Continuous Data (2 of 2)

Chapter 11, *Last updated: Jan 02, 2023*

Exploring Univariate Continuous Data using `ggplot2` and `ggpubr`

This chapter demonstrates the use of the popular **`ggplot2`** and **`ggpubr`** packages to further explore *univariate, continuous* data.

1. **`ggplot2`**: In the `ggplot2` package for instance, the function `geom_boxplot()` produces box plots, `geom_violin()` creates violin plots, and `geom_histogram()` and `geom_density()` generate histograms and density plots, respectively. The related `ggbeeswarm` package can be used for creating bee swarm plots. [1]
2. **`ggpubr`**: The `ggpubr` package in R augments `ggplot2` by offering tools for creating publication-ready plots. It enables simplified plotting with easy-to-use functions like gghistogram(), ggdensity(), ggboxplot(), ggviolin, and makes it easy to merge multiple plots with `ggarrange()`, and provides specialized themes for a polished look. Essentially, `ggpubr` merges `ggplot2`'s extensive customization with the ease of creating visually appealing and informative plots. [2]
3. We load the necessary packages, including `ggplot2`, `dplyr` and `ggthemes` packages. The package `ggthemes` allows us to use a variety of themes. [3]

```
# Load the required libraries, suppressing annoying startup messages
library(dplyr, quietly = TRUE, warn.conflicts = FALSE)
library(tibble, quietly = TRUE, warn.conflicts = FALSE)
library(ggplot2, quietly = TRUE, warn.conflicts = FALSE) # For data visualization
library(ggpubr, quietly = TRUE, warn.conflicts = FALSE) # For data visualization

library(rmarkdown, quietly = TRUE, warn.conflicts = FALSE)
library(knitr, quietly = TRUE, warn.conflicts = FALSE)
library(kableExtra, quietly = TRUE, warn.conflicts = FALSE)

library(ggthemes)
```

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

```
# 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
```

5. Let's take a closer look at some of the most effective ways of Visualizing Univariate Continuous Data using `ggplot2` and related packages, including

- Bee Swarm plots using `ggbeeswarm`
- Histograms using `ggplot2` and `ggpubr`
- PDF and CDF Density plots using `ggplot2` and `ggpubr`
- Bar plots using `ggplot2`
- Box plots using `ggplot2` and `ggpubr`
- Violin plots using `ggplot2` and `ggpubr`
- Quantile-Quantile (Q-Q) Plots using `ggplot2`

Note that it is inconvenient to create Stem-and-Leaf plots using `ggplot2`.

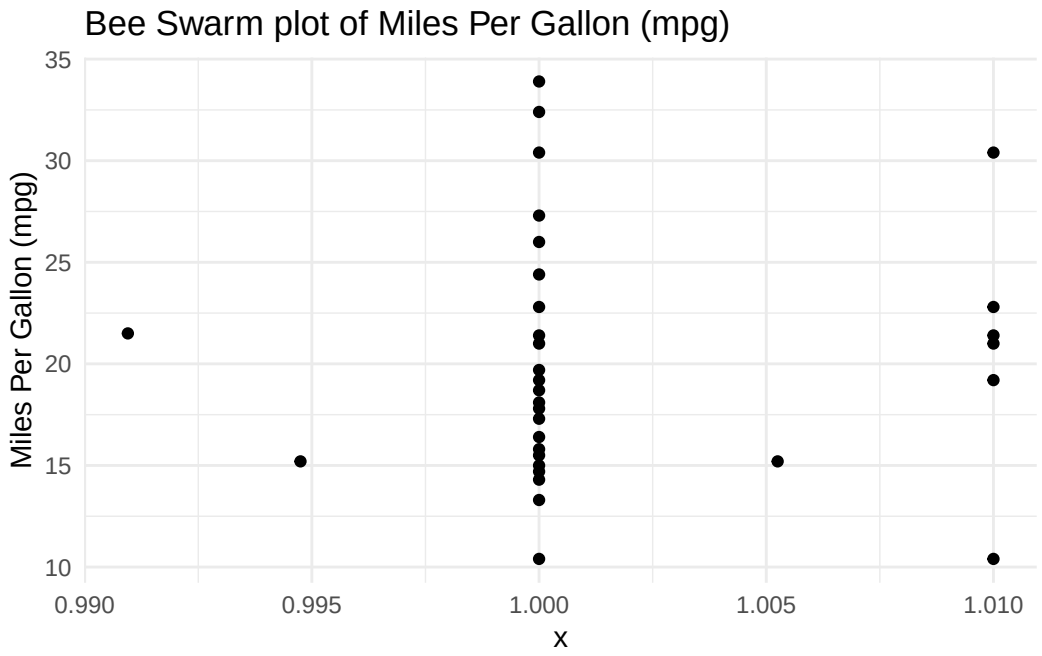
Bee Swarm plot using `ggbeeswarm`

1. The bee swarm plot is an alternative to the box plot, where each point is plotted in a manner that avoids overlap.
2. We use the `ggbeeswarm` package on the `mpg` column of the `tb` tibble.

```
# Load necessary libraries
library(ggplot2)
library(ggbeeswarm) # Provides the geom_beeswarm() function

# Create a bee swarm plot for visualizing the distribution of mpg
ggplot(tb,
```

```
      aes(x = 1,  # Dummy x-axis value
          y = mpg)) +  # mpg values on the y-axis
geom_beeswarm() +  # Use beeswarm plot  points
labs(title = "Bee Swarm plot of Miles Per Gallon (mpg)",
      y = "Miles Per Gallon (mpg)") +  # Label for the y-axis
theme_minimal()  # theme for a clean and clear presentation
```



3. Discussion:

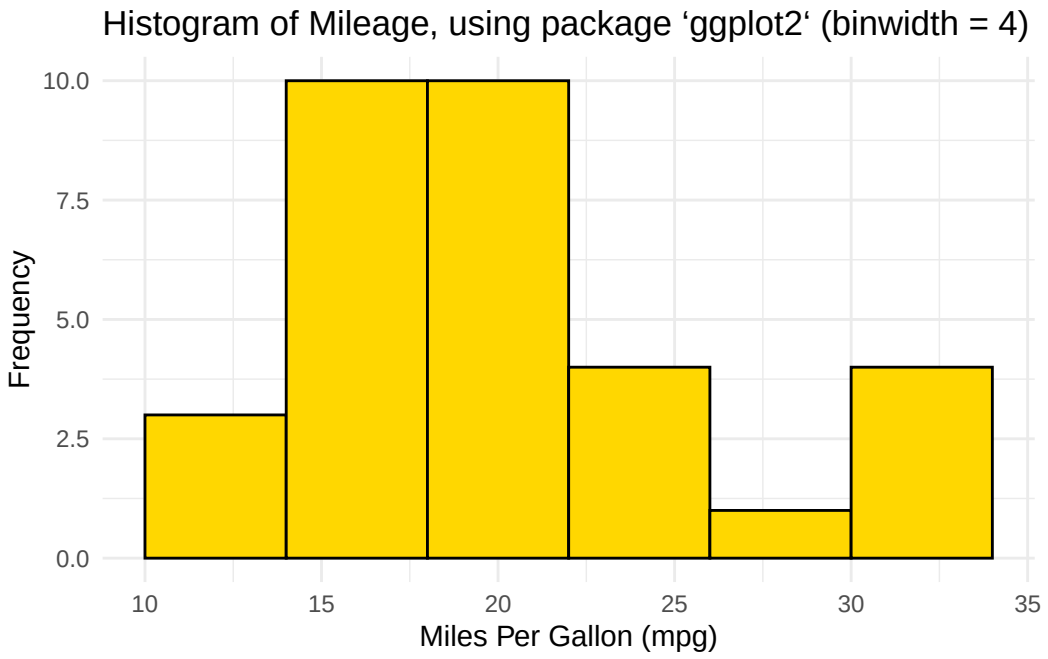
- Initially, we declare our dataset and the aesthetic mappings, defining how variables in the data are visually represented. For the bee swarm plot, we only need a y aesthetic, which is `mpg`. We set the x aesthetic to 1 as a placeholder, because bee swarm plots require an x aesthetic, but we only have one variable.
- Following that, we append a bee swarm plot using the `geom_beeswarm()` function.
- We use the `labs()` function to label the plot.
- We then adopt a minimalist theme by using `theme_minimal()` to give our plot a sleek and simple look. [4]

