12: Categorical x Continuous data (1 of 2)

Aug 13, 2023

1. THIS CHAPTER explores **Categorical** x **Continuous** data. It explains how to summarize and visualize *bivariate continuous data across categories*. Here, we delve into the intersection of continuous data and categorical variables, examining how the former can be split, summarized, and compared across different levels of one or more categorical variables.

2. We bring to light methods for generating statistics per group and data manipulation techniques. This includes processes like grouping, filtering, and summarizing continuous data, contingent on categorical variables. We visualize such data by creating juxtaposed box plots, segmented histograms, and density plots that reveal the distribution of continuous data across varied categories.

3. **Data**: Suppose we run the following code to prepare the `mtcars` data for subsequent analysis and save it in a tibble called `tb`.

```
# Load the required libraries, suppressing annoying startup messages
library(dplyr, quietly = TRUE, warn.conflicts = FALSE)
library(tibble, quietly = TRUE, warn.conflicts = FALSE)
library(knitr) # For formatting tables
# Read the mtcars dataset into a tibble called tb
data(mtcars)
tb <- as_tibble(mtcars)
# Convert relevant columns into factor variables
tb$cyl <- as.factor(tb$cyl) # cyl = {4,6,8}, number of cylinders
tb$am <- as.factor(tb$am) # am = {0,1}, 0:automatic, 1: manual transmission
tb$vs <- as.factor(tb$vs) # vs = {0,1}, v-shaped engine, 0:no, 1:yes
tb$gear <- as.factor(tb$gear) # gear = {3,4,5}, number of gears
# Directly access the data columns of tb, without tb$mpg
attach(tb)
```

Summarizing Continuous Data

Across one Category

- We review the use of the inbuilt functions (i) `aggregate()`; (ii) `tapply()`; and the function (iii) `describeBy()` from package `pysch`, to summarize continuous data split across a category.

1. **Using `aggregate()`**

- We use the `aggregate()` function to investigate the bivariate relationship between mileage (`mpg`) and number of cylinders (`cyl`). The following code displays a summary table showing the average mileage of the cars broken down by number of cylinders (`cyl` = 4, 6, 8) using `aggregate()`.

```
A0 <- aggregate(tb$mpg,
          by = list(tb$cyl),
          FUN = mean)
names(A0) <- c("Cylinders", "Mean_mpg")
kable(A0, digits=2, caption = "Mean of Mileage (mpg) by Cylinder (cyl=4,6,8)")
```

Table 0.1: Mean of Mileage (mpg) by Cylinder (cyl=4,6,8)

Cylinders	Mean_mpg
4	26.66
6	19.74
8	15.10

2. **Discussion**:

- The first argument in `aggregate()` is the data vector `tb$mpg`.
- The second argument, `by`, denotes a list of variables to group by. Here, we have supplied `tb$cyl`, since we wish to partition our data based on the unique values of `cyl`.
- The third argument, `FUN`, is the function we want to apply to each subset of data. We are using `mean` here, calculating the average mpg for each unique `cyl` value. We can alternately aggregate based on a variety of statistical functions including `sum`, `median`, `min`, `max`, `sd`, `var`, `length`, `IQR`.
- The output of `aggregate()` is saved in a new tibble named `agg`. We utilize the `names()` function to rename the columns and display `agg`. [1]

3. **Using `tapply()`**

- The `tapply()` function is another convenient tool to apply a function to subsets of a vector, grouped by some factors.

```
A1 <- tapply(tb$mpg,
             tb$cyl,
             mean)
A1
```

```
       4        6        8 
26.66364 19.74286 15.10000 
```

4. **Discussion**:

- In this code, `tapply(tb$mpg, tb$cyl, mean)` calculates the average miles per gallon (`mpg`) for each unique number of cylinders (`cyl`) within the `tb` tibble.
- `tb$mpg` represents the vector to which we want to apply the function.
- `tb$cyl` serves as our grouping factor.
- `mean` is the function that we're applying to each subset of our data.
- The result will be a vector where each element is the average `mpg` for a unique number of cylinders (`cyl`), as determined by the unique values of `tb$cyl`. [1]

5. **Using `describeBy()` from package psych**

- The `describeBy()` function, part of the `psych` package, can be used to compute descriptive statistics of a numeric variable, broken down by levels of a grouping variable.

```
library(psych)
A2 <- describeBy(mpg, cyl)
print(A2)
```

```
 Descriptive statistics by group 
group: 4
   vars  n  mean   sd median trimmed  mad  min  max range skew kurtosis   se
X1    1 11 26.66 4.51     26   26.44 6.52 21.4 33.9  12.5 0.26    -1.65 1.36
------------------------------------------------------------ 
group: 6
   vars n  mean   sd median trimmed  mad  min  max range  skew kurtosis   se
X1    1 7 19.74 1.45   19.7   19.74 1.93 17.8 21.4   3.6 -0.16    -1.91 0.55
------------------------------------------------------------ 
```

```
group: 8
   vars  n mean   sd median trimmed  mad  min  max range  skew kurtosis   se
X1    1 14 15.1 2.56   15.2   15.15 1.56 10.4 19.2   8.8 -0.36    -0.57 0.68
```

6. **Discussion**:

- `describeBy(mpg, cyl)` computes descriptive statistics of miles per gallon `mpg` variable, broken down by the unique values in the number of cylinders (`cyl`).
- It calculates statistics such as the mean, sd, median, for `mpg`, separately for each unique number of cylinders (`cyl`). [2]

Across two Categories

- We extend the above discussion and study how to summarize continuous data split across **two** categories.
- We review the use of the inbuilt functions (i) `aggregate()` and the function (ii) `describeBy()` from package `pysch`. While the `tapply()` function can theoretically be employed for this task, the resulting code tends to be long and lacks efficiency. Therefore, we opt to exclude it from practical use.

1. Using **`aggregate()`**

- Distribution of Mileage (`mpg`) by Cylinders (`cyl` = {4,6,8}) and Transmisson Type (`am` = {0,1})

```
B0 <- aggregate(tb$mpg,
          by = list(tb$cyl, tb$am),
          FUN = mean)
names(B0) <- c("Cylinders","Transmission","Mean_mpg")
kable(B0,
      digits=2, caption = "Mean of Mileage (mpg) by Cylinders (cyl=4,6,8) and Transmission
```

Table 0.2: Mean of Mileage (mpg) by Cylinders (cyl=4,6,8) and Transmission (am=0,1)

Cylinders	Transmission	Mean_mpg
4	0	22.90
6	0	19.12
8	0	15.05
4	1	28.08
6	1	20.57
8	1	15.40

2. **Discussion**:

- In our code, the first argument of `aggregate()` is `tb$mpg`, indicating that we want to perform computations on the `mpg` variable.
- The by argument is a list of variables by which we want to group our data, specified as `list(tb$cyl, tb$am)`. This means that separate computations are done for each unique combination of `cyl` and `am`.
- The `FUN` argument indicates the function to be applied to each subset of our data. Here, we use mean, meaning that we compute the mean mpg for each group.

