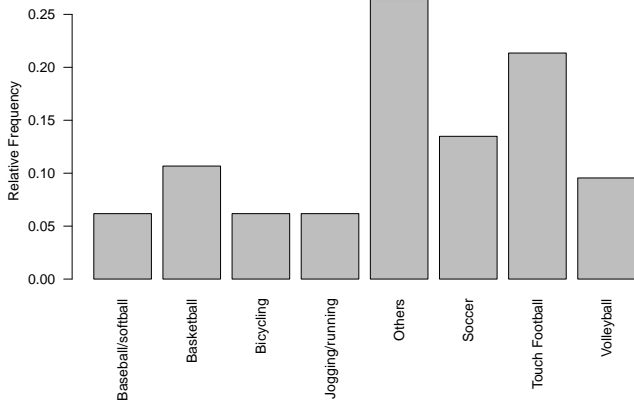
How could we visualize these information?
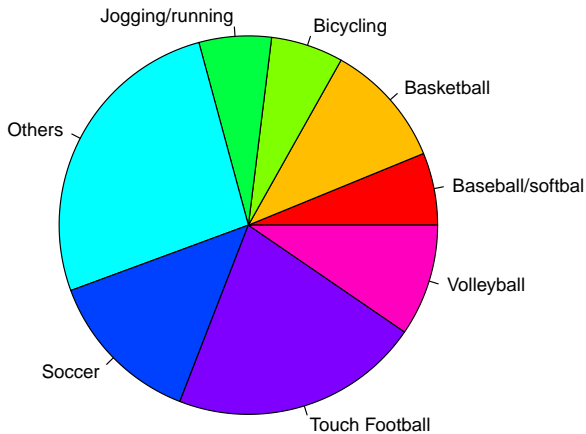⇒ Making a bar chart and/or a pie chart

# Bar Charts

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A bar chart draws a bar with a height proportional to the count in the table:

# Bar Charts cont'd

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# Pie Charts

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# Pie Charts cont'd

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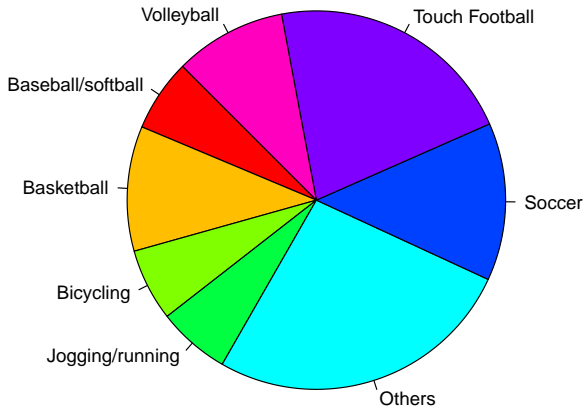
Discussion: Which one you prefer to visualize categorical variables. Why?

# A Good Bar Chart

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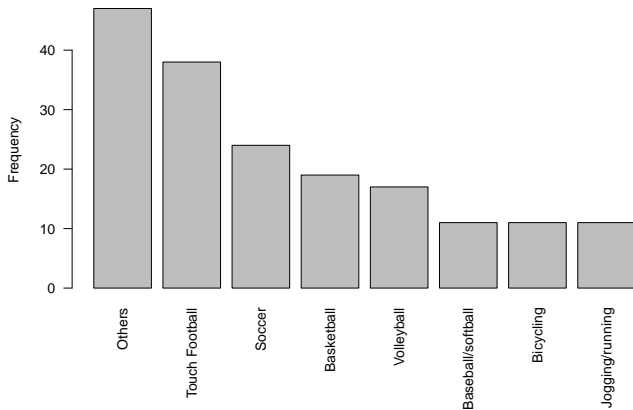
# A (Potential) Misleading Bar Chart

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## Same Data, Different Y-Axis
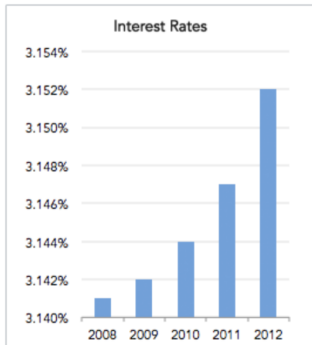
# Example: O'Hare Airport Flight Data