Histogram using `ggplot2`

Histogram with binwidth

1. The following code creates a histogram using the `ggplot2` package. Here, we pre-specify the bin width and the resulting number of bins in the histogram depend on the range of the data. [1]

```
# histogram using ggplot2 to visualize the distribution of miles per gallon (mpg)
ggplot(tb,
       aes(x = mpg)) +  # Set mpg as the x-axis variable
  geom_histogram(binwidth = 4,  # Define the binwidth for the histogram
                 fill = "gold",  # Set the fill color of the bins to gold
                 color = "black") +  # Set the border color of the bin
  theme_minimal() +  # Apply a minimal theme for a cleaner look
  labs(title = "Histogram of Mileage, using package `ggplot2` (binwidth = 4)",
       x = "Miles Per Gallon (mpg)",  # Label for the x-axis
       y = "Frequency")  # Label for the y-axis
```



2. Discussion:

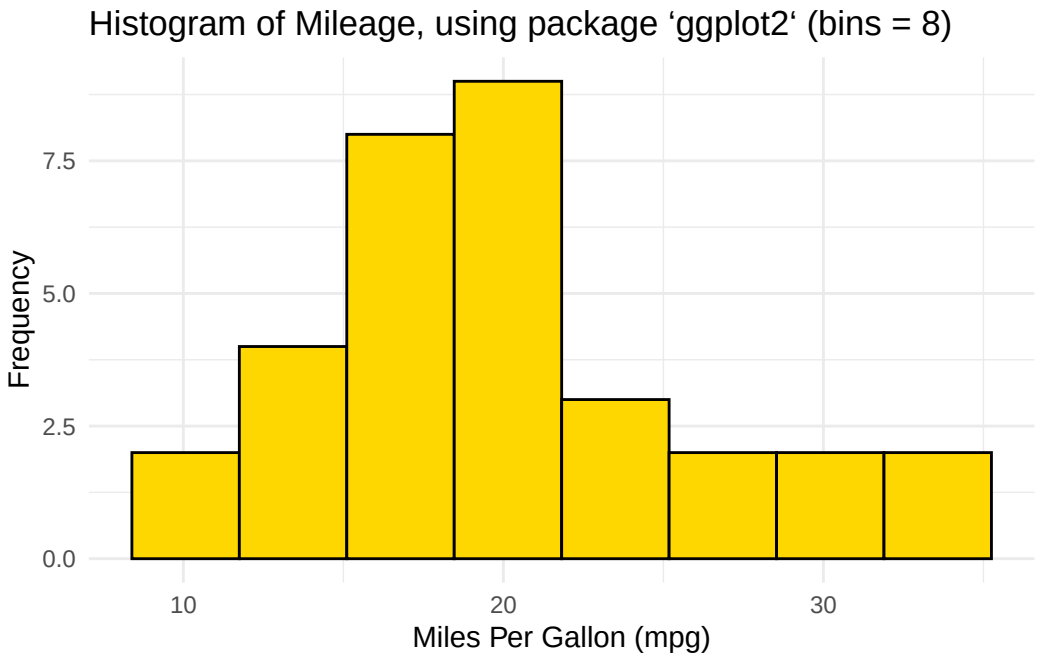
- The code `ggplot(tb, aes(x = mpg))` initializes a plot using the `tb` data frame, mapping the `mpg` column to the x-axis.

- The histogram is created with `geom_histogram()`, using an adjustable `binwidth = 4`. Given this bin width, the resulting number of bins in the histogram depend on the range of `mpg`.
- The `binwidth` argument specifies the width of the bins in the histogram, and we have chosen `4` as an arbitrary width.
- We use `fill` and `color` to set the bar colors to be gold with a black border.
- A clean appearance is achieved with `theme_minimal()`, and titles and labels are added using `labs()`. [1]

Histogram with bins

3. We could alternately set the number of bins in the histogram, instead of specifying the bin width. In this case, the bin-width gets calculated depending on the range of the data and the specified number of bins.

```
# Create a histogram of mpg from the tb dataset
ggplot(tb, aes(x = mpg)) +
  geom_histogram(bins = 8, fill = "gold", color = "black") +
  # Set histogram bins to 8 with gold fill and black border
  theme_minimal() + # Use a minimalistic theme
  labs(title = "Histogram of Mileage, using package `ggplot2` (bins = 8)",
       x = "Miles Per Gallon (mpg)",
       y = "Frequency") # Add title and axis labels
```



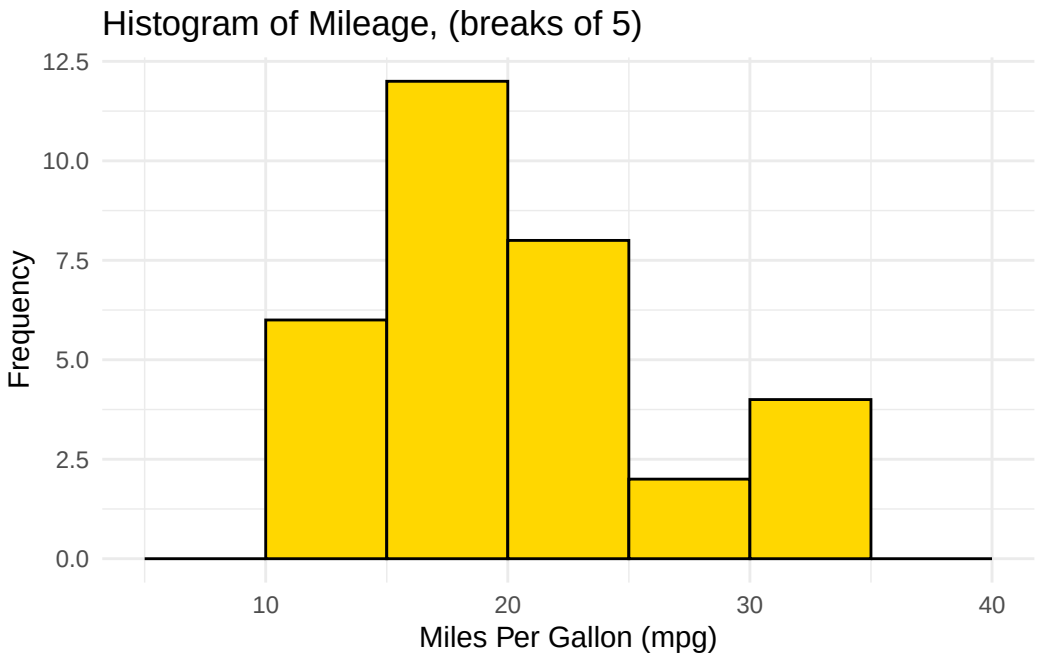
4. Discussion:

- We instruct R to create a histogram having 8 bins of equal width, by setting `bins = 8` in`geom_histogram()‘`
- The width of each bin is adjusted by dividing the range of `mpg` by the number of specified bins. [1]

Histogram with bin range

5. Alternately, we can specify custom bin ranges in a histogram. In this this approach, we supply a vector of breakpoints which defines the range of each bin. For example, the following code defines histogram bins with ranges of 5-10, 10-15, 15-20, 20-25, 25-30, 30-35, 35-40, for the `mpg` variable

```
# Plot a histogram of mpg values from the tb dataset using ggplot2
ggplot(tb, aes(x = mpg)) +
  geom_histogram(breaks = seq(5, 40, by = 5), fill = "gold", color = "black") +
  # Define histogram breaks at intervals of 5
  theme_minimal() + # Apply a minimal theme for clarity
  labs(title = "Histogram of Mileage, (breaks of 5)",
       x = "Miles Per Gallon (mpg)",
       y = "Frequency") # Add plot title and axis labels
```



6. **Discussion:**

- `ggplot(tb, aes(x = mpg))` initializes a ggplot object with the `tb` data frame and sets the `mpg` column as the x-axis variable.
- `geom_histogram()` adds a histogram layer, in which `breaks = seq(5, 40, by = 5)` specifies bin edges using a sequence that starts at 5, ends at 40, and increases by 5 units. This results in bins like [5,10), [10,15), and so on. [1]