3. Using `aggregate()` for multiple continuous variables: Consider this extension of the above code for calculating the mean of three variables - `mpg`, `wt`, and `hp`, grouped by both am and cyl variables:

- Distribution of Mileage (`mpg`), Weight (`wt`), Horsepower (`hp`) by Cylinders (`cyl` = {4,6,8}) and Transmisson Type (`am` = {0,1})

```
B1 <- aggregate(list(tb$mpg, tb$wt, tb$hp),
          by = list(tb$am, tb$cyl),
          FUN = mean)
names(B1) <- c("Transmission","Cylinders","Mean_mpg","Mean_wt","Mean_hp")
kable(B1,
      digits=2, caption = "Mean of Mileage (mpg), Weight (wt), Horsepower (hp) by Transmis
```

Table 0.3: Mean of Mileage (mpg), Weight (wt), Horsepower (hp) by Transmission (am=0,1) and Cylinders (cyl=4,6,8)

Transmission	Cylinders	Mean_mpg	Mean_wt	Mean_hp
0	4	22.90	2.94	84.67
1	4	28.08	2.04	81.88
0	6	19.12	3.39	115.25
1	6	20.57	2.76	131.67
0	8	15.05	4.10	194.17
1	8	15.40	3.37	299.50

4. **Discussion**:

- In this code, the `aggregate()` function takes a list of the three variables as its first argument, indicating that the mean should be calculated for each of these variables separately within each combination of `am` and `cyl`.
- The sequence of the categorizing variables also varies - initially, the data is grouped by

`cyl`, followed by a subdivision based on `am`.

5. Using **`aggregate()`** with multiple functions: Consider an extension of the above code for calculating the mean and the SD of `mpg`, grouped by both `am` and `cyl` factor variables:

- Distribution of Mileage (`mpg`), by Cylinders (`cyl` = {4,6,8}) and Transmission Type (`am` = {0,1})

```
agg_mean <- aggregate(tb$mpg,
                      by = list(tb$cyl, tb$am),
                      FUN = mean)
agg_sd <- aggregate(tb$mpg,
                    by = list(tb$cyl, tb$am),
                    FUN = sd)
agg_median <- aggregate(tb$mpg,
                        by = list(tb$cyl, tb$am),
                        FUN = median)

# Merge them together, two data frames at a time
B2 <- merge(agg_mean, agg_sd,
            by = c("Group.1", "Group.2"))
B2 <- merge(B2, agg_median,
            by = c("Group.1", "Group.2"))

# Rename columns for clarity
names(B2) <- c("Cylinders", "Transmission", "Mean_mpg", "SD_mpg", "Median_mpg")

kable(B2,
      digits=2, caption = "Mean, SD, Median of Mileage (mpg) by Cylinders (cyl=4,6,8) and
```

Table 0.4: Mean, SD, Median of Mileage (mpg) by Cylinders (cyl=4,6,8) and Transmission (am=0,1)

Cylinders	Transmission	Mean_mpg	SD_mpg	Median_mpg
4	0	22.90	1.45	22.80
4	1	28.08	4.48	28.85
6	0	19.12	1.63	18.65
6	1	20.57	0.75	21.00
8	0	15.05	2.77	15.20
8	1	15.40	0.57	15.40

6. **Discussion**:

- We analyze our dataset to comprehend the relationships between vehicle miles per gallon (`mpg`), number of cylinders (`cyl`), and type of transmission (`am`).
- Initially, we computed the mean, standard deviation, and median of `mpg` for every unique combination of `cyl` and `am`.
- After individual computations, we combined these results into a single, comprehensive data frame called `merged_data`. This structured dataset now clearly presents the average, variability, and median of fuel efficiency segmented by cylinder count and transmission type.

7. **Using `describeBy()` from package `psych`**

- The `describeBy()` function, part of the `psych` package, can be used to compute descriptive statistics of continuous variable, broken down by levels of a two categorical varaibles. Consider the following code:

```
tb_columns <- tb[c("mpg", "wt", "hp")]
tb_factors <- list(tb$am,
                   tb$cyl)
# Use describeBy()
B3 <- describeBy(tb_columns,
                    tb_factors)
print(B3)
```

```
 Descriptive statistics by group
: 0
: 4
    vars n  mean    sd median trimmed  mad   min   max range  skew kurtosis
mpg    1 3 22.90  1.45  22.80   22.90 1.93 21.50 24.40  2.90  0.07    -2.33
wt     2 3  2.94  0.41   3.15    2.94 0.06  2.46  3.19  0.73 -0.38    -2.33
hp     3 3 84.67 19.66  95.00   84.67 2.97 62.00 97.00 35.00 -0.38    -2.33
       se
mpg  0.84
wt   0.24
hp  11.35
------------------------------------------------------------
: 1
: 4
    vars n  mean    sd median trimmed   mad   min    max range  skew kurtosis
mpg    1 8 28.08  4.48  28.85   28.08  4.74 21.40  33.90 12.50 -0.21    -1.66
wt     2 8  2.04  0.41   2.04    2.04  0.36  1.51   2.78  1.27  0.35    -1.15
hp     3 8 81.88 22.66  78.50   81.88 20.76 52.00 113.00 61.00  0.14    -1.81
```

```
    se
mpg 1.59
wt  0.14
hp  8.01
------------------------------------------------------------
: 0
: 6
    vars n   mean   sd median trimmed  mad    min    max range  skew kurtosis
mpg    1 4  19.12 1.63  18.65   19.12 1.04  17.80  21.40  3.60  0.48    -1.91
wt     2 4   3.39 0.12   3.44    3.39 0.01   3.21   3.46  0.25 -0.73    -1.70
hp     3 4 115.25 9.18 116.50  115.25 9.64 105.00 123.00 18.00 -0.09    -2.33
    se
mpg 0.82
wt  0.06
hp  4.59
------------------------------------------------------------
: 1
: 6
    vars n   mean    sd median trimmed  mad    min    max range  skew kurtosis
mpg    1 3  20.57  0.75  21.00   20.57 0.00  19.70  21.00  1.30 -0.38    -2.33
wt     2 3   2.76  0.13   2.77    2.76 0.16   2.62   2.88  0.25 -0.12    -2.33
hp     3 3 131.67 37.53 110.00  131.67 0.00 110.00 175.00 65.00  0.38    -2.33
     se
mpg  0.43
wt   0.07
hp  21.67
------------------------------------------------------------
: 0
: 8
    vars  n   mean    sd median trimmed   mad    min    max range  skew
mpg    1 12  15.05  2.77  15.20   15.10  2.30  10.40  19.20  8.80 -0.28
wt     2 12   4.10  0.77   3.81    4.04  0.41   3.44   5.42  1.99  0.85
hp     3 12 194.17 33.36 180.00  193.50 40.77 150.00 245.00 95.00  0.28
    kurtosis   se
mpg    -0.96 0.80
wt     -1.14 0.22
hp     -1.44 9.63
------------------------------------------------------------
: 1
: 8
    vars n   mean    sd median trimmed   mad    min    max range skew kurtosis
mpg    1 2  15.40  0.57  15.40   15.40  0.59  15.00  15.80   0.8    0    -2.75
wt     2 2   3.37  0.28   3.37    3.37  0.30   3.17   3.57   0.4    0    -2.75
```

```
hp     3 2 299.50 50.20 299.50  299.50 52.63 264.00 335.00  71.0    0    -2.75
      se
mpg  0.4
wt   0.2
hp  35.5
```

