Doing data science

Data Science in a Box

datasciencebox.org

What's in a data analysis?

Five core activities of data analysis

1. Stating and refining the question
2. Exploring the data
3. Building formal statistical models
4. Interpreting the results
5. Communicating the results

Roger D. Peng and Elizabeth Matsui. "The Art of Data Science." A Guide for Anyone Who Works with Data. Skybrude Consulting, LLC (2015).

Stating and refining the question

Six types of questions

1. **Descriptive:** summarize a characteristic of a set of data
2. **Exploratory:** analyze to see if there are patterns, trends, or relationships between variables (hypothesis generating)
3. **Inferential:** analyze patterns, trends, or relationships in representative data from a population
4. **Predictive:** make predictions for individuals or groups of individuals
5. **Causal:** whether changing one factor will change another factor, on average, in a population
6. **Mechanistic:** explore "how" as opposed to whether

Jeffery T. Leek and Roger D. Peng. "What is the question?." Science 347.6228 (2015): 1314-1315.

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5. **Causal:** whether people with COVID-19 who were randomly assigned to take Vitamin D supplements or those who were not are hospitalised
6. **Mechanistic:** how increased vitamin D intake leads to a reduction in the number of viral illnesses

Questions to data science problems

- Do you have appropriate data to answer your question?
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> Suppose I want to estimate the average number of children in households in Edinburgh. I conduct a survey at an elementary school in Edinburgh and ask students at this elementary school how many children, including themselves, live in their house. Then, I take the average of the responses. Is this a biased or an unbiased estimate of the number of children in households in Edinburgh? If biased, will the value be an overestimate or underestimate?

Exploratory data analysis

Checklist

- Formulate your question
- Read in your data
- Check the dimensions
- Look at the top and the bottom of your data
- Validate with at least one external data source
- Make a plot
- Try the easy solution first

Formulate your question

- Consider scope:
  - Are air pollution levels higher on the east coast than on the west coast?
  - Are hourly ozone levels on average higher in New York City than they are in Los Angeles?
  - Do counties in the eastern United States have higher ozone levels than counties in the western United States?
- Most importantly: "Do I have the right data to answer this question?"

Read in your data

- Place your data in a folder called `data`
- Read it into R with `read_csv()` or friends (`read_delim()`, `read_excel()`, etc.)

```r
library(readxl)
fav_food <- read_excel("data/favourite-food.xlsx")
fav_food
```

```
## # A tibble: 5 x 6
##   `Student ID` `Full Name`      favourite.f~1 mealP~2 AGE   SES  
##          <dbl> <chr>            <chr>         <chr>   <chr> <chr>
## 1            1 Sunil Huffmann   Strawberry y~ Lunch ~ 4     High 
## 2            2 Barclay Lynn     French fries  Lunch ~ 5     Midd~
## 3            3 Jayendra Lyne    N/A           Breakf~ 7     Low  
## 4            4 Leon Rossini     Anchovies     Lunch ~ 99999 Midd~
## 5            5 Chidiegwu Dunkel Pizza         Breakf~ five  High 
## # ... with abbreviated variable names 1: favourite.food,
## #   2: mealPlan
```

clean_names()

If the variable names are malformatted, use `janitor::clean_names()`

```
library(janitor)
fav_food %>% clean_names()
```

```
## # A tibble: 5 x 6
##   student_id full_name        favourite_food  meal_~1 age   ses
##        <dbl> <chr>            <chr>           <chr>   <chr> <chr>
## 1          1 Sunil Huffmann   Strawberry yog~ Lunch ~ 4     High
## 2          2 Barclay Lynn     French fries    Lunch ~ 5     Midd~
## 3          3 Jayendra Lyne    N/A             Breakf~ 7     Low
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## 5          5 Chidiegwu Dunkel Pizza           Breakf~ five  High
## # ... with abbreviated variable name 1: meal_plan
```

Case study: NYC Squirrels!