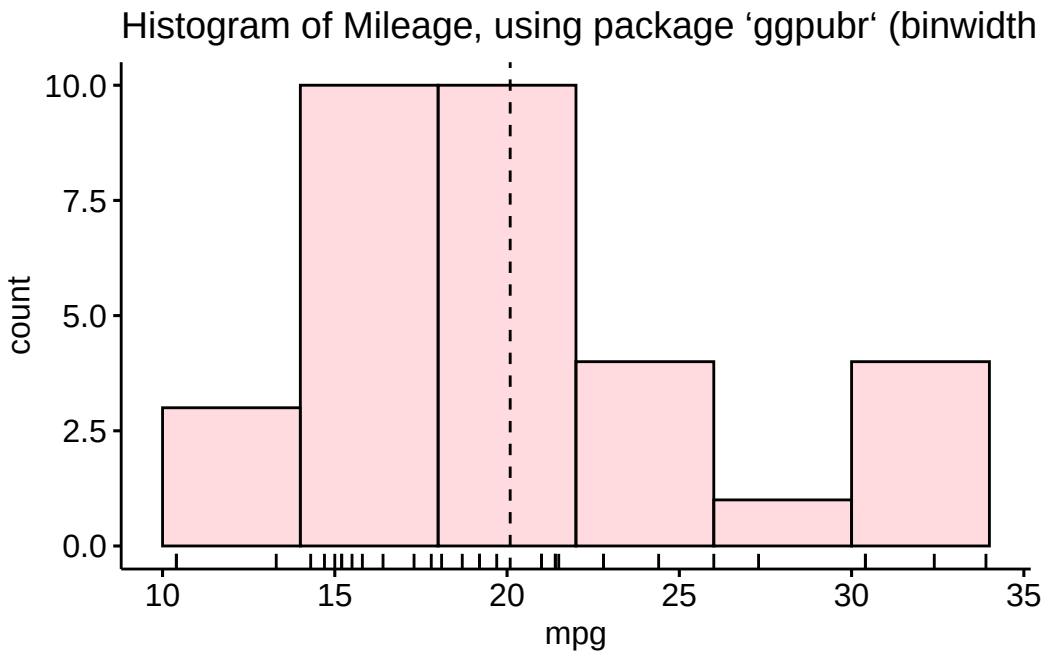
Histogram using `ggpubr`

7. Recreating a histogram with binwidth of 4, using `ggpubr`:

```
# Load the ggpubr package for enhanced ggplot2-based plotting
library(ggpubr)

# Create a histogram using gghistogram from ggpubr
gghistogram(tb,
            x = "mpg",  # Set 'mpg' as the variable for histogram
            binwidth = 4,  # Set the width of bins in the histogram
            add = "mean",  # Add a line indicating the mean of 'mpg'
            rug = TRUE,  # Add a rug plot to show individual data points
            color = "black",  # Set the color of bins to black
```

```
            fill = "lightpink",  # Set the fill color of bins to light pink
            title = "Histogram of Mileage, using package `ggpubr` (binwidth = 4)"
)
```



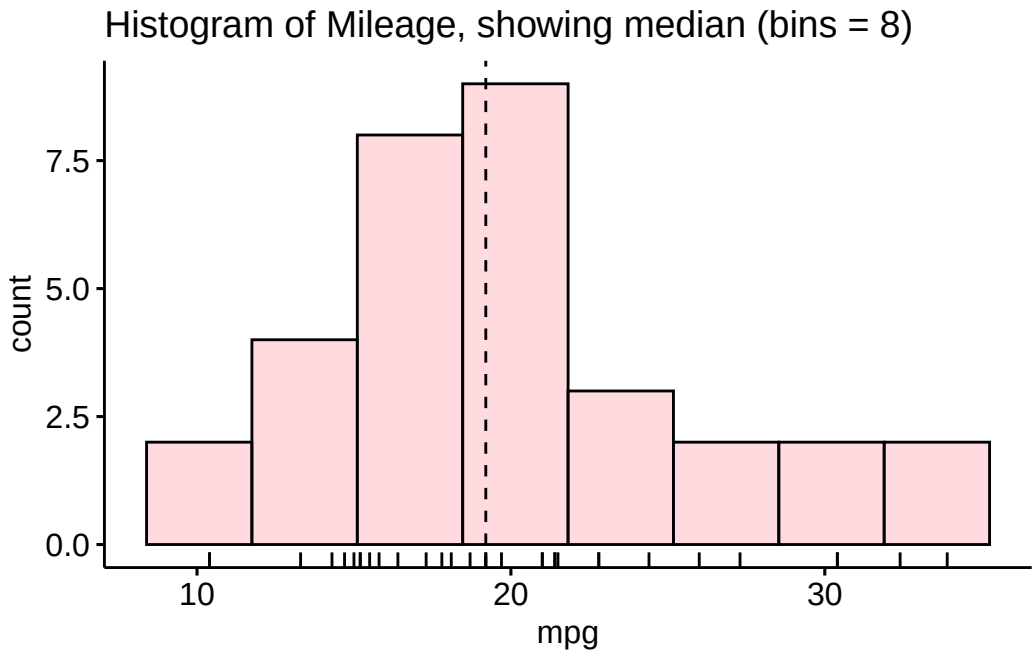
8. **Discussion:**

- Here, we're invoking the `gghistogram()` function from `ggpubr` to craft a histogram. The data source is specified as `tb`, and the variable of interest is `mpg`.
- `x = "mpg"`: This denotes the variable from tb we're visualizing.
- `binwidth = 4`: Each bin in the histogram will span a range of 4 units of `mpg`.
- `add = "mean"`: Superimposes the mean of `mpg` on the histogram.
- `rug = TRUE`: Includes a rug plot at the base, which displays individual data points.
- `color = "black"`: The outline of the bars will be in black.
- `fill = "lightpink"`: Bars in the histogram will be filled with a light pink shade.
- `title =`: Gives a descriptive title to the histogram.
- In sum, we're visualizing the distribution of the mpg variable from the `tb` dataset as a light pink histogram, emphasized with black borders, with a bin width of 4 units. We've also marked the mean value and showcased individual data points as a rug plot beneath the histogram. [2]

9. Recreating a histogram with 8 bins, using package `ggpubr`:

```
# Load the ggpubr package
library(ggpubr)

# Create a histogram of the 'mpg' variable from the tb dataset
gghistogram(tb,
            x = "mpg",  # Specify 'mpg' for the x-axis
            bins = 8,  # Set the number of bins to 8
            add = "median",  # Add a line indicating the median
            rug = TRUE,  # Include a rug plot to show individual data points
            color = "black",  # Set the color of the histogram bins to black
            fill = "lightpink",  # Set the fill color of the bins to light pink
            title = "Histogram of Mileage, showing median (bins = 8)"
)
```



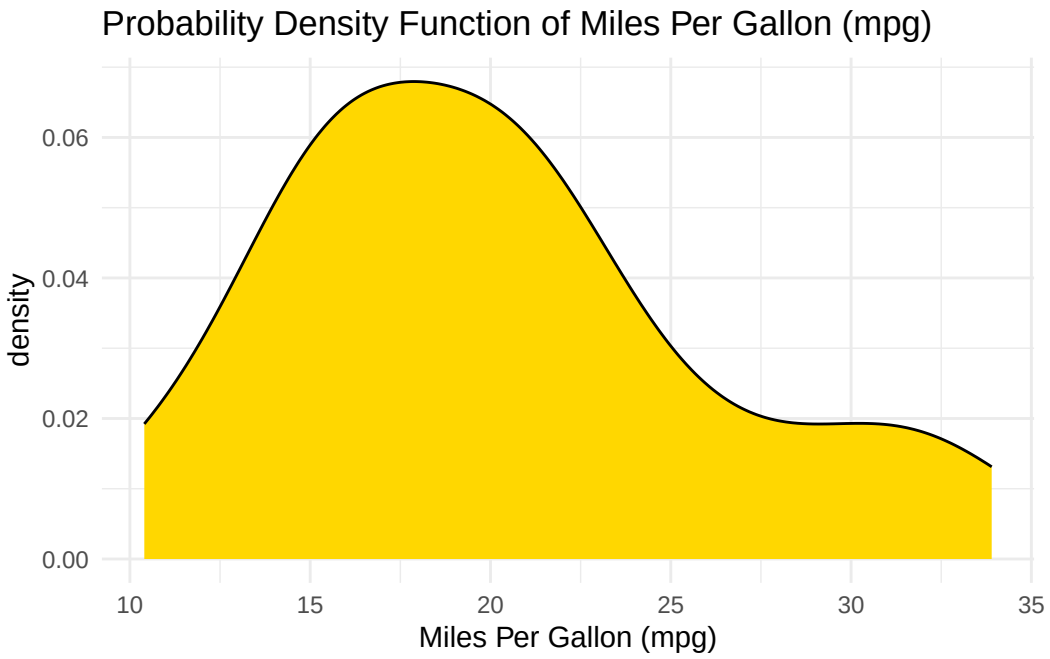
10. **Discussion:**

In essence, the difference is that this code visualizes the mpg data from the `tb` dataset as a histogram with 8 bins, set using `bins = 8`. [2]