7. **Discussion**:

- We specify a subset of the dataframe `tb` that includes only the columns of interest – `mpg`, `wt`, and `hp` and save it into a variable `tb_columns`.
- Next, we create a list, `tb_factors`, that contains the factors `am` and `cyl`.
- After that, we call the `describeBy()` function from the `psych` package. This function calculates descriptive statistics for each combination of levels of the factors `am` and `cyl` and for each of the continuous variables `mpg`, `wt`, and `hp`.

Visualizing Continuous Data

Let's take a closer look at some of the most effective ways of visualizing univariate continuous data, including

(i) Bee Swarm plots;

(ii) Stem-and-Leaf plots;

(iii) Histograms;

(iv) PDF and CDF Density plots;

(v) Box plots;

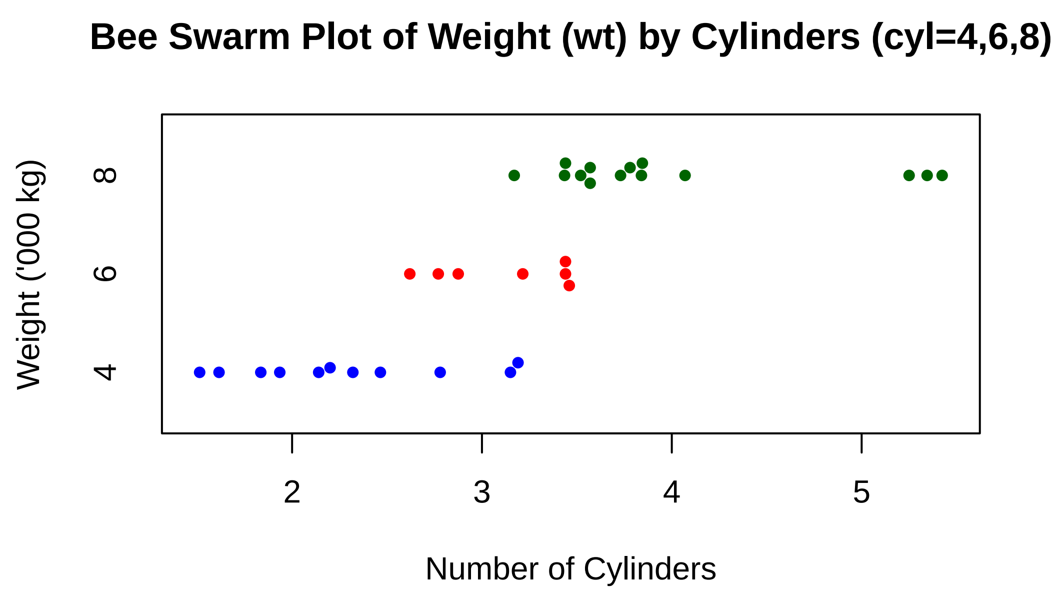
(vi) Violin plots;

(vii) Q-Q plots.

Bee Swarm Plot

1. We extend a Bee Swarm plot of a *one-dimensional scatter plot* for a continuous variable, split by a categorical variable. [6]
2. Consider the following code, which generates a beeswarm plot displaying vehicle weights (`wt`) segmented by their number of cylinders (`cyl`):

```r
# Load the beeswarm package
library(beeswarm)
# Create a bee swarm plot of wt column split by cyl
beeswarm(tb$wt ~ tb$cyl,
         main="Bee Swarm Plot of Weight (wt) by Cylinders (cyl=4,6,8)",
         xlab="Number of Cylinders",
         ylab="Weight ('000 kg)",
         pch=16,  # type of points
         cex=0.8, # size of the points
         col=c("blue","red","darkgreen"),
         horizontal = TRUE)
```



3. **Discussion**:

- **Data**: We use tb*wt tb*cyl to specify that we want a beeswarm plot for Weight (`wt`), split by no of cylinders (`cyl`),
- **Title**: It is labeled “Bee Swarm Plot of Weight (wt) by Number of Cylinders”.
- **Axes Labels**: The x-axis shows “Number of Cylinders”, while the y-axis denotes “Weight (’000 kg)”.
- **Data Points**: Using `pch=16`, data points appear as solid circles.
- **Size of Points**: With `cex=0.8`, these circles are slightly smaller than default.
- **Colors**: The `col` parameter assigns colors (“blue”, “red”, and “dark green”) based on cylinder counts.

- **Orientation**: Set as horizontal with `horizontal=TRUE`.
- To summarize, this visual distinguishes vehicle weights across cylinder counts and highlights data point densities for each group.

