Continuous x Continuous data (2 of 2)

Sep 17, 2023.

Exploring bivariate Continuous x Continuous data, using `ggplot2`

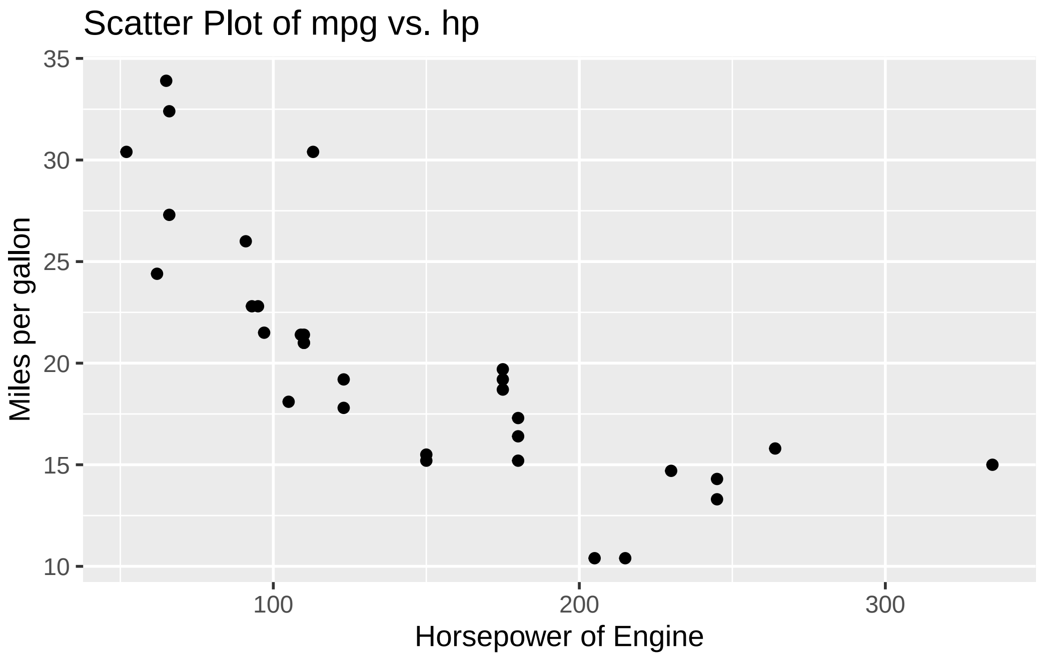
This chapter demonstrates the use of the popular **`ggplot2`** and **`ggpubr`** packages to further explore the interaction between *bivariate continuous data*.

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(ggplot2, quietly = TRUE, warn.conflicts = FALSE) # For data visualization
library(ggpubr, quietly = TRUE, warn.conflicts = FALSE) # For data visualization
# 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
```

Scatterplot using `ggplot2`

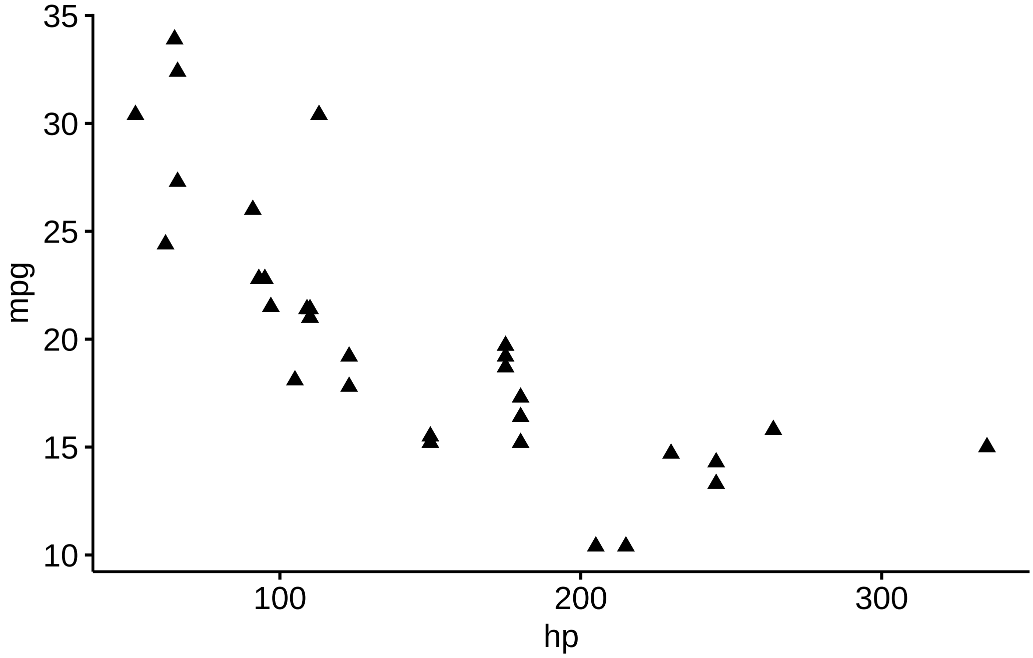
```
ggplot(tb,
       aes(x = hp, y = mpg)) +
  geom_point() +
  xlab("Horsepower of Engine") +
  ylab("Miles per gallon") +
  ggtitle("Scatter Plot of mpg vs. hp")
```



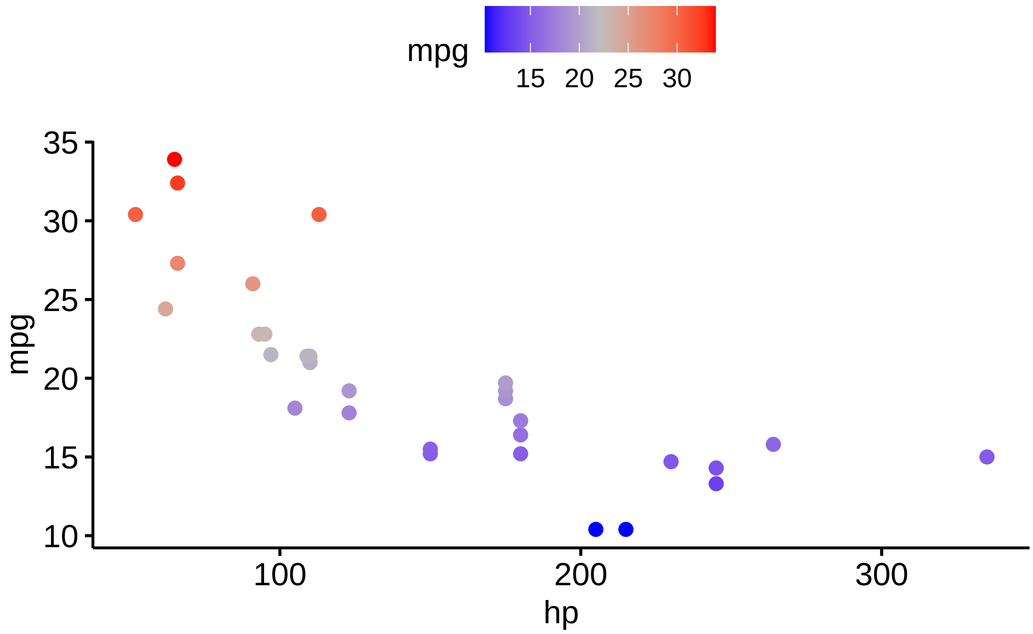
Discussion:

- The `ggplot2` package uses a layering approach, enabling users to build plots incrementally, piece by piece, using a combination of data, aesthetics, and geometric objects.