Probability Density Function (PDF) plot using `ggplot2`

1. Recall that this type of plot shows the distribution of a single variable, and the area under the curve represents the probability of an observation falling within a particular range of values. The following code generates it using `ggplot2`:

```
# Use ggplot2 to create a density plot of mpg values from the tb dataset
ggplot(tb, aes(x = mpg)) +
  geom_density(fill = "gold") +  # Create a density plot with gold fill color
  theme_minimal() +  # Apply a minimal theme for a clean and simple appearance
  labs(title = "Probability Density Function of Miles Per Gallon (mpg)",
       x = "Miles Per Gallon (mpg)",  # Label for the x-axis
       y = "density")  # Label for the y-axis
```



2. **Discussion**:

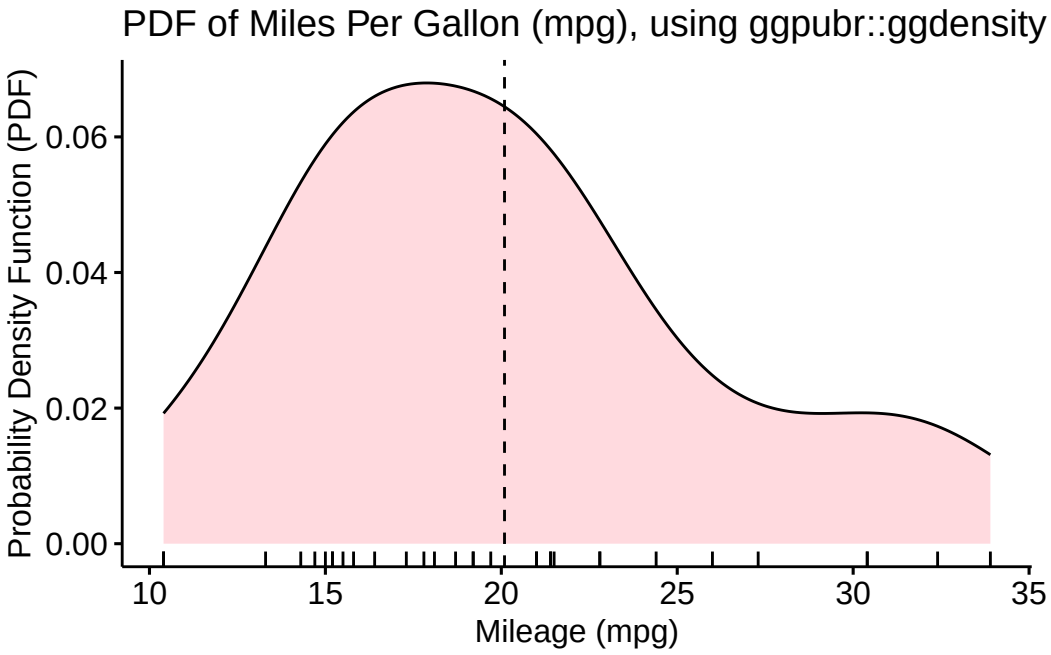
- We designate our data source and the aesthetic mappings using the `ggplot()` function. The aesthetic mapping for x is `mpg`.
- Subsequently, we append a density plot to our plot by using the `geom_density()` function. We fill the area under the curve by setting `fill` to "gold". [1]

PDF using ggpubr

3. The following R code creates a PDF of the mpg variable in the tb dataset, using the ggdensity() function from the ggpubr package.

```
# Load the ggpubr package for enhanced data visualization
library(ggpubr)

# Create a probability density function plot for 'mpg' using ggdensity
ggdensity(tb,
          x = "mpg",  # Specify 'mpg' as the variable for the plot
          add = "mean",  # Add a line indicating the mean of 'mpg'
          rug = TRUE,  # Include a rug plot to show individual data points
          color = "black",  # Set the color of the plot to black
          fill = "lightpink",  # Set the fill color to light pink
          title = "PDF of Miles Per Gallon (mpg), using ggpubr::ggdensity()",
          xlab = "Mileage (mpg)",  # Label for the x-axis
          ylab = "Probability Density Function (PDF)"  # Label for the y-axis
)
```



4. **Discussion**:

- The ggdensity() function from ggpubr package, is utilized here to visualize a probability density function (PDF) of the mpg variable from the tb dataset.

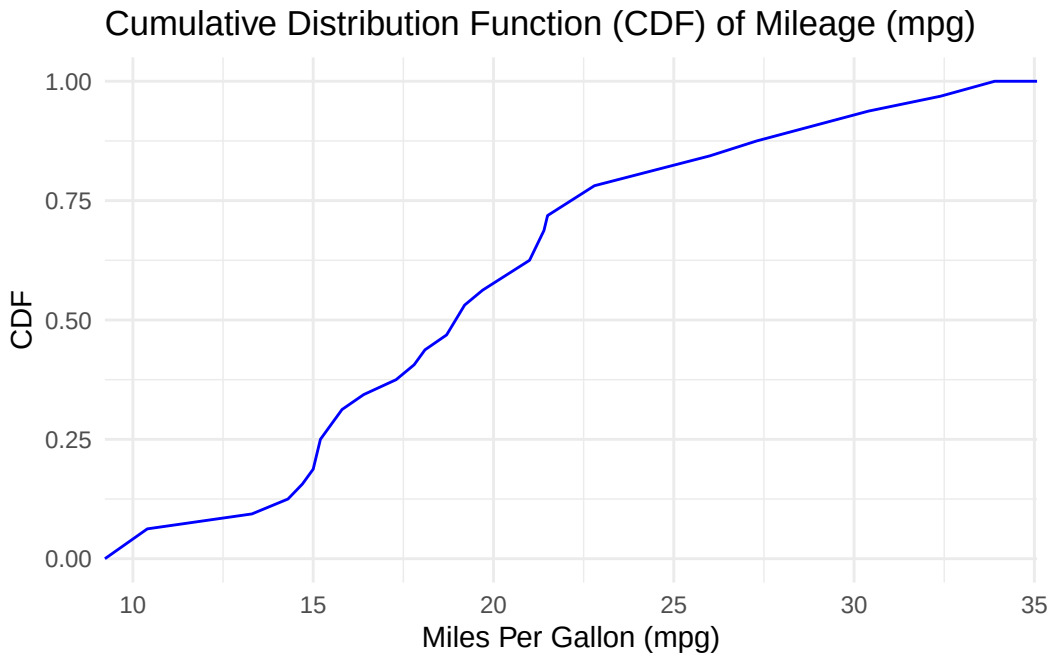
- `x = "mpg"`: This specifies the column `mpg` from the `tb` dataset as the variable we aim to visualize.
- `add = "mean"`: This argument ensures that a line or marker is added to the plot, indicating the mean value of the mpg data.
- `rug = TRUE`: By setting this to TRUE, a rug plot is added at the bottom, showcasing individual data points.
- `color = "black"`: This defines the border color of the density plot as black.
- `fill = "lightpink"`: This fills the interior of the density plot with a light pink color.
- `title =` : This provides a descriptive title to our plot, aiding in clarity and understanding. [3]

Cumulative Distribution Function (CDF) Plot using `ggplot2`

1. The following code generates a CDF using `ggplot2`:

```
# Load required library
library(ggplot2)

# Create a CDF (Cumulative Distribution Function) plot for mpg
ggplot(tb, aes(x = mpg)) +
  stat_ecdf(geom = "line", color = "blue") +  # Use stat_ecdf to plot the CDF
  labs(x = "Miles Per Gallon (mpg)", y = "CDF",  # Set labels for x and y axes
       title = "Cumulative Distribution Function (CDF) of Mileage (mpg)") +
  theme_minimal()  # Apply a minimalistic theme for clarity
```



2. **Discussion**:

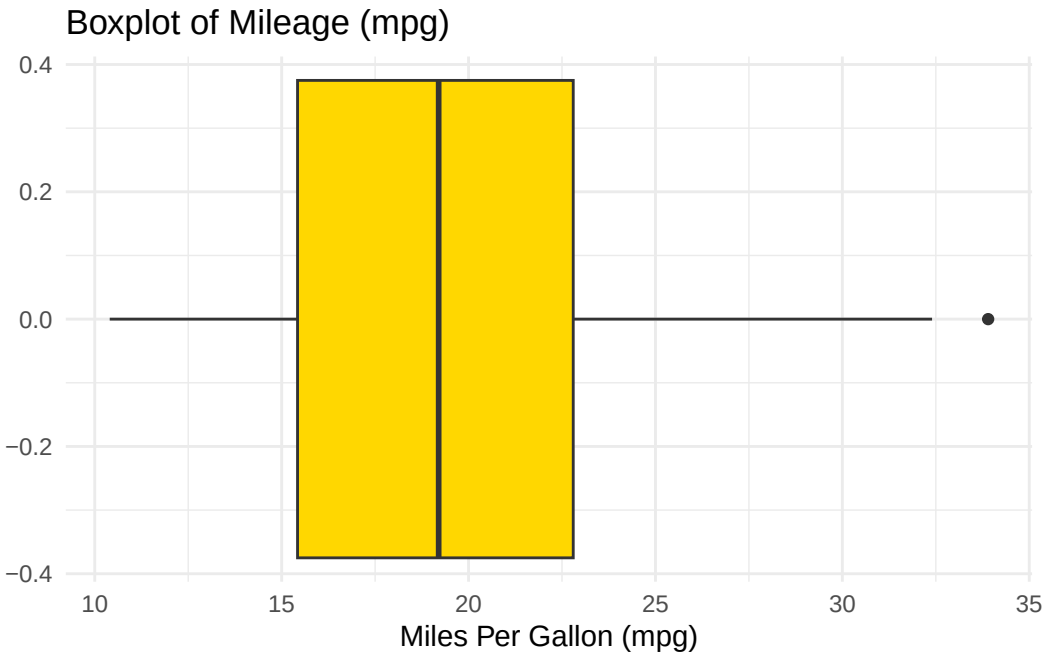
- Here, we're initiating a plot using the `ggplot()` function, specifying `tb` as our data source and the `mpg` column as the variable of interest. ‘
- We employ the `stat_ecdf()` function to represent the empirical cumulative distribution function (CDF) of the `mpg` data. The `geom = "line"` argument means the CDF will be displayed as a continuous line, and `color = "blue"` ensures this line is blue.
- The `labs()` function is used to define axis labels and a plot title, enhancing readability.
- By invoking `theme_minimal()`, we apply a clean and straightforward theme to our plot, which removes extraneous details and emphasizes content.
- To sum up, this code creates a plot depicting the cumulative distribution function (CDF) of the `mpg` data from the `tb` dataset. [1]

Boxplots using `ggplot2`

1. The following code generates a boxplot using `ggplot2`:

```
# Use ggplot2 to create a boxplot for the mpg variable from the tb dataset
ggplot(tb, aes(y = mpg)) +
  geom_boxplot(fill = "gold") +  # Create a boxplot with gold color
```

```
theme_minimal() +  # Apply a minimal theme for a clean appearance
coord_flip() +  # Flip coordinates to horizontal boxplot
labs(title = "Boxplot of Mileage (mpg)",  # Set the title
     y = "Miles Per Gallon (mpg)")  # Label for the y-axis
```



2. **Discussion:**

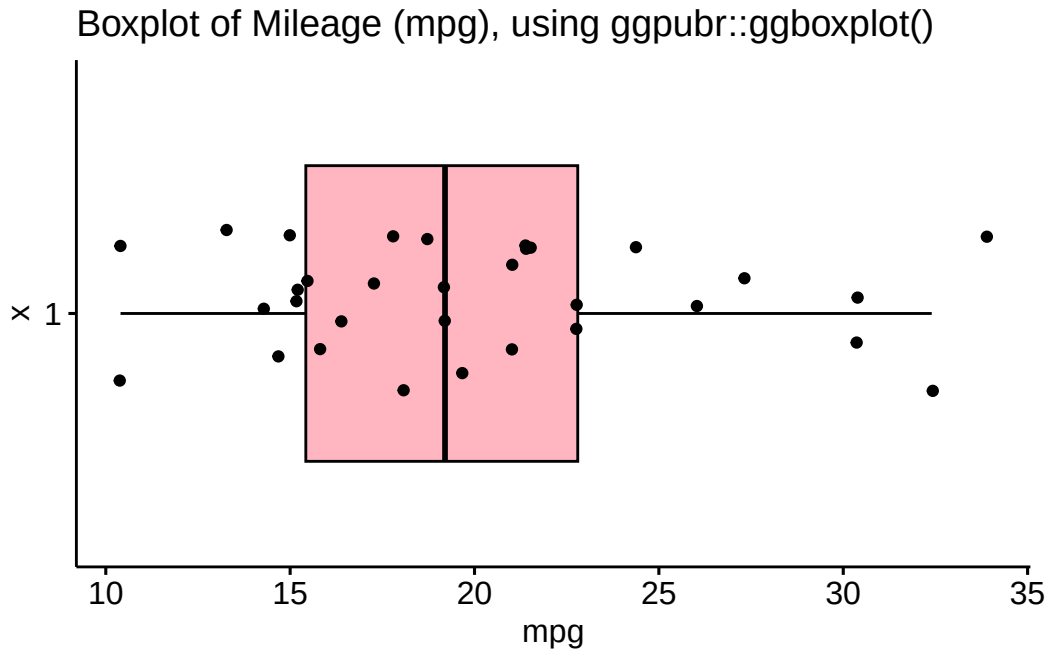
- `ggplot(tb, aes(y = mpg))`: Initializes a `ggplot2` plot using `tb` with `mpg` as the y-axis.
- `geom_boxplot(fill = "gold")`: Adds a gold-filled boxplot layer.
- `theme_minimal()`: Applies a clean, minimalistic theme to the plot.
- `coord_flip()`: Flips the plot to display a horizontal boxplot.
- `labs()`: Sets the plot title to "Boxplot of Mileage (mpg)" and labels the x-axis as "Miles Per Gallon (mpg)".
- In summary, this code creates a horizontal boxplot of the mpg values from the tb data frame, with the boxes filled in gold color, presented with a minimalistic theme, and labeled appropriately. [1]

Boxplot using `ggpubr`

1. The following code recreates the boxplot using the `ggboxplot()` function from the `ggpubr` package.

```
# Load the ggpubr package for enhanced boxplot functionalities
library(ggpubr)

# Create a boxplot for the 'mpg' using ggboxplot from ggpubr
ggboxplot(tb,
          y = "mpg",  # Specify 'mpg' as the variable for the boxplot
          orientation = "horizontal",  # Set the orientation to horizontal
          rug = TRUE,  # Add a rug plot to show individual data points
          color = "black",  # Set the color to black
          fill = "lightpink",  # Set the fill color  to light pink
          add = "jitter",  # Add jitter to display individual data points
          title = "Boxplot of Mileage (mpg), using ggpubr::ggboxplot()"
)
```