Stem-and-Leaf Plot across one Category

1. Suppose we wanted to visualize the distribution of a continuous variable across different levels of a categorical variable, using stem-and-leaf plots.
2. To illustrate, let us display vehicle weights (`wt`) separately for each transmission type (`am`) using stem-and-leaf plots.

```
# Choose 'wt' and 'cyl' columns from 'tb' dataframe. Assign the result to 'tb3'.
tb3 <- tb[, c("wt", "am")]

# Split the 'tb3' tibble into subsets based on 'am'. Each subset consists of rows with the
tb_split <- split(tb3, tb3$am)

# Apply a function to each subset of 'tb_split' using 'lapply()'.
# The function takes a subset 'x' and creates a stem-and-leaf plot of the 'wt' values in '
lapply(tb_split,
       function(x)
         stem(x$wt))
```

```
The decimal point is at the |

2 | 5
3 | 22244445567888
4 | 1
5 | 334


The decimal point is at the |

1 | 5689
2 | 123
2 | 6889
3 | 2
3 | 6
```

```
$`0`
NULL

$`1`
NULL
```

3. **Discussion**:

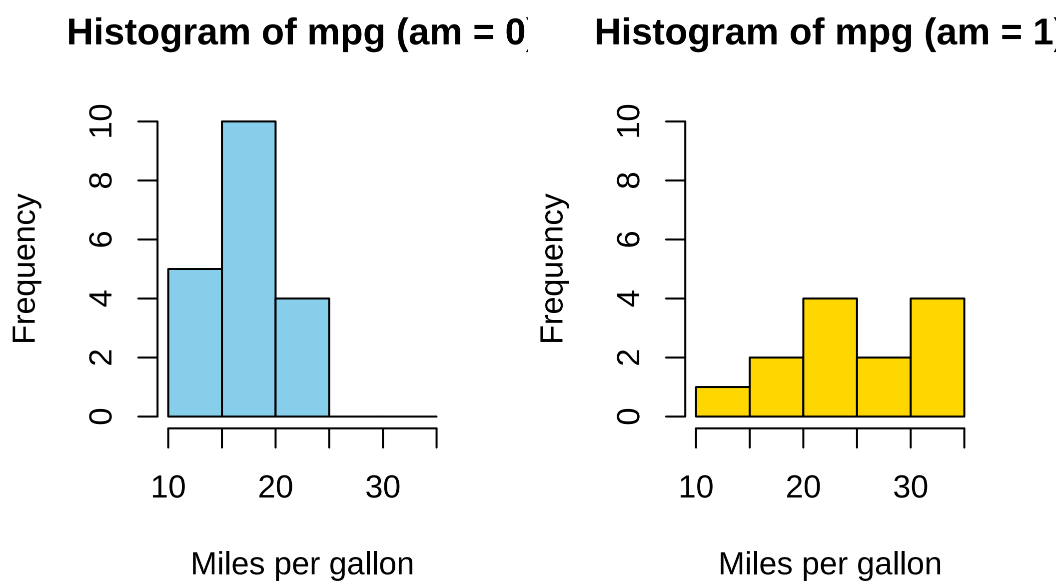
- Column Selection: The code extracts the `wt` (weight) and `am` (transmission type) columns from `tb` and saves them in `tb3`.
- Data Splitting: It then divides `tb3` into subsets based on `am` values, resulting in separate groups for each transmission type.
- Visualization: Using `lapply()`, the code generates stem-and-leaf plots for the `wt` values in each subset, showcasing weight distributions for different transmission types. In this context, it shows the distribution of vehicle weights for each transmission type (automatic and manual).

Histograms across one Category

1. Visualizing histograms of car mileage (`mpg`) broken down by transmission (`am`=0,1)

```r
split_data <- split(tb$mpg, tb$am) # Split the data by 'am' variable
par(mfrow = c(1, 2)) # Create a 1-row 2-column layout
color_vector <- c("skyblue", "gold") # Define the color vector

# Create a histogram for subset with am = 0
hist(split_data[[1]],
     main = "Histogram of mpg (am = 0)",
     breaks = seq(10, 35, by = 5), # This creates bins with ranges 10-15, 15-20, etc.
     xlab = "Miles per gallon",
     col = color_vector[1], # Use the color vector,
     border = "black",
     ylim = c(0, 10))

# Create a histogram for subset with am = 1
hist(split_data[[2]],
     main = "Histogram of mpg (am = 1)",
     breaks = seq(10, 35, by = 5), # This creates bins with ranges 10-15, 15-20, etc.
     xlab = "Miles per gallon",
     col = color_vector[2], # Use the color vector,
     border = "black",
```

```
    ylim = c(0, 10))
```



In Appendix A1, we have alternative code written using a for loop

2. **Discussion**:

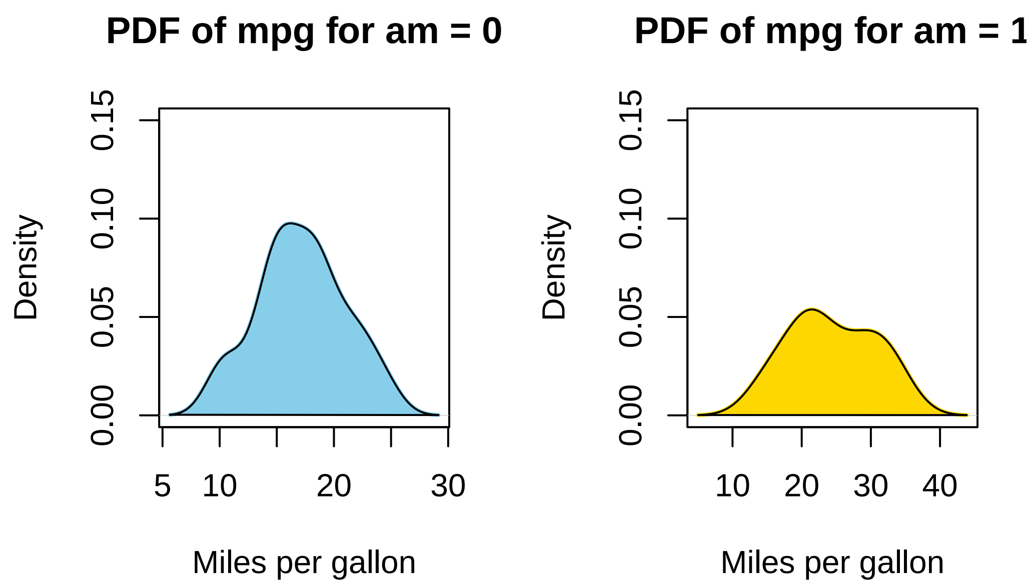
- We aim to visualize the distribution of the `mpg` values from the `tb` dataset based on the `am` variable, which can be either 0 or 1.
- Data Splitting: We segregate `mpg` values into two subsets using the `split` function, depending on the `am` values. In R, the double brackets [[ ]] are used to access the elements of a list or a specific column of a data frame. `split_data[[1]]` accesses the first element of the list `split_data`.
- Layout Setting: The `par` function is configured to display two plots side by side in a single row and two columns format.