- The Squirrel Census is a multimedia science, design, and storytelling project focusing on the Eastern gray (*Sciurus carolinensis*). They count squirrels and present their findings to the public.
- This table contains squirrel data for each of the 3,023 sightings, including location coordinates, age, primary and secondary fur color, elevation, activities, communications, and interactions between squirrels and with humans.

```
#install_github("mine-cetinkaya-rundel/nycsquirrels18")
library(nycsquirrels18)
```

Locate the codebook

mine-cetinkaya-rundel.github.io/nycsquirrels18/reference/squirrels.html

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Check the dimensions

```
dim(squirrels)
```

```
## [1] 3023   35
```

Look at the top...

```
squirrels %>% head()
```

```
## # A tibble: 6 x 35
##    long   lat unique_squ~1 hectare shift date       hecta~2 age
##   <dbl> <dbl> <chr>        <chr>   <chr> <date>       <dbl> <chr>
## 1 -74.0  40.8 13A-PM-1014~ 13A     PM    2018-10-14       4 <NA>
## 2 -74.0  40.8 15F-PM-1010~ 15F     PM    2018-10-10       6 Adult
## 3 -74.0  40.8 19C-PM-1018~ 19C     PM    2018-10-18       2 Adult
## 4 -74.0  40.8 21B-AM-1019~ 21B     AM    2018-10-19       4 <NA>
## 5 -74.0  40.8 23A-AM-1018~ 23A     AM    2018-10-18       2 Juve~
## 6 -74.0  40.8 38H-PM-1012~ 38H     PM    2018-10-12       1 Adult
## # ... with 27 more variables: primary_fur_color <chr>,
## #   highlight_fur_color <chr>,
## #   combination_of_primary_and_highlight_color <chr>,
## #   color_notes <chr>, location <chr>,
## #   above_ground_sighter_measurement <chr>,
## #   specific_location <chr>, running <lgl>, chasing <lgl>,
## #   climbing <lgl>, eating <lgl>, foraging <lgl>, ...
```

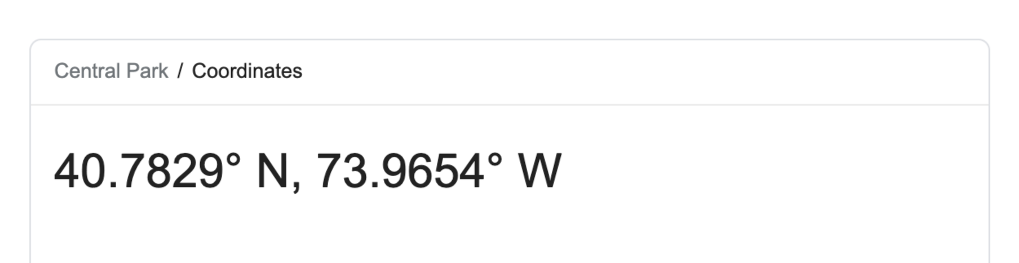
...and the bottom

```
squirrels %>% tail()
```

```
## # A tibble: 6 x 35
##    long   lat unique_squ~1 hectare shift date       hecta~2 age  
##   <dbl> <dbl> <chr>        <chr>   <chr> <date>       <dbl> <chr>
## 1 -74.0  40.8 6D-PM-1020-~ 06D     PM    2018-10-20       1 Adult
## 2 -74.0  40.8 21H-PM-1018~ 21H     PM    2018-10-18       1 Juve~
## 3 -74.0  40.8 31D-PM-1006~ 31D     PM    2018-10-06       2 Adult
## 4 -74.0  40.8 37B-AM-1018~ 37B     AM    2018-10-18       4 Adult
## 5 -74.0  40.8 21C-PM-1006~ 21C     PM    2018-10-06       1 Adult
## 6 -74.0  40.8 7G-PM-1018-~ 07G     PM    2018-10-18       4 Adult
## # ... with 27 more variables: primary_fur_color <chr>,
## #   highlight_fur_color <chr>,
## #   combination_of_primary_and_highlight_color <chr>,
## #   color_notes <chr>, location <chr>,
## #   above_ground_sighter_measurement <chr>,
## #   specific_location <chr>, running <lgl>, chasing <lgl>,
## #   climbing <lgl>, eating <lgl>, foraging <lgl>, ...
```

Validate with at least one external data source

```
## # A tibble: 3,023 x 2
##       long   lat
##      <dbl> <dbl>
##   1 -74.0  40.8
##   2 -74.0  40.8
##   3 -74.0  40.8
##   4 -74.0  40.8
##   5 -74.0  40.8
##   6 -74.0  40.8
##   7 -74.0  40.8
##   8 -74.0  40.8
##   9 -74.0  40.8
## 10 -74.0  40.8
## 11 -74.0  40.8
## 12 -74.0  40.8
## 13 -74.0  40.8
## 14 -74.0  40.8
## 15 -74.0  40.8
## # ... with 3,008 more rows
```