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```
  carrier origin
1    UA     EWR
2    AA     LGA
3    AA     LGA
4    AA     LGA
5    UA     LGA
6    UA     EWR
```

In this example, we have two categorical variables, `carrier` and `origin`, respectively. How to summarize/visualize this dataset?
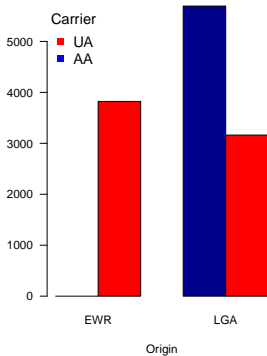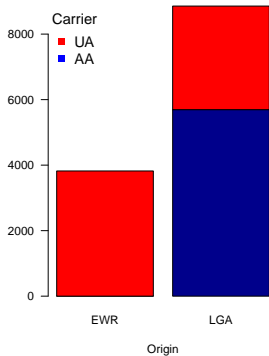
# ORD Flight Data Cont'd

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# Summarizing Numerical Variables

# Example: Murder arrests (per 100,000) in US States in 1973

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**Data**: 13.2, 10.0, 8.1, 8.8, 9.0, 7.9, 3.3, 5.9,
15.4, 17.4, 5.3, 2.6, 10.4, 7.2, 2.2, 6.0,
9.7, 15.4, 2.1, 11.3, 4.4, 12.1, 2.7, 16.1,
9.0, 6.0, 4.3, 12.2, 2.1, 7.4, 11.4, 11.1,
13.0, 0.8, 7.3, 6.6, 4.9, 6.3, 3.4, 14.4, 3.8,
13.2, 12.7, 3.2, 2.2, 8.5, 4.0, 5.7, 2.6, 6.8.

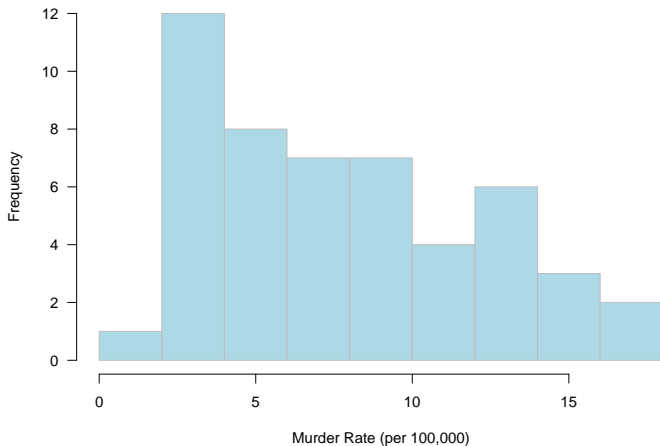**Question:** How to graphically summarize this data set?

# Stem-and-Leaf Plot