3. Color Vector: We introduce a `color_vector` to assign distinct colors to each histogram for differentiation.
4. Histogram: Two histograms are generated, one for each `am` value (0 and 1). These histograms use various parameters like title, x-axis label, color, and y-axis limits to provide a clear representation of the data's distribution. [4]

Probability Density Function (PDF) across one Category

1. Visualizing Probability Density Functions (PDF) of car mileage (`mpg`) broken down by transmission (`am`=0,1)

```
split_data <- split(tb$mpg, tb$am)  # Split 'mpg' data by 'am' values
par(mfrow = c(1, 2))  # Set layout for 2 plots side by side
color_vector <- c("skyblue", "gold")  # Define colors for the plots

# Calculate density for am = 0 and plot it
dens_0 <- density(split_data[[1]])
plot(dens_0,
     main = "PDF of mpg for am = 0",
     xlab = "Miles per gallon",
     col = color_vector[1],
     border = "black",
     ylim = c(0, 0.15),
     lwd = 2)  # Plot density curve for am = 0
polygon(dens_0, col = color_vector[1], border = "black")  # Fill under the curve

# Calculate density for am = 1 and plot it
dens_1 <- density(split_data[[2]])
plot(dens_1,
     main = "PDF of mpg for am = 1",
     xlab = "Miles per gallon",
     col = color_vector[2],
     border = "black",
     ylim = c(0, 0.15),
     lwd = 2)  # Plot density curve for am = 1
polygon(dens_1, col = color_vector[2], border = "black")  # Fill under the curve
```



In Appendix A2, we have alternative code written using a for loop

2. **Discussion**:

- `dens_0 <- density(split_data[[1]])` calculates the density values for the subset where `am` is 0.
- The subsequent plot function visualizes the density curve, setting various parameters like the title, x-axis label, color, and line width.
- The polygon function fills the area under the density curve with the specified color, giving a shaded appearance to the plot.
- The process is repeated for the subset where `am` is 1. The code calculates the density, plots it, and then uses the polygon function to shade the area under the curve.

In Appendix A3, we demonstrate how to draw overlapping PDFs on the same plot, using base R functions.

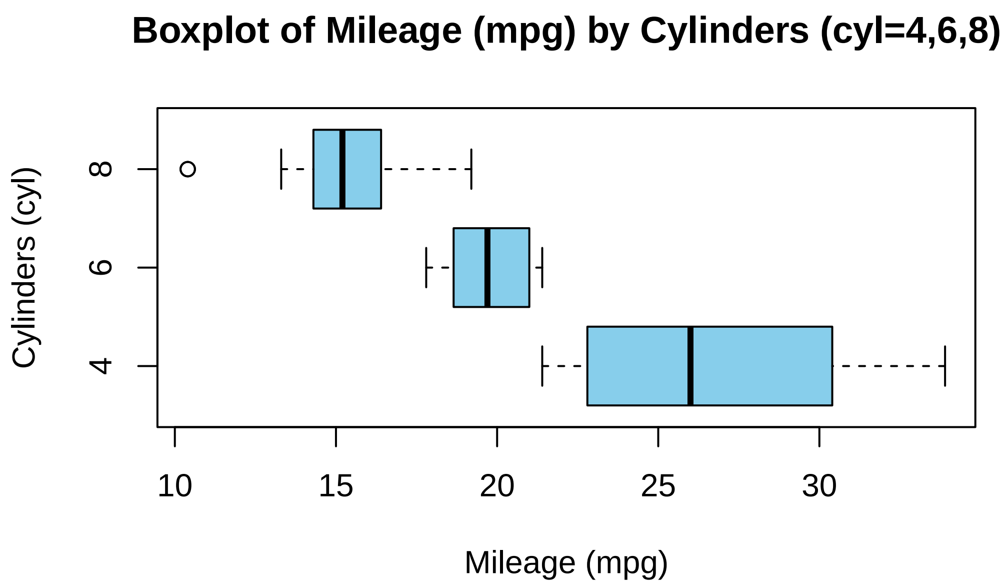
Cumulative Density Function (CDF) across one Category

In Appendix A4, we demonstrate how to draw a CDF, using base R functions

Box Plots across one Category

1. Visualizing Median using Box Plot – median weight of the cars broken down by cylinders (`cyl`=4,6,8)

```
boxplot(mpg~cyl,
        main = "Boxplot of Mileage (mpg) by Cylinders (cyl=4,6,8)",
        xlab = "Mileage (mpg)",
        ylab = "Cylinders (cyl)",
        col = c("skyblue"),
        horizontal = TRUE
        )
```



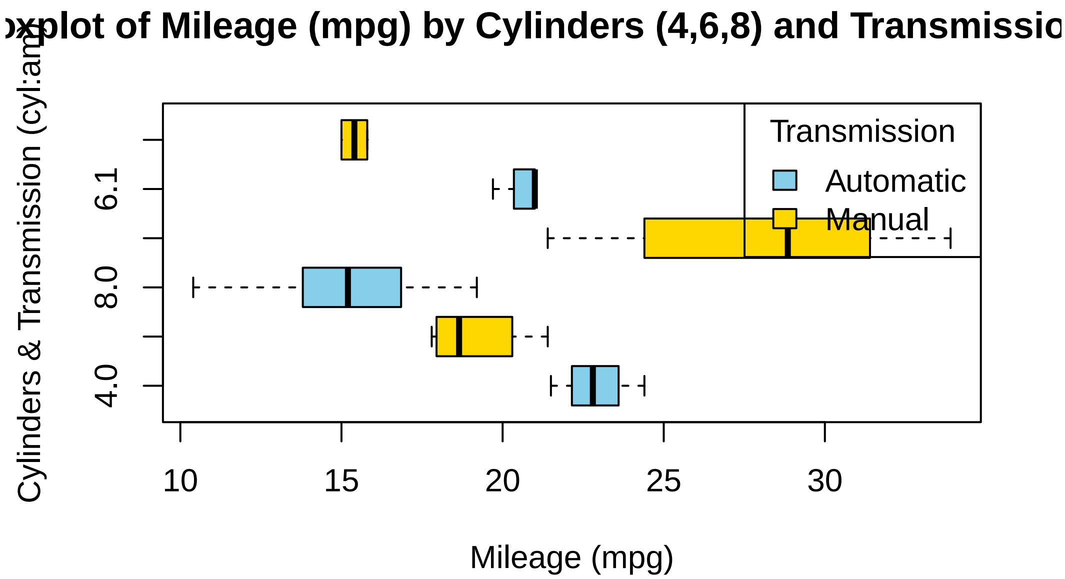
2. **Discussion**:

- This code creates a visual representation of the distribution of miles per gallon (`mpg`) based on the number of cylinders (`cyl`), using the `boxplot` function from the base graphics package in R. down:
- Data Input: The formula `mpg ~ cyl` instructs R to create separate boxplots for each unique value of `cyl`, with each boxplot representing the distribution of `mpg` values for that particular cylinder count.
- Title Configuration: `main` specifies the title of the plot as “Boxplot of Miles Per Gallon (mpg) by Cylinders.”