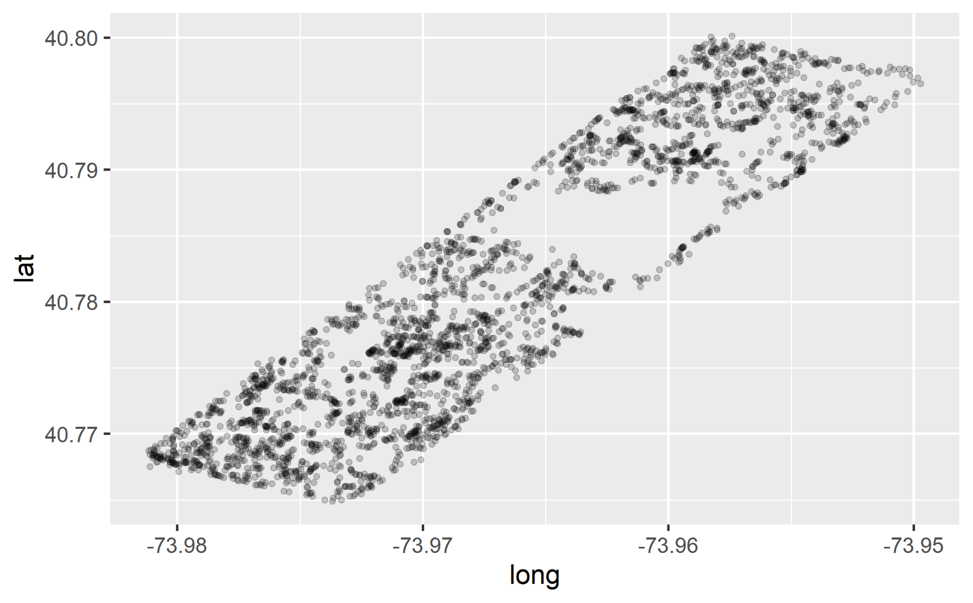


Central Park / Coordinates

40.7829° N, 73.9654° W

Make a plot

```
ggplot(squirrels, aes(x = long, y = lat)) +
  geom_point(alpha = 0.2)
```