```
The decimal point is at the |

 0 | 8
 1 |
 2 | 1122667
 3 | 2348
 4 | 0349
 5 | 379
 6 | 00368
 7 | 2349
 8 | 158
 9 | 007
10 | 04
11 | 134
12 | 127
13 | 022
14 | 4
15 | 44
16 | 1
17 | 4
```
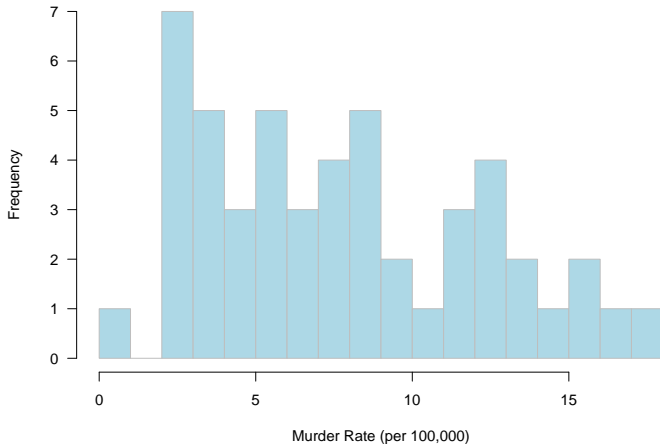
# Histogram

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Histogram of US Murder Rate in 1973

# Histogram

Histogram of US Murder Rate in 1973

# Box-and-Whisker Plot

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**Murder Rate (per 100,000)**

# Shape of Distributions

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Negative Skew          Positive Skew
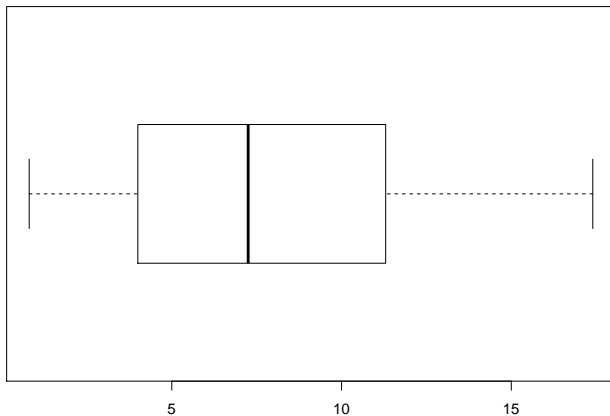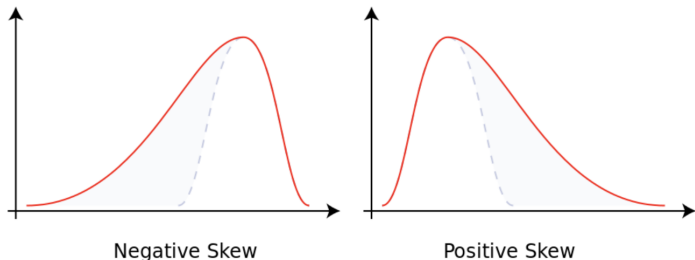
**Source:** Skewness - Wikipedia

In the rest of the class, we will talk about how to summarize a numerical variable in terms of its center and spread

# Measures of Center

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- A **measure of center** attempts to report a "typical" value for the variable

- When a measure of center is calculated with **sample data** it is a **statistic**

- When a measure of center is calculated with popular (e.g., census data) it is a **parameter**

- **Measures:** Mean, Median, Mode

# Mean

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- The population mean, denoted by $\mu_X$, is the sum of all the population values ($\{X_i, \cdots, X_N\}$) divided by the size of the population ($N$). That is,

$$\mu_X = \frac{\sum_{i=1}^{N} X_i}{N}$$

- The sample mean, denoted by $\bar{X}$ is the sum of all the sample values ($\{X_1, \cdots, X_n\}$) divided by the sample size ($n$). That is,

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

# Median

The median is the value separating the higher half from the lower half of a data sample

**How to compute the median:** Order the $n$ observations in a data set from smallest to largest, then

$$\text{Median} = \begin{cases} \text{the single middle value,} & \text{n odd} \\ \text{the average of the middle two values,} & \text{n even} \end{cases}$$

# Mode

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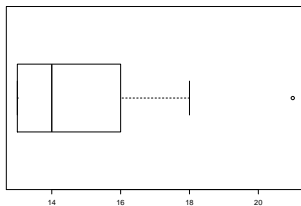
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The mode is the value of the observation that appears most frequently

**How to compute the mode(s):** Order the observations in a data set from smallest to largest, then find the number that is repeated more often than any other

# Example

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Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 21, 13

- Plot this "data set" and describe the shape of the distribution

# Example cont'd

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Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 21, 13

- Find the sample mean

$$\bar{X} = \sum_{i=1}^{9} \frac{13 + 18 + 13 + 14 + 13 + 16 + 14 + 21 + 13}{9} = 15$$

- Find the sample median
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 21

**Example cont'd**

Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 21, 13

- Find the sample mean

$$\bar{X} = \sum_{i=1}^{9} \frac{13 + 18 + 13 + 14 + 13 + 16 + 14 + 21 + 13}{9} = 15$$

- Find the sample median
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 21

**Example cont'd**

Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 21, 13

- Find the sample mean

$$\bar{X} = \sum_{i=1}^{9} \frac{13 + 18 + 13 + 14 + 13 + 16 + 14 + 21 + 13}{9} = 15$$

- Find the sample median

  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 21

  2. Compute the sample size $n$ and identify (or compute) the median value

**Example cont'd**

Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 21, 13

- Find the sample mean

$$\bar{X} = \sum_{i=1}^{9} \frac{13 + 18 + 13 + 14 + 13 + 16 + 14 + 21 + 13}{9} = 15$$

- Find the sample median
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 21
  2. Compute the sample size $n$ and identify (or compute) the median value