- Axis Labels: The labels for the x-axis and y-axis are set using `xlab` and `ylab`, respectively. Here, `xlab` labels the mileage (or `mpg`), while `ylab` labels the number of cylinders (`cyl`).
- Color Choice: The `col` argument is set to "skyblue," which colors the body of the boxplots in a light blue shade.
- Orientation: By setting `horizontal` to `TRUE`, the boxplots are displayed in a horizontal orientation rather than the default vertical orientation.
- In essence, we're visualizing the variations in car mileage based on the number of cylinders using horizontal boxplots. This type of visualization helps in understanding the central tendency, spread, and potential outliers of mileage for different cylinder counts.

3. Visualizing Median using Box Plot – median weight of the cars broken down by cylinders (`cyl`=4,6,8) and Transmission (`am`=0,1)

```
boxplot(mpg ~ cyl * am,
        main = "Boxplot of Mileage (mpg) by Cylinders (4,6,8) and Transmission (0,1)",
        xlab = "Mileage (mpg)",
        ylab = "Cylinders & Transmission (cyl:am)",
        col = c("skyblue", "gold"), # added a second color for differentiation
        horizontal = TRUE
        )
# Add a legend
legend("topright",
       legend = c("Automatic", "Manual"),
       fill = c("skyblue", "gold"),
       title = "Transmission"
)
```



4. **Discussion**:

- This R code presents a horizontal boxplot showcasing the distribution of mileage (`mpg`) based on the interaction between the number of car cylinders (`cyl`) and the type of transmission (`am`).
- Boxplot Creation: The `boxplot` function is used to generate the visualization. With the formula `mpg ~ cyl * am`, we plot the distribution of `mpg` for every combination of `cyl` and `am`.
- Color Configuration: The `col` argument specifies the colors for the boxplots. We've opted for "skyblue" and "gold" for differentiation. Depending on the order of factor levels in your data, one color typically represents one level of `am` (e.g., automatic) and the other color represents the second level (e.g., manual).
- Orientation: The `horizontal` argument, set to `TRUE`, orients the boxplots horizontally.
- Legend Addition: Following the boxplot, we add a legend using the `legend` function. Placed at the "topright" position, this legend differentiates between "Automatic" and "Manual" transmissions using the designated colors.
- In essence, our code generates a detailed visualization that elucidates the mileage distribution for various combinations of cylinder counts and transmission types in cars.

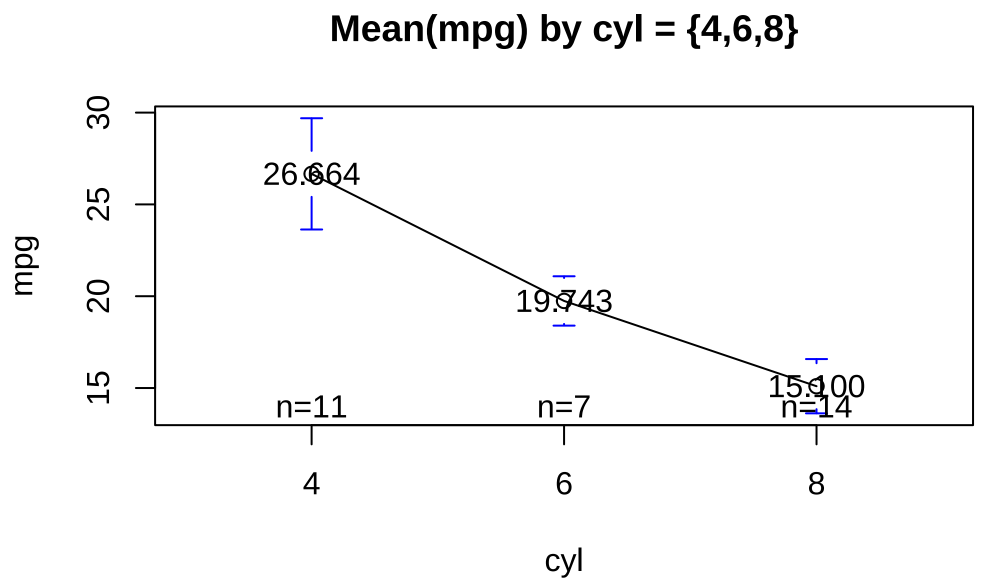
Means Plot across one Category

Visualizing Means – mean plot showing the average weight of the cars, broken down by transmission (`am`= 0 or 1)

```r
library(gplots)
```

```
Attaching package: 'gplots'

The following object is masked from 'package:stats':

    lowess
```

```r
plotmeans(data = tb,
          mpg ~ cyl,
          mean.labels = TRUE,
          digits=3,
          main = "Mean(mpg) by cyl = {4,6,8}"
          )
```

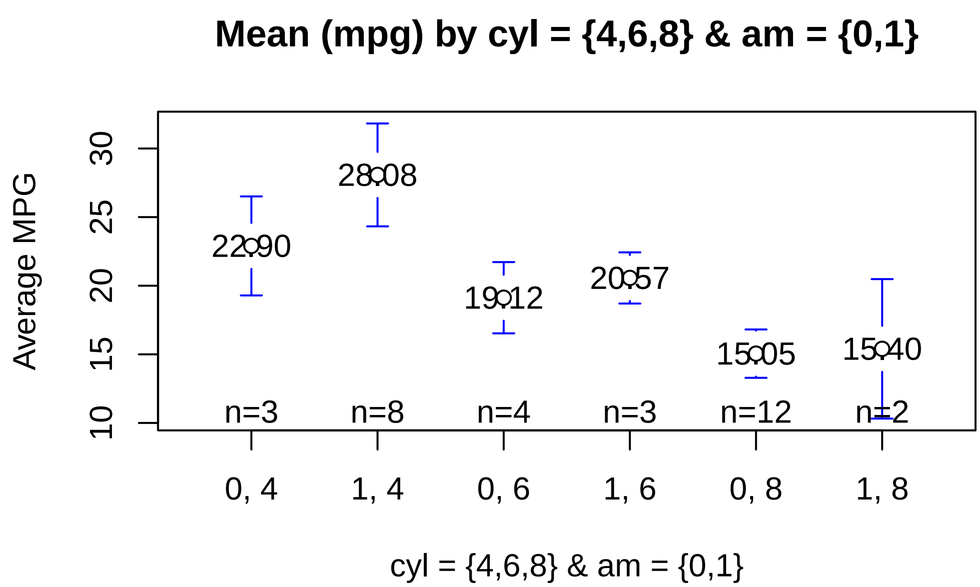


Means Plot across two Categories

We show a mean plot showing the mean weight of the cars broken down by Transmission Type (`am`= 0 or 1) & cylinders (`cyl` = 4,6,8).

```r
library(gplots)
plotmeans(mpg ~ interaction(am,
```

```
                  cyl,
                  sep = ", "),
data = tb,
mean.labels = TRUE,
digits=2,
connect = FALSE,
main = "Mean (mpg) by cyl = {4,6,8} & am = {0,1}",
xlab= "cyl = {4,6,8} & am = {0,1}",
ylab="Average MPG"
)
```



References

[1] R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Fox, J. and Weisberg, S. (2011). An R Companion to Applied Regression, Second Edition. Thousand Oaks CA: Sage.