2. **Discussion:**

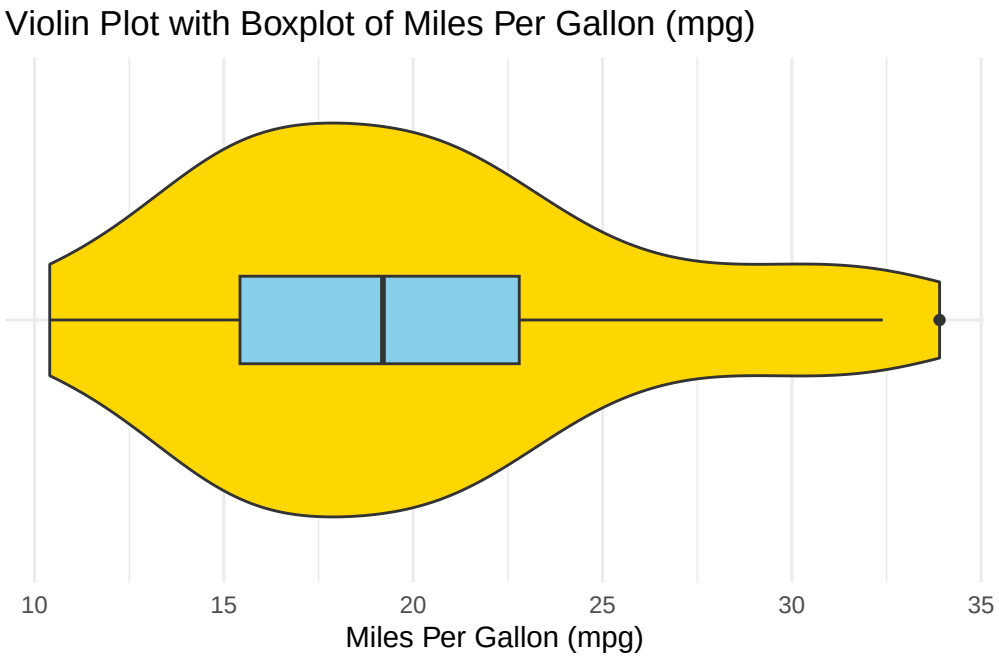
- `ggboxplot(tb, y = "mpg")`: Creates a boxplot of `mpg` values from the `tb` data frame.
- `orientation = "horizontal"`: Sets the boxplot to display horizontally.

- `rug = TRUE`: Shows a rug plot indicating the density of data points.
- `color = "black"`: Sets the boxplot's border color to black.
- `fill = "lightpink"`: Colors the inside of the boxes light pink.
- `add = "jitter"`: Adds jittered points to the boxplot for clearer data visualization.
- `title = .."`: Sets the plot's title. [2]

Violin plot using `ggplot2`

1. The following code generates a violin plot using `ggplot2`, adding a boxplot to the violin plot:

```
# Use ggplot2 to create a combined violin and boxplot for mpg values
ggplot(tb, aes(x = "", y = mpg)) +
  geom_violin(fill = "gold") +  # Create a violin plot with gold fill color
  geom_boxplot(fill = "skyblue", width = 0.2) +
  # Overlay a boxplot with sky blue fill and reduced width
  labs(x = "", # Set labels for x and y axes (x-label is empty)
       y = "Miles Per Gallon (mpg)",
       title = "Violin Plot with Boxplot of Miles Per Gallon (mpg)") +
  coord_flip() +  # Flip coordinates to make the plot horizontal
  theme_minimal()  # Apply a minimal theme for a simple appearance
```



2. Discussion:

- `geom_violin()` generates the violin plot
- `geom_boxplot()` embeds a box plot within it. [1]

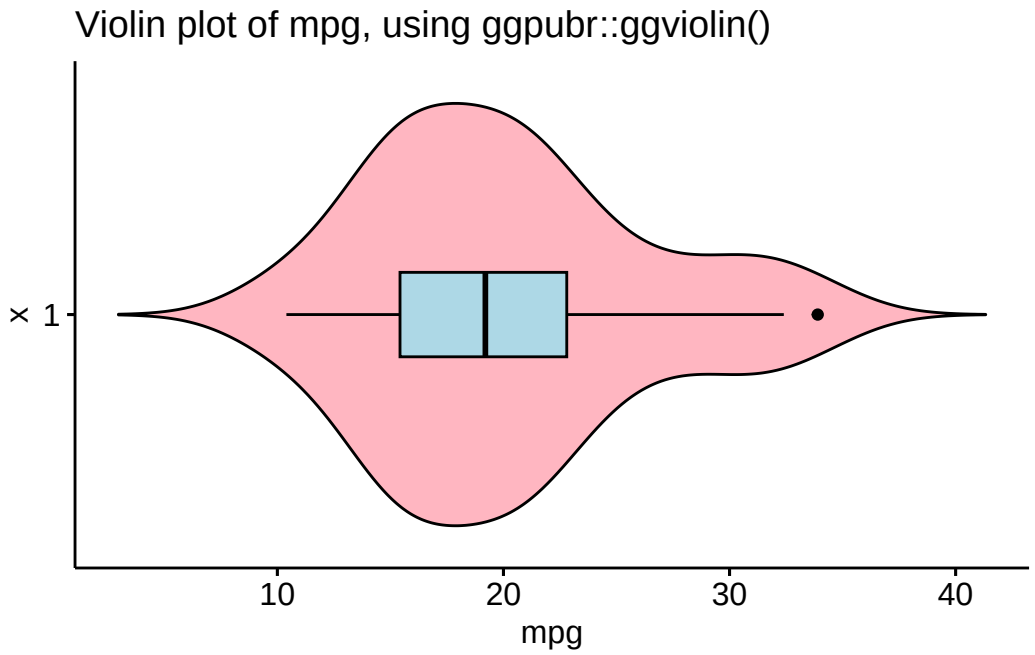
Violin plot using `ggpubr`

3. The following code recreates the violin plot using the `ggviolin()` function from the `ggpubr` package.

```
# Load the ggpubr package for enhanced data visualization
library(ggpubr)

# Create a violin plot for the 'mpg' variable using ggviolin
ggviolin(tb,
         y = "mpg",  # Specify 'mpg' as the variable for the violin plot
         orientation = "horizontal",  # Set the orientation to horizontal
         rug = TRUE,  # Include a rug plot to show individual data points
         color = "black",  # Set the outline color of the violin to black
         fill = "lightpink",  # Set the fill color of the violin to light pink
         add = "boxplot", add.params = list(fill = "lightblue"),
         # Add a boxplot inside the violin plot with light blue fill
```

```
        title = "Violin plot of mpg, using ggpubr::ggviolin()"
)
```



4. **Discussion:**

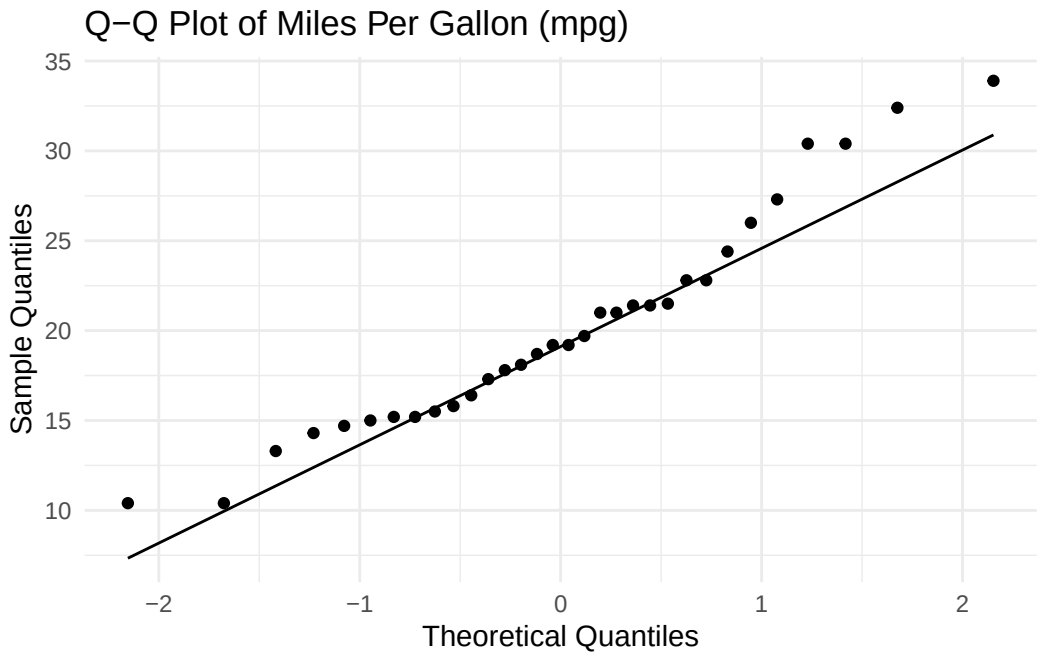
- `tb`: This refers to the dataset we're using. The dataset should have a variable named "mpg" as we've specified it in the next parameter.
- `y = "mpg"`: This indicates that we want the "mpg" variable (Miles Per Gallon) from the `tb` dataset to be plotted on the y-axis.
- `orientation = "horizontal"`: This parameter sets the orientation of the violin plot to be horizontal.
- `rug = TRUE`: This adds a "rug" to the plot, which essentially places small vertical bars (or ticks) at the actual data points along the axis.
- `color = "black"`: The edge color of the violin plot is set to black.
- `fill = "lightpink"`: This sets the main color inside the violin plot to light pink.
- `add = "boxplot"`: This specifies that a boxplot should be added inside the violin plot. A boxplot provides a summary of the distribution, showing the median, quartiles, and potential outliers.
- `add.params = list(fill = "lightblue")`: This further customizes the added boxplot by setting its fill color to light blue.