- The function `ggplot()` initializes the plotting system. It requires a dataset to operate on and an aesthetic mapping to determine how data variables will be plotted. Here, the dataset is represented by `tb`.
- Inside the `aes()` function, which stands for aesthetics, the code specifies that the variable `hp` from the `tb` data frame will be plotted on the x-axis and the variable `mpg` will be plotted on the y-axis. Hence, the resulting plot will display a relationship between horsepower (`hp`) and miles per gallon (`mpg`).
- The `geom_point()` function is an added layer, instructing `ggplot2` to render the relationship between `hp` and `mpg` as a scatter plot, with individual data points being represented as points.
- The functions `xlab()` and `ylab()` are used to set custom labels for the x and y axes, respectively. In this code, the x-axis is labeled as “Horsepower of Engine” and the y-axis is labeled as “Miles per gallon”.
- Finally, the `ggtitle()` function is used to assign a title to the entire plot. In this instance, the title is set as “Scatter Plot of mpg vs. hp”, clearly indicating the purpose and content of the visualization.

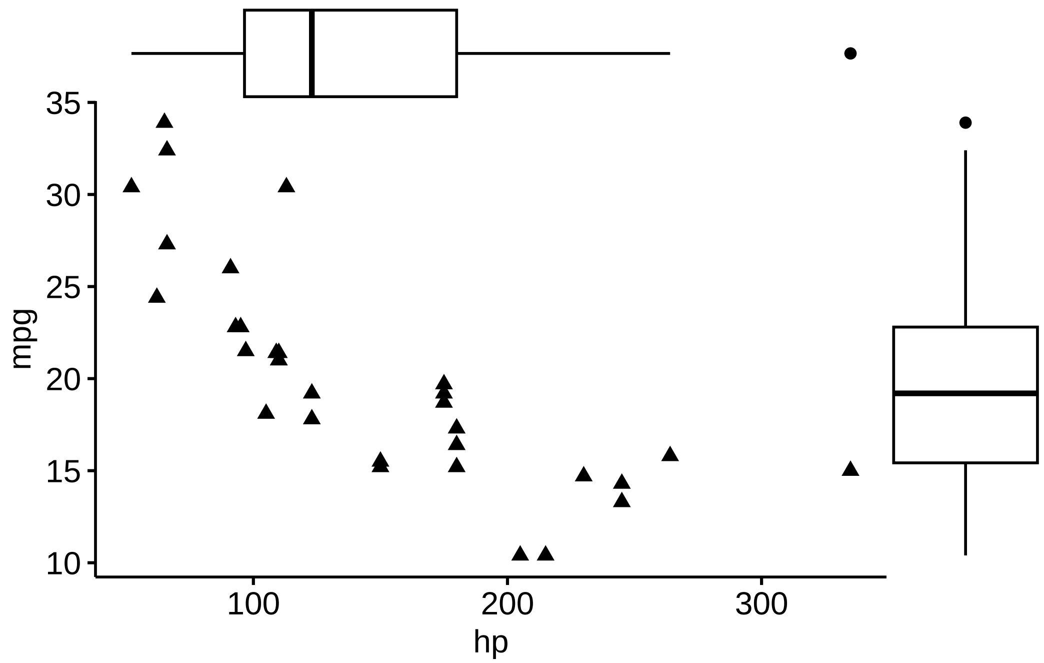
```
ggscatter(tb,
          x = "hp", y = "mpg",
          shape = 17)
```



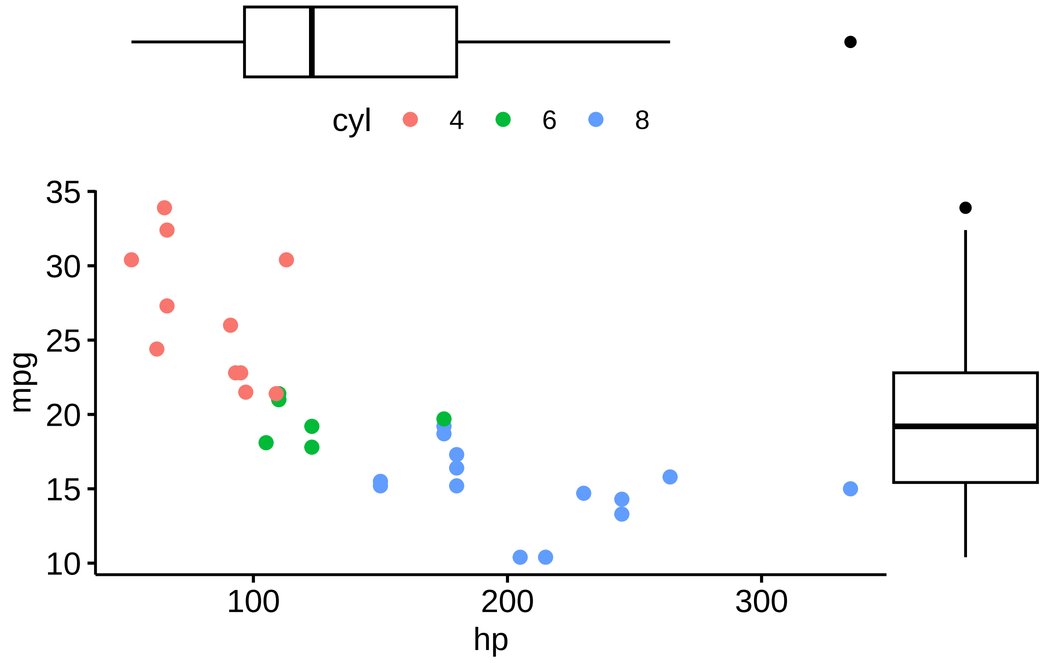
```
# Color by continuous variable
ggscatter(tb,
          x = "hp", y = "mpg",