[2] Revelle, W. (2020). psych: Procedures for Psychological, Psychometric, and Personality Research. Northwestern University, Evanston, Illinois. R package version 2.0.9. https://CRAN.R-project.org/package=psych

[3] Chambers, J. M., Freeny, A. E., & Heiberger, R. M. (1992). Analysis of variance; designed experiments. In Statistical Models in S (pp. 145–193). Pacific Grove, CA: Wadsworth &

Brooks/Cole.

[4] Venables, W. N., & Ripley, B. D. (2002). Modern Applied Statistics with S (4th ed.). Springer.

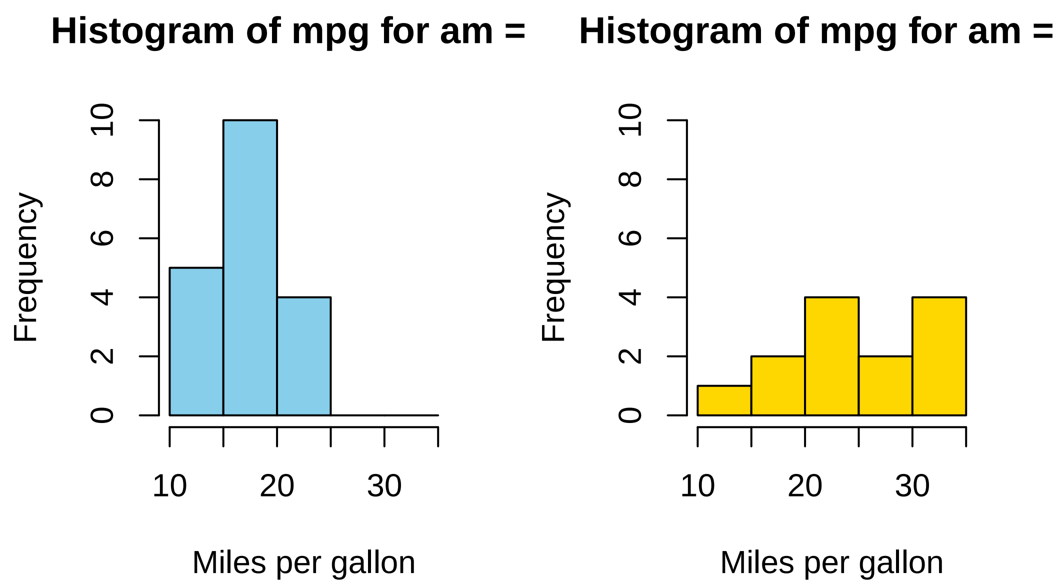
Appendix

Appendix A1

Visualizing histograms of car mileage (`mpg`) broken down by transmission (`am`=0,1)

Code written using a for loop

```
# Split the data by 'am' variable
split_data <- split(tb$mpg, tb$am)

# Create a 1-row 2-column layout
par(mfrow = c(1, 2))

# Define the color vector
color_vector <- c("skyblue", "gold")

# Create a histogram for each subset
for (i in 1:length(split_data)) {
  hist(split_data[[i]],
       main = paste("Histogram of mpg for am =", i - 1),
       breaks = seq(10, 35, by = 5), # This creates bins with ranges 10-15, 15-20, etc.
       xlab = "Miles per gallon",
       col = color_vector[i], # Use the color vector,
       border = "black",
       ylim = c(0, 10))
}
```

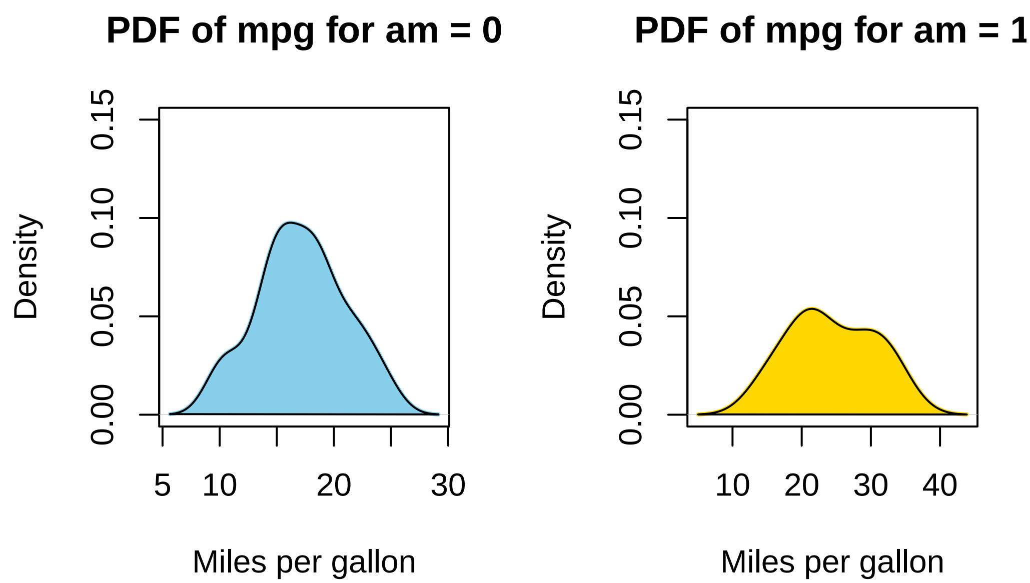


Appendix A2

Visualizing Probability Density Function (PDF) of car milegage (`mpg`) broken down by transmission (`am`=0,1), using for loop

```
# Split the data by 'am' variable
split_data <- split(tb$mpg, tb$am)

# Create a 1-row 2-column layout
par(mfrow = c(1, 2))

# Define the color vector
color_vector <- c("skyblue", "gold")

# Create a density plot for each subset
for (i in 1:length(split_data)) {
  # Calculate density
  dens <- density(split_data[[i]])

  # Plot density
  plot(dens,
       main = paste("PDF of mpg for am =", i - 1),
       xlab = "Miles per gallon",
       col = color_vector[i],
```

```
        border = "black",
        ylim = c(0, 0.15), # Adjust this value if necessary
        lwd = 2) # line width

  # Add a polygon to fill under the density curve
  polygon(dens, col = color_vector[i], border = "black")
}
```