- `title = "Violin plot of Miles Per Gallon (mpg), using ggpubr::ggviolin()"`: This sets the title of the plot.
- In summary, the code generates a horizontal violin plot for the "mpg" variable from the `tb` dataset. The violin plot showcases the distribution of the "mpg" variable, colored in light pink with a light blue boxplot added inside. The rug adds an additional layer of visualization, showing the actual data points along the axis. [2]

Quantile-Quantile (Q-Q) Plots using `ggplot2`

1. Recall that a Q-Q plot is a graphical method for comparing two probability distributions by plotting their quantiles against each other. The following code generates a Quantile-Quantile (Q-Q) plot using `ggplot2`. [1]

```
# Use ggplot2 to create a Q-Q plot for the mpg variable
ggplot(tb, aes(sample = mpg)) +
  stat_qq() +  # Create a Q-Q plot
  stat_qq_line() +  # Add a line to the Q-Q plot for reference
  labs(x = "Theoretical Quantiles",  # Label for the x-axis
       y = "Sample Quantiles",  # Label for the y-axis
       title = "Q-Q Plot of Miles Per Gallon (mpg)") +
  theme_minimal()  # Apply a minimal theme for a clean appearance
```



2. **Discussion:**

- `ggplot(tb, aes(sample = mpg))` : Here, we initiate a `ggplot` graphic using the `tb` dataset and set the aesthetic (`aes`) to the "mpg" variable. In the context of the `stat_qq()` function (which we'll come to shortly), the `sample` aesthetic specifies the data variable for which we want to create the Q-Q plot.
- `stat_qq()` : This function adds the Q-Q plot points to the graphic. The x-axis of this plot represents the quantiles from a theoretical distribution (often the standard normal distribution), and the y-axis represents the quantiles from our sample data ("mpg").
- `stat_qq_line()` : This function adds a reference line to the Q-Q plot, which represents the expected line if the sample comes from the specified distribution (again, often the standard normal distribution). If our data points lie roughly on this line, it suggests that the data follows the theoretical distribution.
- In summary, this code produces a Q-Q plot for the "mpg" variable from the `tb` dataset. The plot compares the quantiles of "mpg" against the quantiles of a theoretical distribution, often the standard normal distribution. [1]

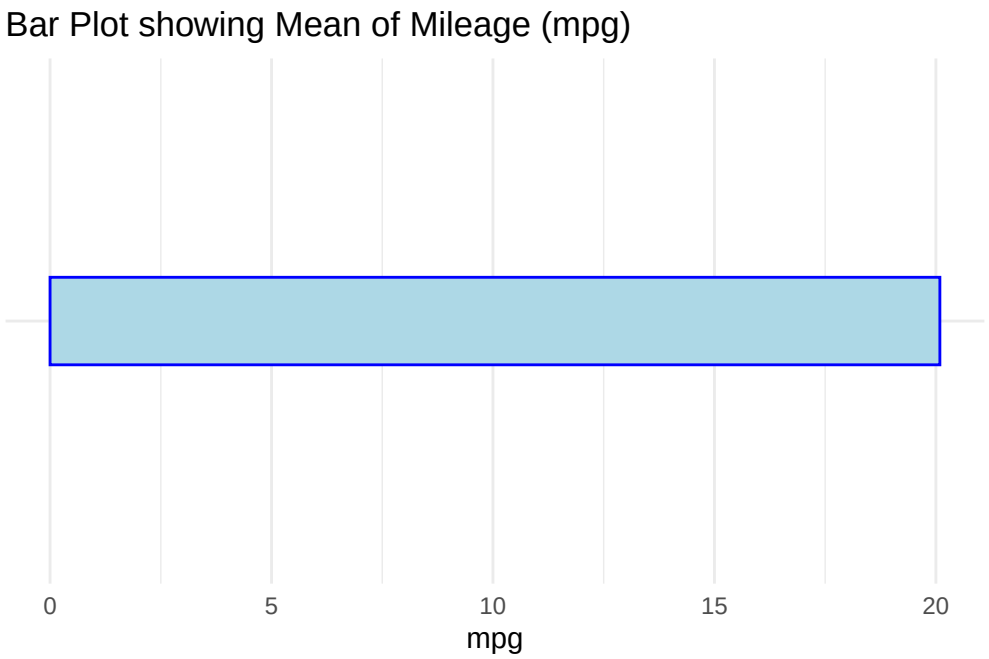
Bar Plot visualizing the Mean and SD using `ggplot2`

1. We can create a Bar Plot to visualize the mean of a continuous variable. [1]

```
# Create a summary data frame
mpgSummary <- tb %>%
  summarise(
    MeanMpg = mean(mpg, na.rm = TRUE),  # Calculate the mean of mpg
    SDMpg = sd(mpg, na.rm = TRUE)  # Calculate the standard deviation
  )

# Create a bar plot visualizing the mean
ggplot(mpgSummary,
       aes(y = "",
           x = MeanMpg)) +
  geom_bar(stat = "identity",  # Use bars to represent values
           fill = "lightblue",
           color = "blue",
           width = 0.2  # Set bar color and width
           ) +
  labs(x = "mpg",
       y = "",  # Set x-axis label to 'mpg' with y-axis label empty
```

```
      title = "Bar Plot showing Mean of Mileage (mpg)") +
  theme_minimal()  # a minimal theme for a cleaner look
```

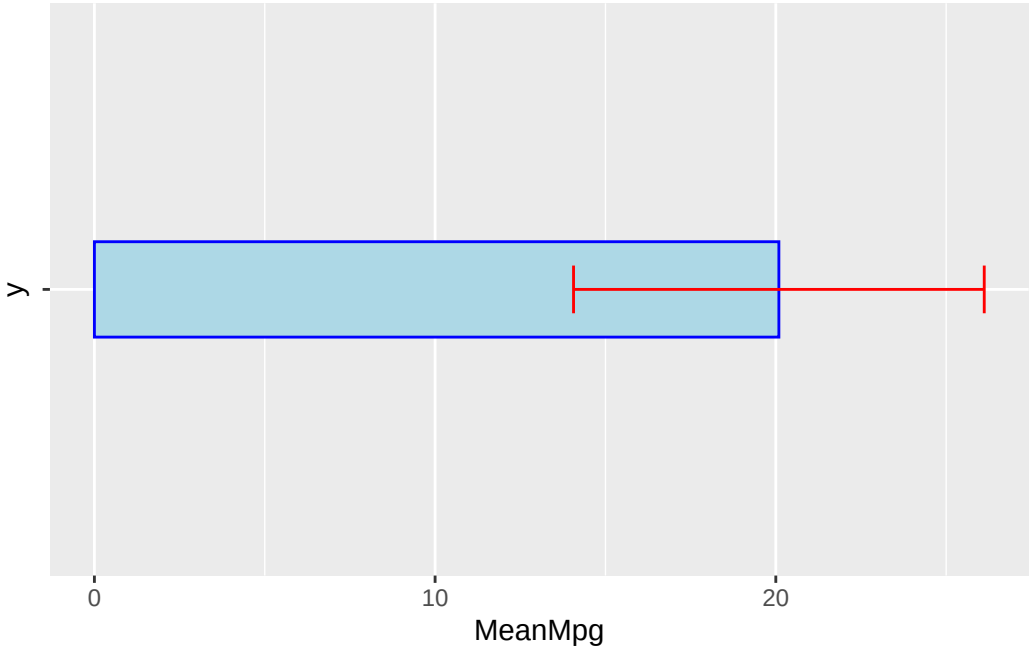


2. We can extend this to create a Bar Plot with Error Bars to visualization the Mean and the Standard Deviation of a continuous variable. [1]

```
# Create a summary data frame
mpgSummary <- tb %>%
  summarise(
    MeanMpg = mean(mpg, na.rm = TRUE),  # Calculate the mean of mpg
    SDMpg = sd(mpg, na.rm = TRUE)  # Calculate the standard deviation of mpg
  )

# Create a bar plot visualizing the mean and error bars visualizing the SD
ggplot(mpgSummary,
       aes(y = "",
           x = MeanMpg)) +
  geom_bar(stat = "identity",
           fill = "lightblue",
           color = "blue",
           width = 0.2  # Create a bar to represent the mean mpg
           ) +
```

```
geom_errorbar(aes(xmin = MeanMpg - SDMpg,
                  xmax = MeanMpg + SDMpg),
              # Set the lower, upper limit of the error bar
              color = "red",  # Color the error bars red
              width = 0.1)  # Set the width of the error bars
```