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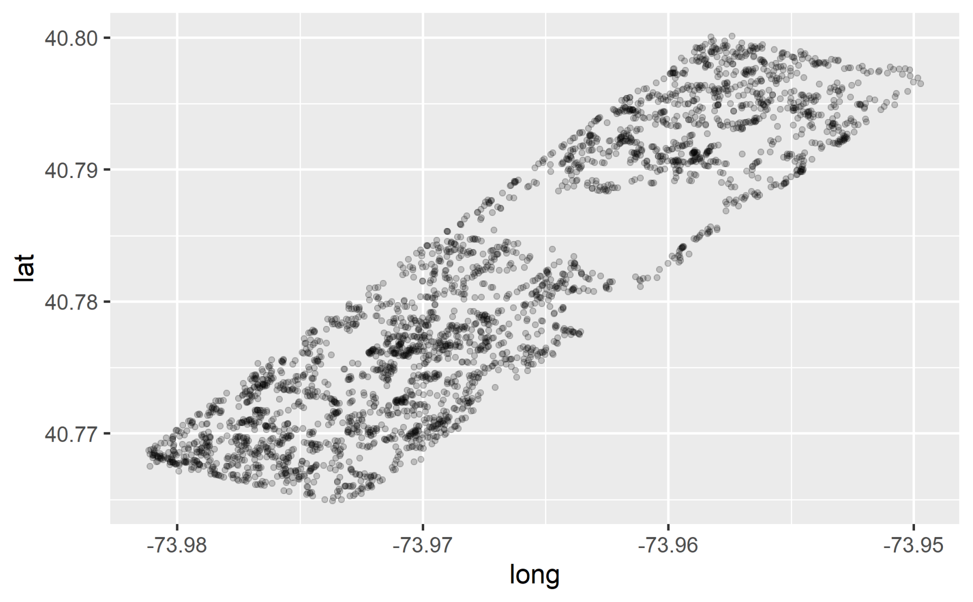
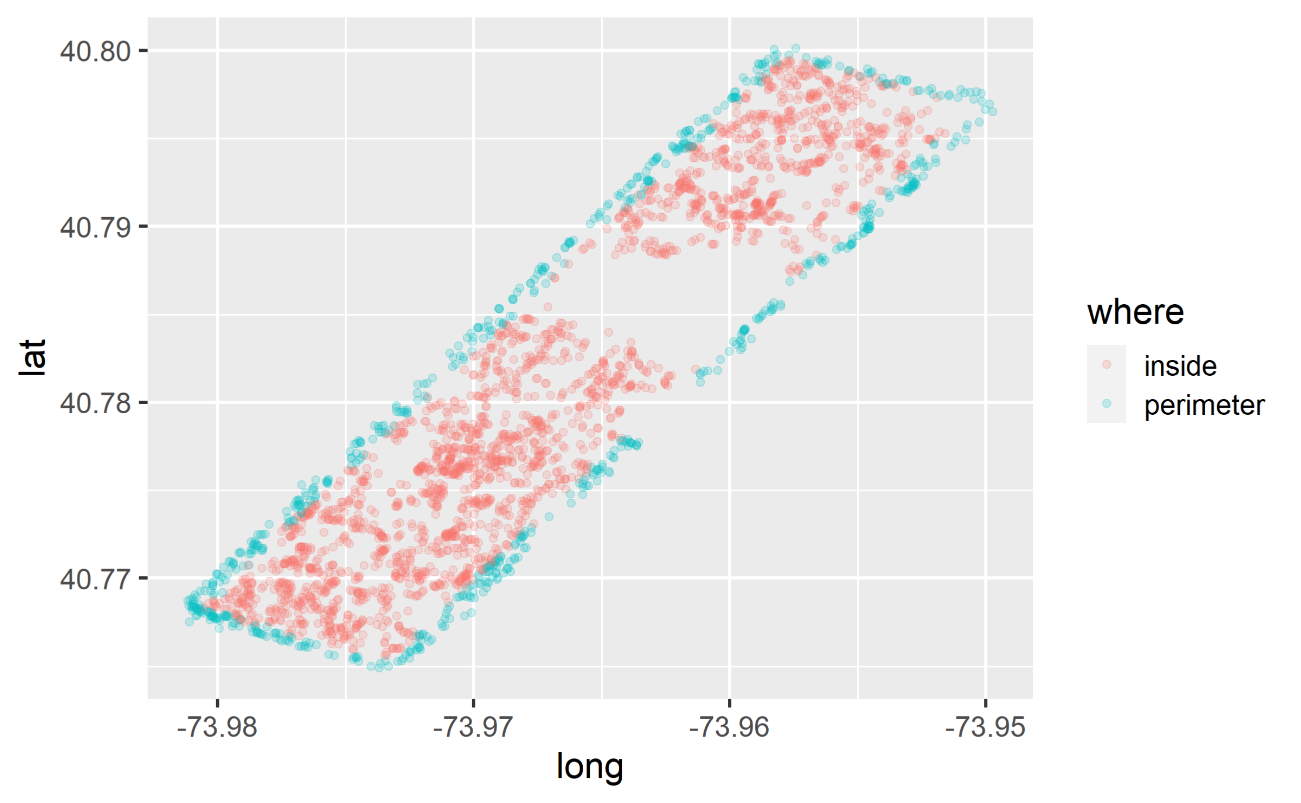
ggplot(squirrels, aes(x = long, y = lat)) +
  geom_point(alpha = 0.2)
```



Hypothesis: There will be a higher density of sightings on the perimeter than inside the park.

Try the easy solution first

Plot Code



Try the easy solution first

Plot Code

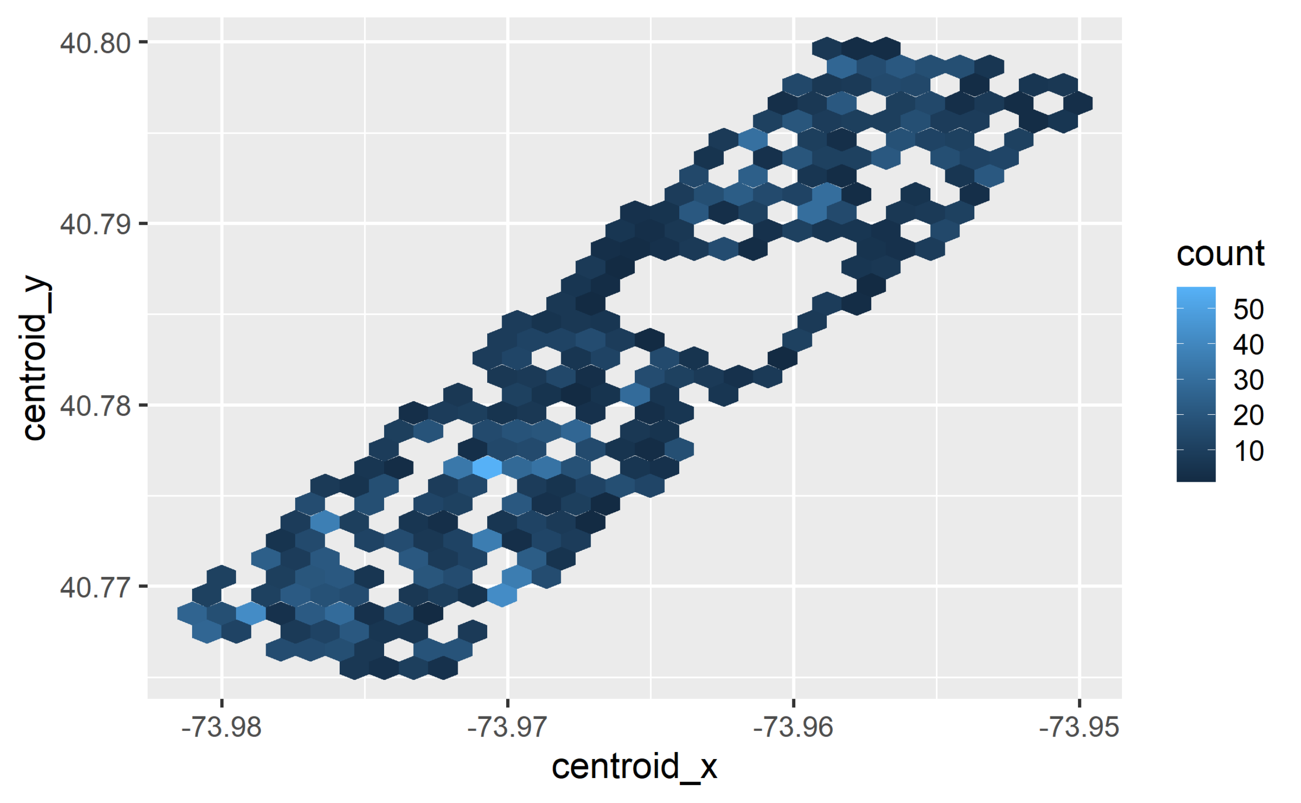
```
squirrels <- squirrels %>%
  separate(hectare, into = c("NS", "EW"), sep = 2, remove = FALSE) %>%
  mutate(where = if_else(NS %in% c("01", "42") | EW %in% c("A", "I"), "perimeter", "inside"))