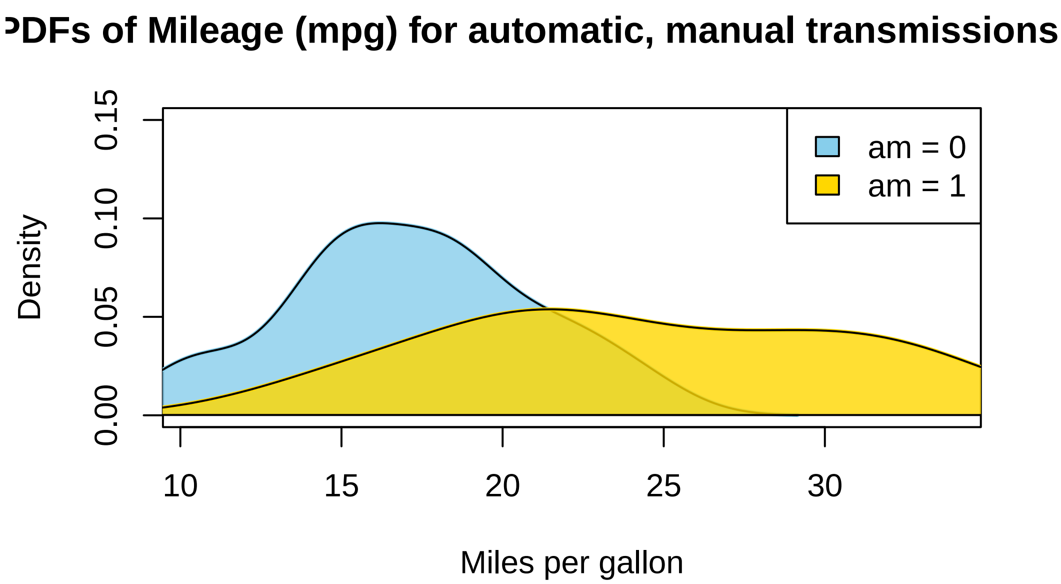


Appendix A3

Visualizing Probability Density Function (PDF) of car milegage (`mpg`) broken down by transmission (`am`=0,1), overlapping PDFs on the same plot

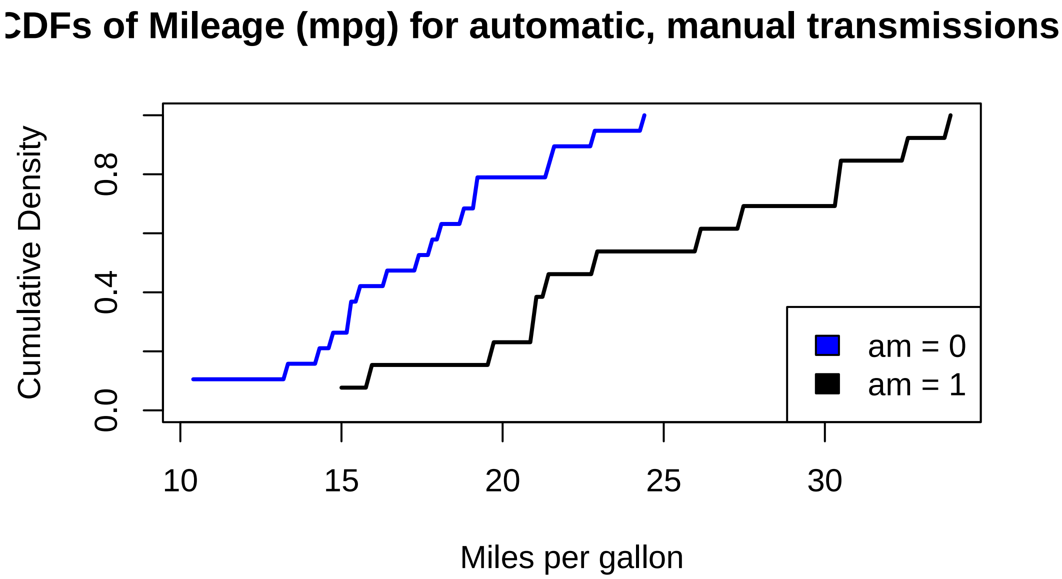
```
# Split the data by 'am' variable
split_data <- split(tb$mpg, tb$am)

# Define the color vector
color_vector <- c("skyblue", "gold")

# Define the legend labels
legend_labels <- c("am = 0", "am = 1")

# Create a density plot for each subset
# Start with an empty plot with ranges accommodating both data sets
```

```r
plot(0, 0, xlim = range(tb$mpg), ylim = c(0, 0.15), type = "n",
     xlab = "Miles per gallon", ylab = "Density",
     main = "PDFs of Mileage (mpg) for automatic, manual transmissions (am)")

for (i in 1:length(split_data)) {
  # Calculate density
  dens <- density(split_data[[i]])

  # Add density plot
  lines(dens,
        col = color_vector[i],
        lwd = 2) # line width

  # Add a polygon to fill under the density curve
  polygon(dens, col = adjustcolor(color_vector[i], alpha.f = 0.8), border = "black")
}

# Add legend to the plot
legend("topright", legend = legend_labels, fill = color_vector, border = "black")
```



Appendix A4

```
# Split the data by 'am' variable
split_data <- split(tb$mpg, tb$am)

# Define the color vector
color_vector <- c("blue", "black")

# Define the legend labels
legend_labels <- c("am = 0", "am = 1")

# Create a cumulative density plot for each subset
# Start with an empty plot with ranges accommodating both data sets
plot(0, 0, xlim = range(mtcars$mpg), ylim = c(0, 1), type = "n",
     xlab = "Miles per gallon", ylab = "Cumulative Density",
     main = "CDFs of Mileage (mpg) for automatic, manual transmissions (am)")

for (i in 1:length(split_data)) {
  # Calculate empirical cumulative density function
  ecdf_func <- ecdf(split_data[[i]])

  # Add CDF plot using curve function
  curve(ecdf_func(x),
        from = min(split_data[[i]]), to = max(split_data[[i]]),
        col = color_vector[i],
        add = TRUE,
        lwd = 2) # line width
}
# Add legend to the plot
legend("bottomright", legend = legend_labels, fill = color_vector, border = "black")
```



CDFs of Mileage (mpg) for automatic, manual transmissions
Cumulative Density
0.0
0.4
0.8
10
15
20
25
30
Miles per gallon
am = 0
am = 1