3. **Discussion**

Summary Data Frame (`mpgSummary`) Creation:

- **`mpgSummary <- tb %>% summarise()`**: This line is initializing the creation of `mpgSummary` data frame using the data in `tb` (which is assumed to contain the `mtcars` dataset) and the `summarise` function from the `dplyr` package.
- **`MeanMpg = mean(mpg, na.rm = TRUE)`**: Calculates the mean of the `mpg` column, ignoring any NA values, and creates a new column `MeanMpg` in `mpgSummary` to store this value.
- **`SDMpg = sd(mpg, na.rm = TRUE)`**: Calculates the standard deviation of the `mpg` column, ignoring any NA values, and creates a new column `SDMpg` in `mpgSummary` to store this value.

Bar Plot with Error Bars Creation:

- **`ggplot(mpgSummary, aes(y = "", x = MeanMpg)) +`**: Initializes the creation of a ggplot object using the `mpgSummary` data frame and sets the aesthetic mappings where `x` is mapped to `MeanMpg` and `y` is set to an empty string.
- **`geom_bar(stat = "identity", fill = "lightblue", color = "blue", width = 0.3)`**: Adds a bar geometry to represent the mean mpg (`MeanMpg`). The bar is colored light blue with a blue border and has a width of 0.3.
- **`geom_errorbar(aes(xmin = MeanMpg - SDMpg, xmax = MeanMpg + SDMpg), color = "red", width = 0.3)`**: Adds error bars to represent the variability of mpg. The error bars extend from `MeanMpg - SDMpg` to `MeanMpg + SDMpg` and are colored red with a width of 0.3.
- **`labs(x = "mpg", y = "", title = "Bar Plot showing (Mean +/- SD) of Mileage (mpg)")`**: Adds labels to the plot, with "mpg" as the x-axis label, no y-axis label, and a title indicating that the plot shows the mean and standard deviation of mileage.
- **`theme_minimal()`**: Applies a minimal theme to the plot for a clean and uncluttered appearance.
- The end result of executing this code is a bar plot visualizing the mean of the `mpg` column and error bars representing one standard deviation above and below the mean, giving a sense of the variability of the miles per gallon in the `mtcars` dataset.

Combining Plots using `ggarrange()`

1. The following code showcases two plots side-by-side. [2]

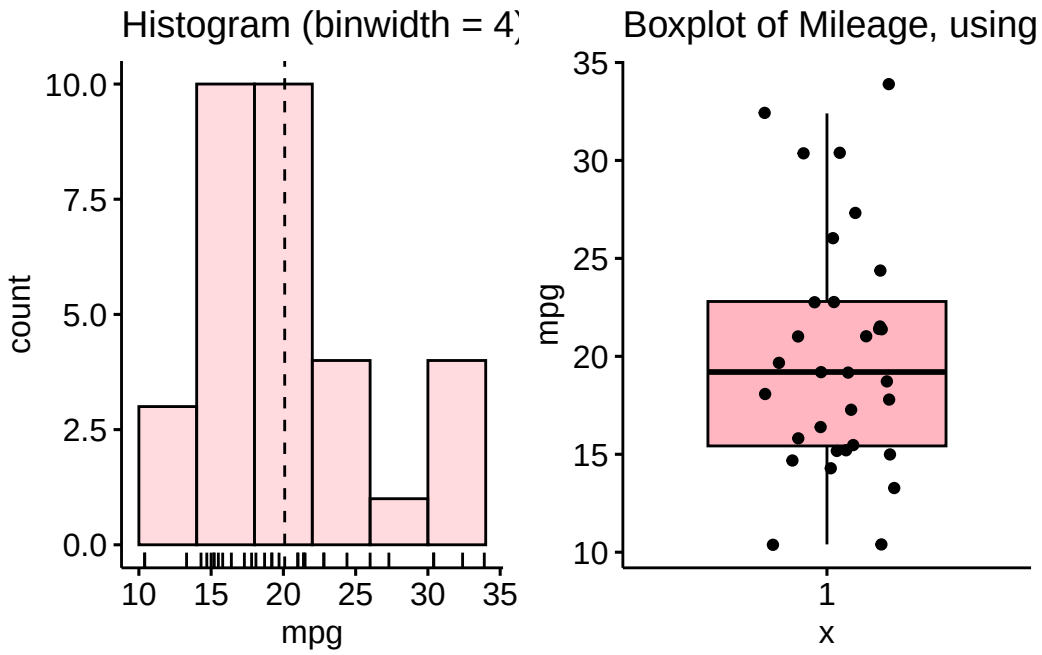
```
# Load necessary libraries
library(ggplot2)
library(ggpubr)

# Create a histogram of the 'mpg' variable using gghistogram
PlotHist <- gghistogram(tb,
            x = "mpg",  # Set 'mpg' as the variable for the histogram
            binwidth = 4,  # Define the width of the bins
            add = "mean",  # Add a line indicating the mean of 'mpg'
            rug = TRUE,  # Include a rug plot to show individual data points
            color = "black",  # Set the color of the histogram to black
            fill = "lightpink",  # Set the fill color of the histogram
            title = "Histogram (binwidth = 4)"  # Title of the histogram
)
```

```r
# Create a box plot of the 'mpg' variable using ggboxplot
PlotBox <- ggboxplot(tb,
             y = "mpg",  # Set 'mpg' as the variable for the box plot
             rug = TRUE,  # Include a rug plot to show individual data points
             color = "black",  # Set the color of the box plot to black
             fill = "lightpink",  # Set the fill color of the box plot
             add = "jitter",  # Add jitter to show individual data points
             title = "Boxplot of Mileage, using ggpubr"
)

# Combine the plots using ggarrange()
combined_plot <- ggarrange(PlotHist, PlotBox, ncol = 2)
# Arrange the histogram and box plot side by side

# Display the combined plot
print(combined_plot)
```



2. **Discussion:**

- We create a histogram and a boxplot using the same code discussed above.
- `ggarrange(PlotHist, PlotBox, ncol = 2)` : This code helps us combine multiple plots into one. Here, `PlotHist` (the histogram) and `PlotBox` (the boxplot) are arranged

side by side, as indicated by `ncol = 2`.

- In essence, this code facilitates a side-by-side comparison of the distribution of the `mpg` variable from the `tb` dataset using two different types of visualizations: a histogram and a boxplot. [1]

Summary of Chapter 11 – Continuous Data (2 of 2)

In this chapter, we explore how to visualize univariate continuous data using the `ggplot2` package in R. We use the `mtcars` data set, converting it to a tibble called `tb` for easier manipulation.

The visualization methods we cover include histograms, density plots (Probability Density Function and Cumulative Density Function), box plots, bee swarm plots, violin plots, and Q-Q plots. These are created using functions like `geom_histogram()`, `geom_density()`, `geom_boxplot()`, `geom_beeswarm()`, `geom_violin()`, `stat_qq()`, and `stat_qq_line()`.

For the histogram, we can adjust bin width, color, and number of bins, or define custom bin ranges. The density plots provide a visual representation of the distribution of a variable, and we can color the area under the curve. To create the CDF plot, we first arrange our data and calculate the cumulative distribution, which is plotted as a line graph. For the violin plot, we show how to add a box plot within the violin for additional information. Finally, we explore Q-Q plots, which compare the quantiles of our data to a theoretical distribution, useful for assessing if the data follows a certain theoretical distribution.

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ggpubr:

[2] Kassambara A (2023). ggpubr: 'ggplot2' Based Publication Ready Plots. R package version 0.6.0, https://rpkgs.datanovia.com/ggpubr/.

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[3] Arnold, J.B. (2020). ggthemes: Extra Themes, Scales and Geoms for 'ggplot2' (Version 4.2.0) [Computer software]. Retrieved from https://CRAN.R-project.org/package=ggthemes

ggbeeswarm

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