          color = "mpg") +
  gradient_color(c("blue", "gray", "red"))
```



```
# Add density distribution as marginal plot
library("ggExtra")
p <- ggscatter(tb,
          x = "hp", y = "mpg",
          shape = 17)
# Change marginal plot type
ggMarginal(p, type = "boxplot")
```

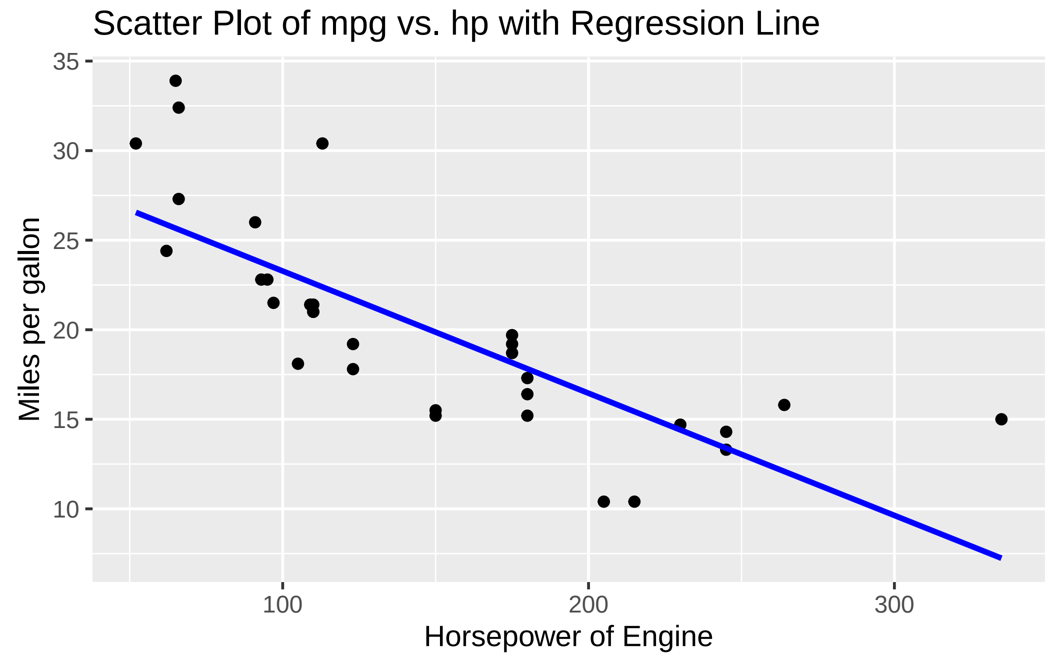


```
# Add density distribution as marginal plot
library("ggExtra")
p <- ggscatter(tb,
          x = "hp", y = "mpg",
          color = "cyl")
# Change marginal plot type
ggMarginal(p, type = "boxplot")
```

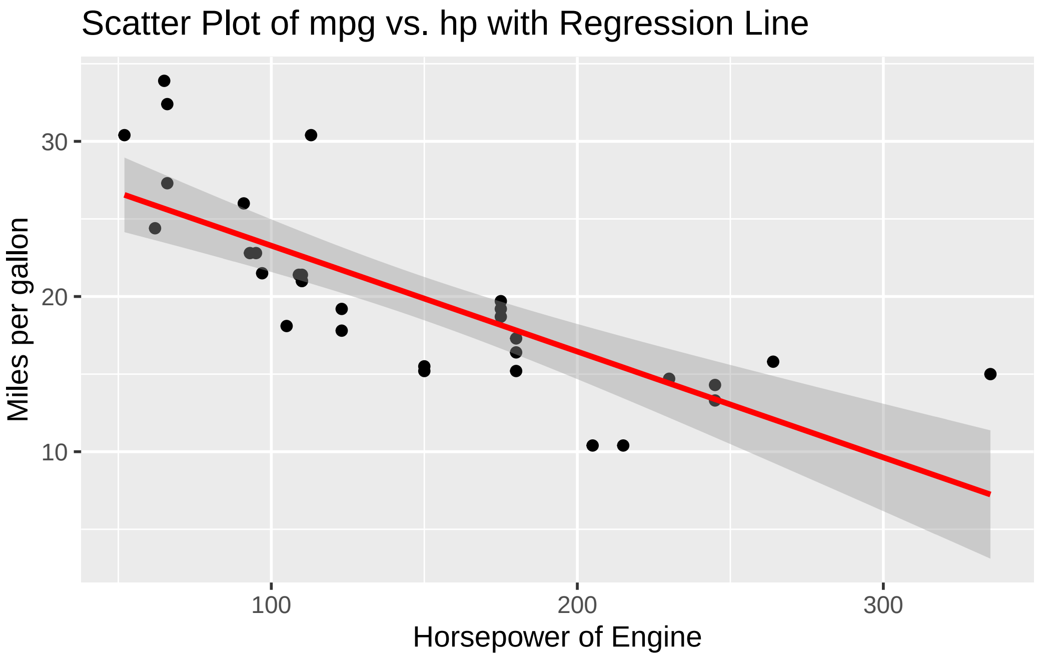


Scatterplot with Regression line using `ggplot2`

```r
ggplot(tb, aes(x = hp, y = mpg)) +
  geom_point() +
  geom_smooth(method = "lm",
              se = FALSE,
              color = "blue") +  # Added this line for the regression
  xlab("Horsepower of Engine") +
  ylab("Miles per gallon") +
  ggtitle("Scatter Plot of mpg vs. hp with Regression Line")
```



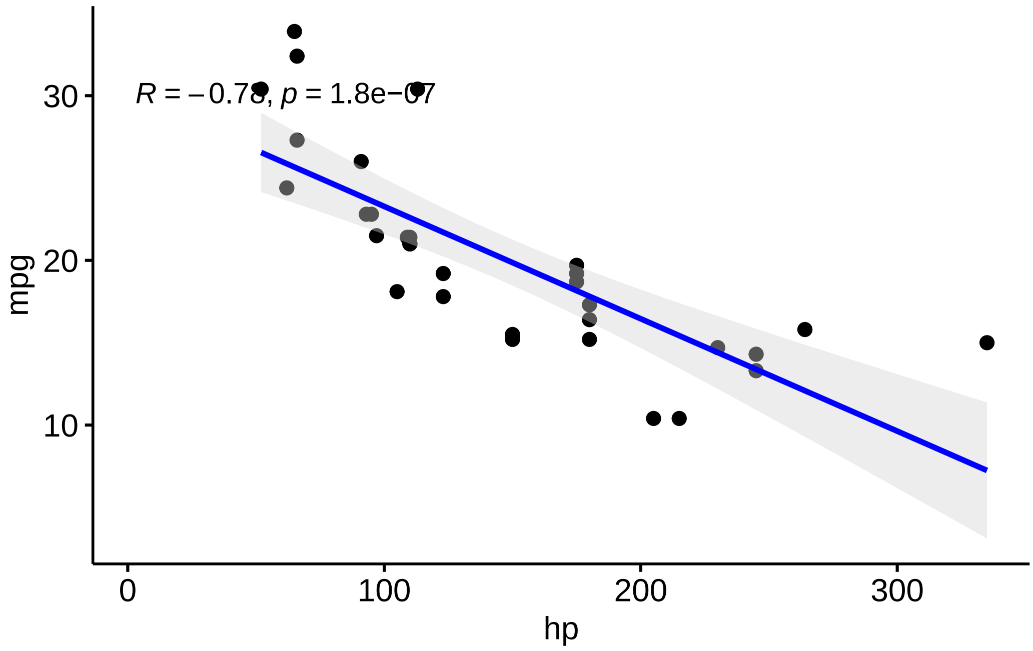
```
ggplot(tb, aes(x = hp, y = mpg)) +
  geom_point() +
  geom_smooth(method = "lm",
              se = TRUE,
              color = "red") +  # Added this line for the regression
  xlab("Horsepower of Engine") +
  ylab("Miles per gallon") +
  ggtitle("Scatter Plot of mpg vs. hp with Regression Line")
```



Discussion:

- `geom_smooth(method = "lm", se = FALSE, color = "blue")`: This function adds a smoothed conditional mean.