ggplot(squirrels, aes(x = long, y = lat, color = where)) +
  geom_point(alpha = 0.2)
```

Then go deeper...

Plot

Code



Then go deeper...

Plot Code

```r
hectare_counts <- squirrels %>%
  group_by(hectare) %>%
  summarise(n = n())

hectare_centroids <- squirrels %>%
  group_by(hectare) %>%
  summarise(
    centroid_x = mean(long),
    centroid_y = mean(lat)
  )

squirrels %>%
  left_join(hectare_counts, by = "hectare") %>%
  left_join(hectare_centroids, by = "hectare") %>%
  ggplot(aes(x = centroid_x, y = centroid_y, color = n)) +
  geom_hex()
```

The squirrel is staring at me!

```
squirrels %>%
  filter(str_detect(other_interactions, "star")) %>%
  select(shift, age, other_interactions)
```

```
## # A tibble: 11 x 3
##   shift age   other_interactions
##   <chr> <chr> <chr>
## 1 AM    Adult staring at us
## 2 PM    Adult he took 2 steps then turned and stared at me
## 3 PM    Adult stared
## 4 PM    Adult stared
## 5 PM    Adult stared
## 6 PM    Adult stared & then went back up tree—then ran to differ~
## # ... with 5 more rows
```

Communicating for your audience

- Avoid: Jargon, uninterpreted results, lengthy output
- Pay attention to: Organization, presentation, flow
- Don't forget about: Code style, coding best practices, meaningful commits
- Be open to: Suggestions, feedback, taking (calculated) risks