**Example cont'd**

Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 21, 13

- Find the sample mean

$$\bar{X} = \sum_{i=1}^{9} \frac{13 + 18 + 13 + 14 + 13 + 16 + 14 + 21 + 13}{9} = 15$$

- Find the sample median

1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 21

2. Compute the sample size $n$ and identify (or compute) the median value

3. $n = 9 \Rightarrow$ the median is the 5th number, which is $14$

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- Find the mode
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 21

# Example cont'd

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- Find the mode
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 21

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- Find the mode
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 21

  2. We have 4 13 and 2 14 ⇒ 13 is the mode

# Example: Resistant (Robust) Statistics

Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 210, 13

- Find the sample mean

$$\bar{X} = \sum_{i=1}^{9} \frac{13 + 18 + 13 + 14 + 13 + 16 + 14 + 210 + 13}{9} = 36$$

- Find the sample median
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 210

# Example: Resistant (Robust) Statistics

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Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 210, 13

- Find the sample mean

$$\bar{X} = \sum_{i=1}^{9} \frac{13 + 18 + 13 + 14 + 13 + 16 + 14 + 210 + 13}{9} = 36$$

- Find the sample median
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 210

# Example: Resistant (Robust) Statistics

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Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 210, 13

- Find the sample mean

$$\bar{X} = \sum_{i=1}^{9} \frac{13 + 18 + 13 + 14 + 13 + 16 + 14 + 210 + 13}{9} = 36$$

- Find the sample median

  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 210

  2. Compute the sample size $n$ and identify (or compute) the median value

# Example: Resistant (Robust) Statistics

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Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 210, 13

- Find the sample mean

$$\bar{X} = \sum_{i=1}^{9} \frac{13 + 18 + 13 + 14 + 13 + 16 + 14 + 210 + 13}{9} = 36$$

- Find the sample median

  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 210

  2. Compute the sample size $n$ and identify (or compute) the median value

# Example: Resistant (Robust) Statistics

Suppose we have the following list of values: 13, 18, 13, 14, 13, 16, 14, 210, 13

- Find the sample mean

$$\bar{X} = \sum_{i=1}^{9} \frac{13 + 18 + 13 + 14 + 13 + 16 + 14 + 210 + 13}{9} = 36$$

- Find the sample median

  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 210

  2. Compute the sample size $n$ and identify (or compute) the median value

  3. $n = 9 \Rightarrow$ the median is the 5th number, which is (still) 14

# Example cont'd

- Find the mode
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 210

# Example cont'd

- Find the mode
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 210

# Example cont'd

- Find the mode
    1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 210

    2. We have 4 13 and 2 14 $\Rightarrow$ 13 is (still) the mode

# Example cont'd

- Find the mode
  1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 210
  2. We have 4 13 and 2 14 $\Rightarrow$ 13 is (still) the mode

# Example cont'd

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- Find the mode
    1. Order the data first: 13, 13, 13, 13, 14, 14, 16, 18, 210

    2. We have 4 13 and 2 14 $\Rightarrow$ 13 is (still) the mode

What is the take-home message?

# Summary

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In this lecture, we learned

- Summarizing Categorical Data

- Summarizing the Central Tendency of Numerical Data

In next lecture we will learn

- How to summarize the spread of numerical data

- How to construct a boxplot

- How to visualize numerical + categorical variables and numerical + numerical variables