  - The `method = "lm"` argument indicates that a linear model (i.e., a regression line) should be used for smoothing. This line will depict the overall trend in the data.
  - If `se = FALSE` then the standard error bands (which show the uncertainty around the regression line) aren't plotted. This determines whether or not the standard error bands (or confidence interval bands) are displayed around the smoothing line. In the case of linear regression (method = "lm"), these bands represent the 95% confidence interval around the predicted values. This means that if you were to repeatedly sample from the population and fit a regression model each time, you'd expect about 95% of the confidence intervals to contain the true regression line.

```
ggscatter(tb,
          x = "hp", y = "mpg",
          add = "reg.line",                                  # Add regression line
          conf.int = TRUE,                                   # Add confidence interval
          add.params = list(color = "blue",
                            fill = "lightgray")
          )+
  stat_cor(method = "pearson", label.x = 3, label.y = 30)  # Add correlation coefficient
```

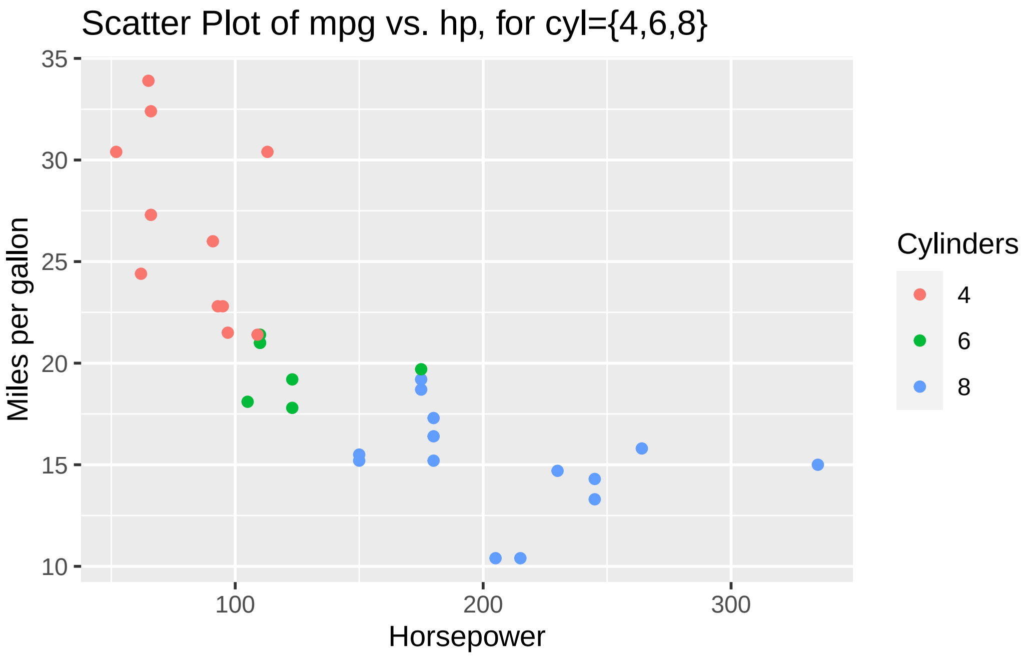


Scatterplots with Categorical Variables

Scatterplot colored by a Categorical variable, using `ggplot()`

This will create a scatterplot of miles per gallon (`mpg`) against horsepower (`hp`), with each point colored according to the number of cylinders (`cyl`) in the engine.

```
# Create a Scatterplot of mpg vs. hp, colored by cyl
ggplot(tb, aes(x = hp,
               y = mpg,
               color = factor(cyl))) +
  geom_point() +
  labs(x = "Horsepower", y = "Miles per gallon") +
  scale_color_discrete(name = "Cylinders")  +
  ggtitle("Scatter Plot of mpg vs. hp, for cyl={4,6,8}")
```



Discussion:

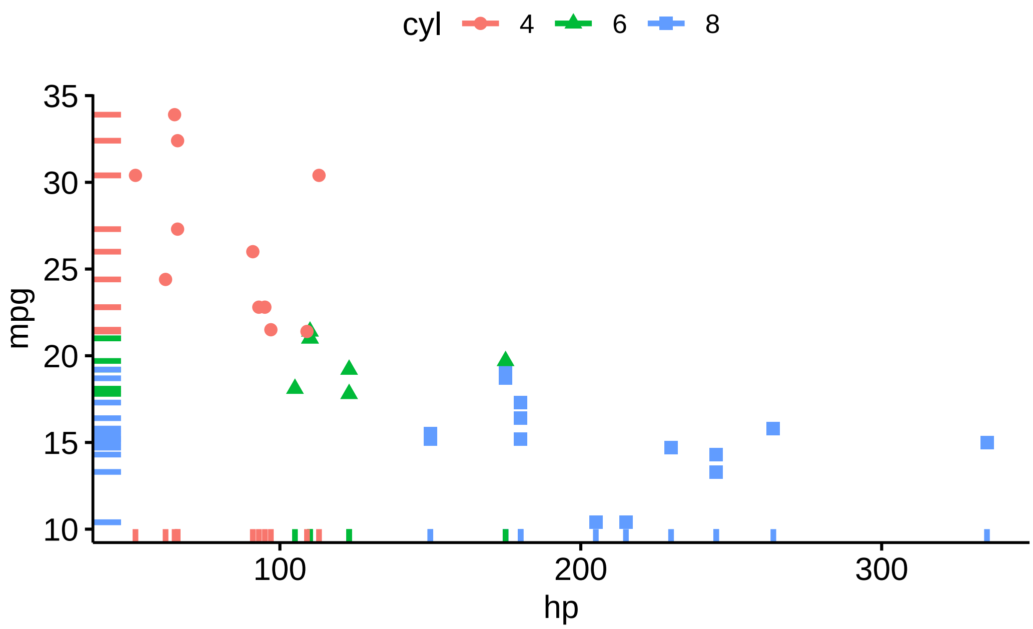
- The `aes()` function, short for aesthetics, designates the variables and their roles in the plot. In this code:
  - The `hp` variable is plotted on the x-axis.
  - The `mpg` variable is mapped to the y-axis.
  - The `color` attribute is set based on the `cyl` variable, which presumably indicates the number of cylinders in a car engine. The use of `factor(cyl)` ensures that the `cyl` variable is treated as a discrete factor rather than a continuous variable, which is essential for color differentiation.

- `geom_point()` introduces a scatter plot layer, meaning that the relationship between `hp` and `mpg` will be represented using individual points, with each point's color reflecting the number of cylinders as specified in the aesthetic mapping.

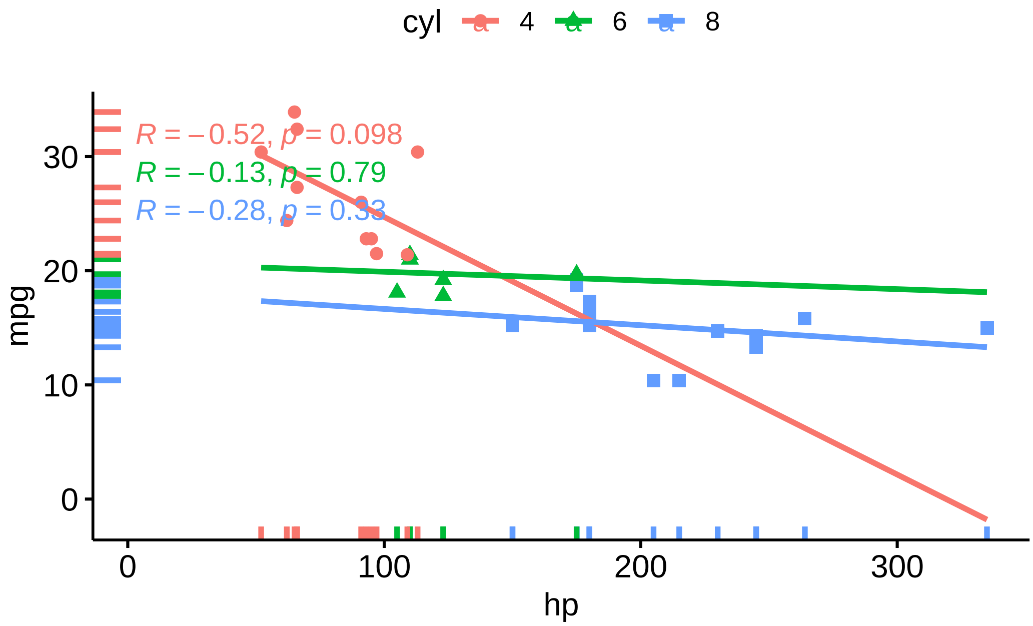
- The `labs()` function provides a convenient way to label the axes. Here, the x-axis receives the label "Horsepower" and the y-axis is labeled "Miles per gallon".

- The `scale_color_discrete()` function customizes the color scale for discrete variables. By specifying the `name` argument as "Cylinders", it ensures that the legend accompanying the color scale in the plot will be labeled as "Cylinders", making it clear to viewers that the colors of the points represent different cylinder counts.

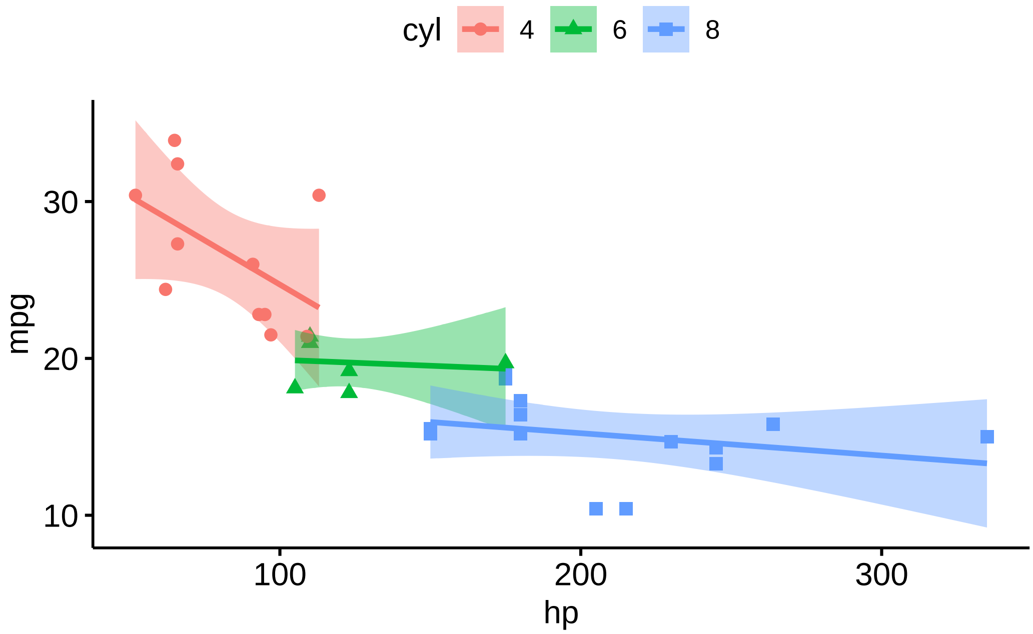
```
ggscatter(tb,
          x = "hp", y = "mpg",
          color = "cyl", # Color by groups "cyl"
          shape = "cyl",  # Change point shape by groups "cyl"
          rug = TRUE                # Add marginal rug
          )
```



```
# Extending the regression line --> fullrange = TRUE
# Add marginal rug (marginal density) ---> rug = TRUE
ggscatter(tb,
          x = "hp", y = "mpg",
          add = "reg.line",         # Add regression line
          color = "cyl",            # Color by groups "cyl"
          shape = "cyl",            # Change point shape by groups "cyl"
          fullrange = TRUE,         # Extending the regression line
          rug = TRUE                # Add marginal rug
          ) +
  stat_cor(aes(color = cyl),
           label.x = 3)            # Add correlation coefficient
```



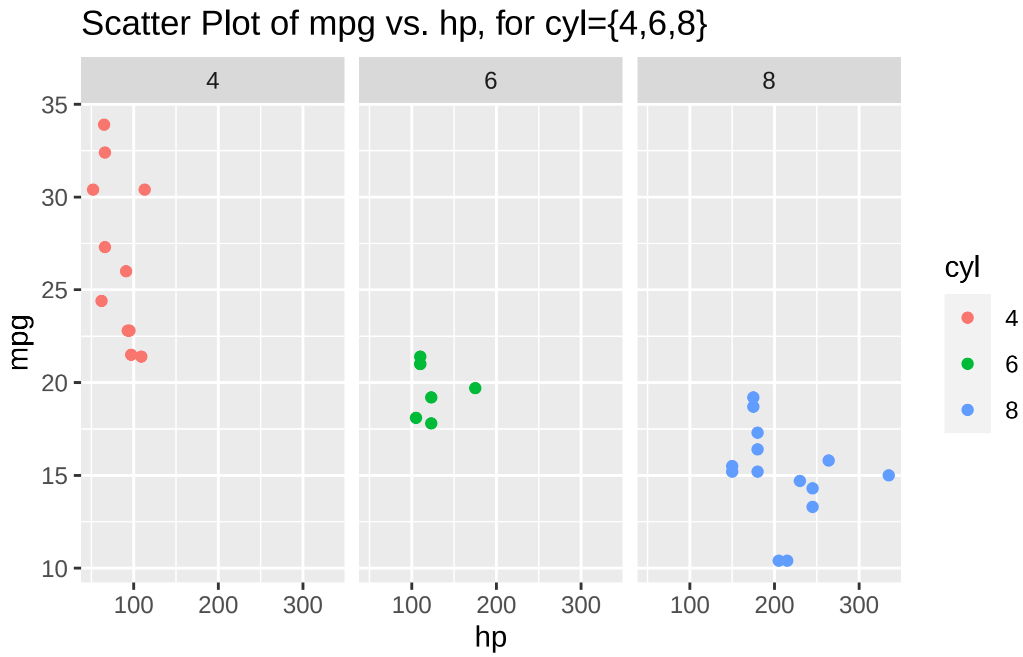
```
ggscatter(tb,
          x = "hp", y = "mpg",
          add = "reg.line",  # Add regression line
          conf.int = TRUE,   # Add confidence interval
          color = "cyl",     # Color by groups "cyl"
          shape = "cyl"      # Change point shape by groups "cyl"
          )
```



Scatterplot faceted by a Categorical variable, using `ggplot()`

This will create a scatterplot of miles per gallon (mpg) against weight, with each plot faceted by the number of cylinders in the engine (cyl).

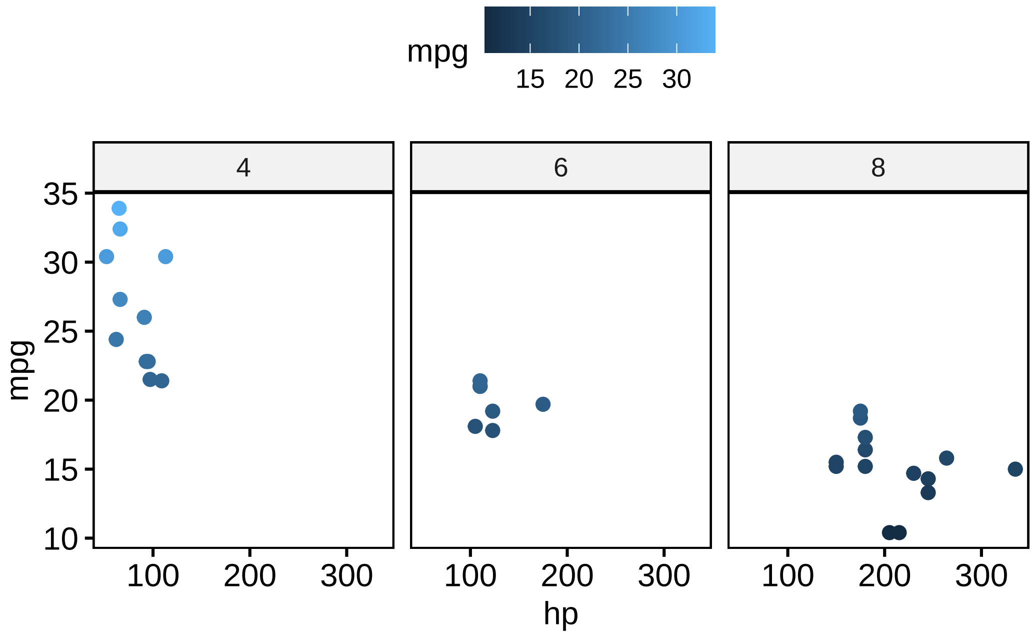
```
# Create a Scatterplot of mpg vs. hp, faceted by cyl
ggplot(tb,
       aes(x = hp,
           y = mpg,
               color = cyl)) +
  geom_point() +
  facet_grid(. ~ cyl) +
  ggtitle("Scatter Plot of mpg vs. hp, for cyl={4,6,8}")
```



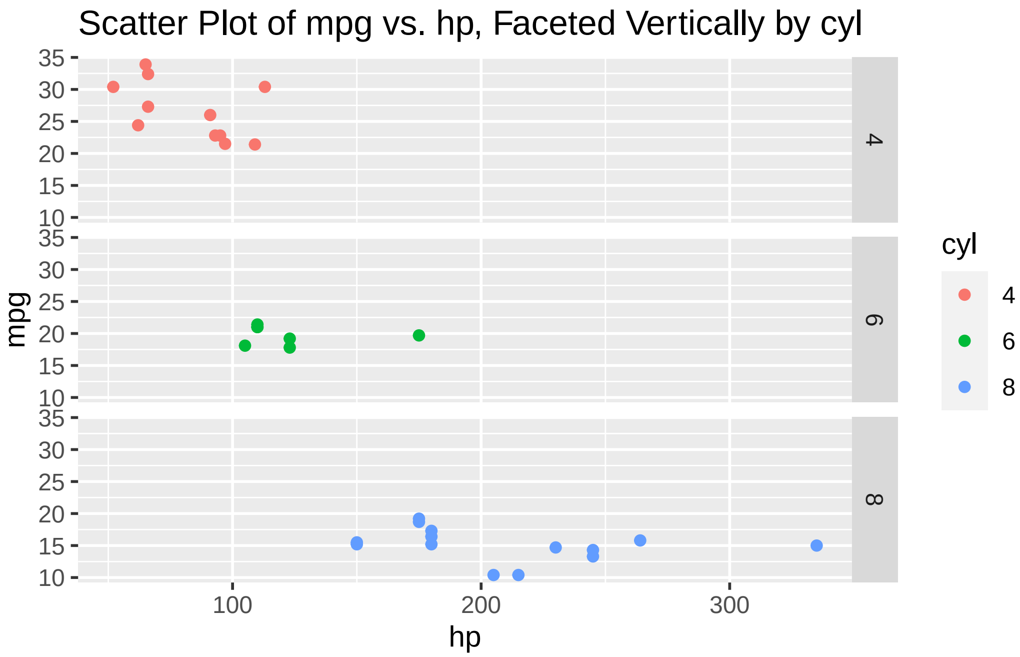
Discussion:

- The foundational layer is initialized with the `ggplot()` function. This function takes in a dataset, `tb`, and aesthetic mappings that determine how variables are displayed. In this piece of code:
  - `hp` is chosen to be plotted on the x-axis.
  - `mpg` is selected for the y-axis.
  - The color of the points will be determined by the `cyl` variable.
- The addition of the `geom_point()` layer ensures that a scatter plot will represent the relationship between `hp` and `mpg`. Each point's color will correspond to the value of the `cyl` variable.
- The `facet_grid()` function introduces the concept of faceting. Faceting divides a plot into multiple panels based on the levels of one or more factors. In this case, the plot is faceted horizontally (`~ cyl`), meaning that separate panels are created for each unique value of `cyl`. The `.` before the `~` indicates that there's no faceting vertically.
- Finally, the `ggtitle()` function provides the entire plot with a title, which is "Scatter Plot of mpg vs. hp, for cyl={4,6,8}". This title clearly communicates the main theme of the plot and indicates that it showcases relationships for cars with 4, 6, or 8 cylinders.

```
# Color by continuous variable
ggscatter(tb,
          x = "hp", y = "mpg",
          color = "mpg",
          facet.by = "cyl"
          )
```



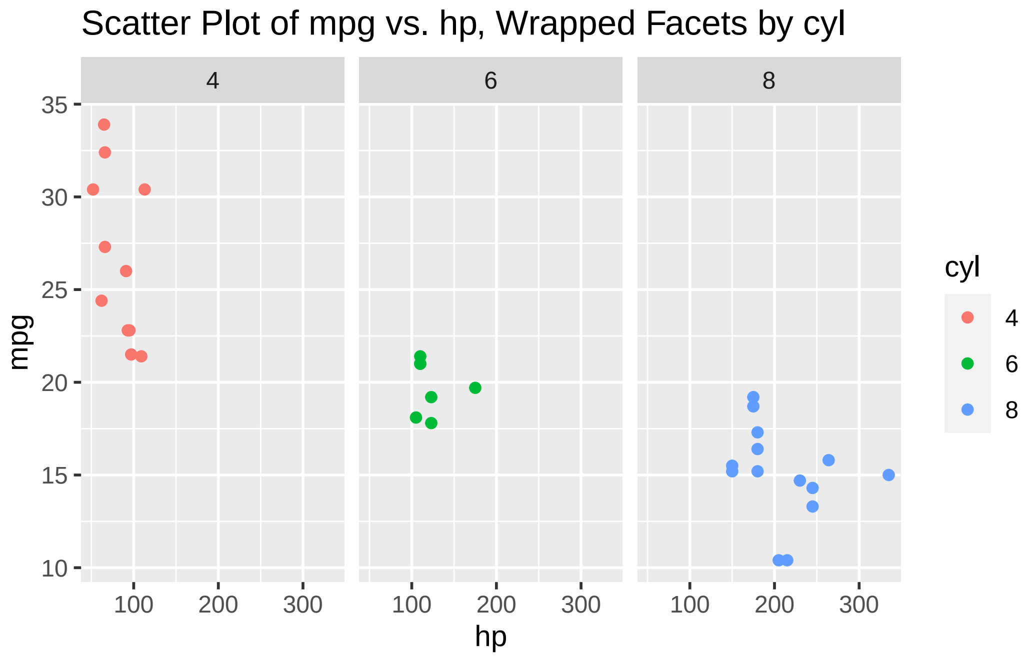
```
ggplot(tb,
       aes(x = hp,
           y = mpg,
           color = cyl)) +
  geom_point() +
  facet_grid(cyl ~ .) +
  ggtitle("Scatter Plot of mpg vs. hp, Faceted Vertically by cyl")
```



Discussion:

- The primary difference between the two code snippets lies in how the faceting is implemented using the `facet_grid()` function.
- In the original code, `facet_grid(. ~ cyl)` is used, which means the scatter plots are faceted horizontally based on the unique values of the `cyl` variable; each unique cylinder count gets its own column.
- Conversely, in the updated code with `facet_grid(cyl ~ .)`, the scatter plots are faceted vertically based on the unique values of the `cyl` variable; each unique cylinder count gets its own row.

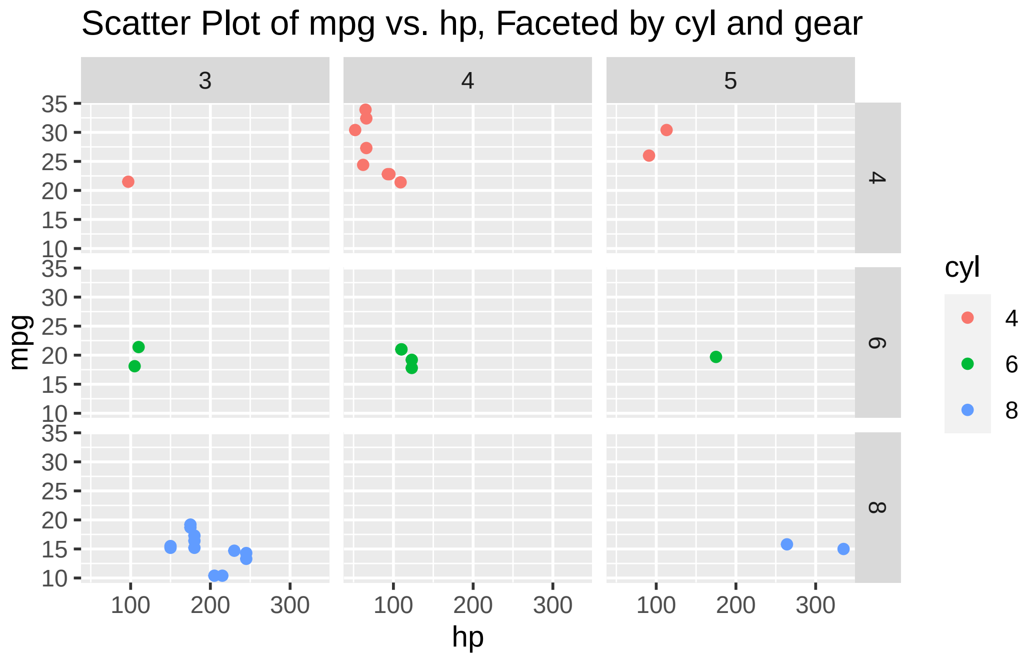
```r
ggplot(tb,
       aes(x = hp,
           y = mpg,
           color = cyl)) +
  geom_point() +
  facet_wrap(~ cyl, ncol = 3) +
  ggtitle("Scatter Plot of mpg vs. hp, Wrapped Facets by cyl")
```



Discussion:

- This approach creates a wrapped grid of facets based on `cyl`.
- The `ncol = 3` argument specifies that up to three facets will be placed in a row before wrapping to the next row. You can adjust this as needed based on the number of levels in the faceting variable and the desired layout.

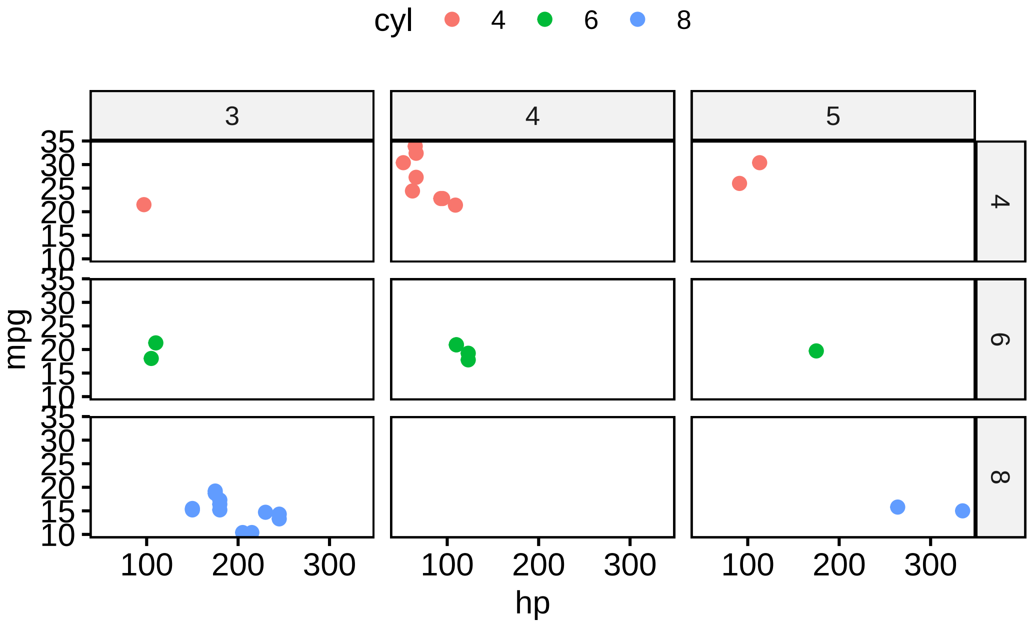
```
ggplot(tb,
       aes(x = hp,
           y = mpg,
           color = cyl)) +
  geom_point() +
  facet_grid(cyl ~ gear) +
  ggtitle("Scatter Plot of mpg vs. hp, Faceted by cyl and gear")
```



Discussion:

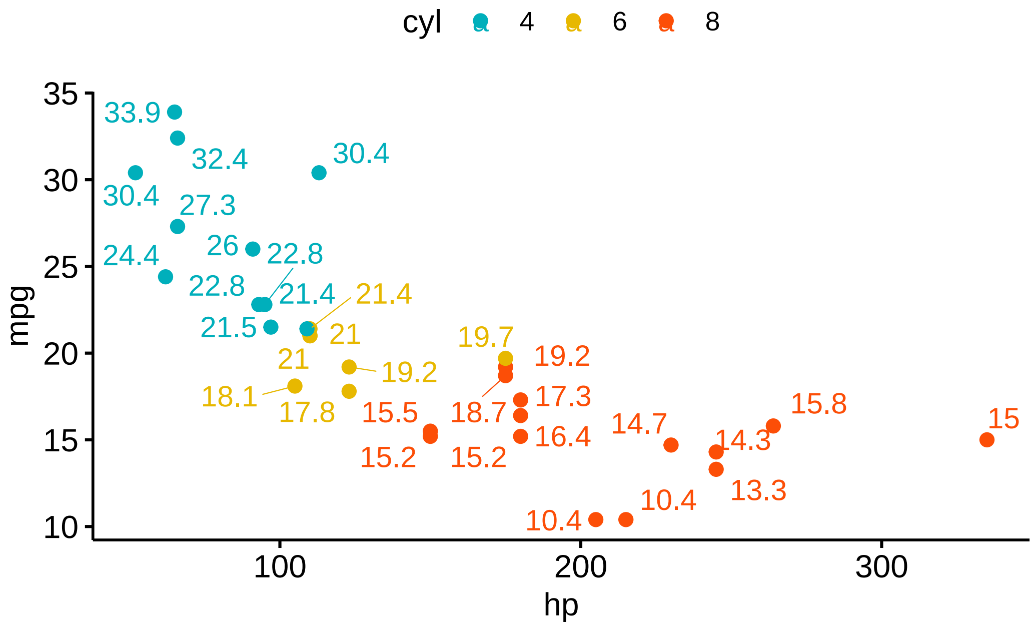
- In this code, within the `aes()` aesthetics function:
  - The variable `hp` is mapped to the x-axis.
  - The variable `mpg` is mapped to the y-axis.
  - The color of individual points is determined by the `cyl` variable, which probably represents the number of cylinders in an engine.
- The `geom_point()` function is introduced to represent the relationship between `hp` and `mpg` as a scatter plot. The colors of the individual points will correspond to the values of the `cyl` variable.
- The `facet_grid(cyl ~ gear)` function is the standout feature in this code. Here, the plots are faceted based on two categorical variables:
  - `cyl`, which is mapped to rows. Each unique value of `cyl` will generate a new row of plots.
  - `gear`, which is mapped to columns. Each unique value of `gear` will generate a new column of plots.
  - The resultant grid will represent combinations of `cyl` and `gear` values, with each cell in the grid showing the relationship between `hp` and `mpg` for a specific combination of `cyl` and `gear`.

```r
# Color by continuous variable
ggscatter(tb,
          x = "hp", y = "mpg",
          color = "cyl",
          facet.by = c("cyl","gear")
          )
```



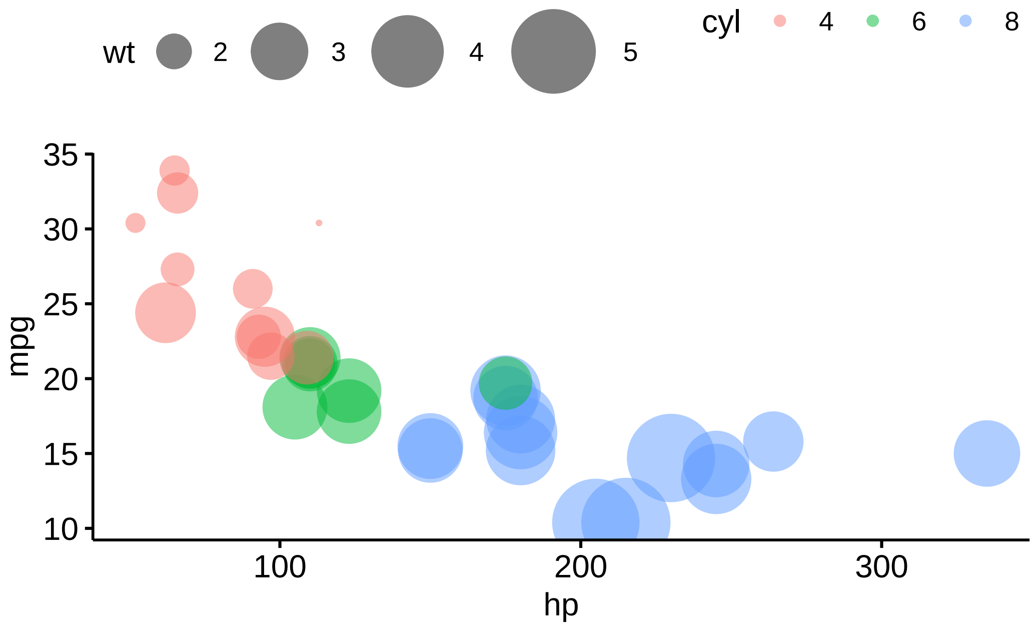
Scatterplot colored by a Categorical variable, with textual annotation, using ggpubr()

```r
# Textual annotation
ggscatter(tb,
          x = "hp",
          y = "mpg",
   color = "cyl",
   palette = c("#00AFBB", "#E7B800", "#FC4E07"),
   label = "mpg",
   repel = TRUE)
```



Bubble Chart

```
ggscatter(tb,
          x = "hp", y = "mpg",
          color = "cyl",
          size = "wt", alpha = 0.5) +
  scale_size(range = c(0.5, 15))    # Adjust the range of points size
```



References

[1] Everitt, B. S., & Hothorn, T. (2014). A Handbook of Statistical Analyses Using R. Chapman and Hall/CRC.