# Three Dimensional (3D) Data

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### Overview of R packages for 3D Plots

This chapter demonstrates how to create 3D plots in R.

#### ggplot2

The ggplot2 package in R is primarily designed for creating 2D plots. However, we can simulate 3D effects, even though it won't provide true 3D plots. [1]

#### scatterplot3d

The scatterplot3d package in R can be used to create 3D scatter plots. It is quite simple to use and can be a good choice for quick visualizations. [2]

#### rgl

The rgl package in R is a powerful tool for creating interactive 3D plots. It allows real-time interaction with the plots, where users can zoom, rotate, and pan the visualization to explore the data in three dimensions. This package provides various functionalities to create a variety of 3D plots, including scatter plots, surface plots, line plots, bar plots. [3]

In this chapter, we focus our attention on ggplot2 and scatterplot3d packages.

```
# Load the required libraries for 3D plots, suppressing annoying startup messages
library(scatterplot3d, quietly = TRUE, warn.conflicts = FALSE)
```

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)

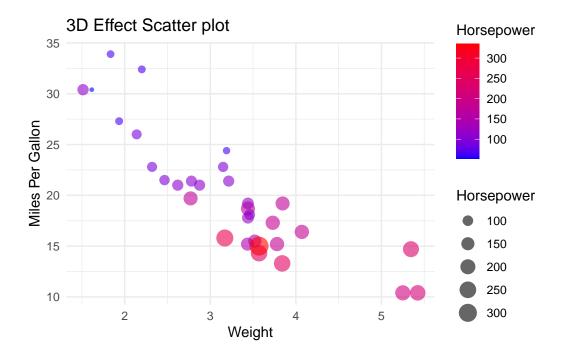
# Convert relevant columns into factor variables
tb$cyl <- as.factor(tb$cyl) # cyl = {4,6,8}, number of cylinders
tb$am <- as.factor(tb$am) # am = {0,1}, 0:automatic, 1: manual transmission
tb$vs <- as.factor(tb$vs) # vs = {0,1}, v-shaped engine, 0:no, 1:yes
tb$gear <- as.factor(tb$gear) # gear = {3,4,5}, number of gears</pre>
```

### 3D Plots using ggplot2

The ggplot2 package in R cannot create true 3D plots. Here is how to simulate a 3D plot using ggplot2. [1]

#### Simulating 3D using ggplot2

```
# Load necessary library
library(ggplot2)
# Create a scatter plot with the perception of depth using size and color
ggplot(tb,
      aes(x = wt,
          y = mpg,
           color = hp,
           size = hp)) + # Define the data and aesthetics for the plot
 geom_point(alpha = 0.6) + # Add points to the plot with transparency
 scale_color_gradient(low = "blue", high = "red") + # Define color gradient
 theme_minimal() + # Set the plot theme to minimal
 labs(title = "3D Effect Scatter plot",
      x = "Weight",
      y = "Miles Per Gallon",
      color = "Horsepower",
      size = "Horsepower") # Set plot labels and title
```



#### Discussion:

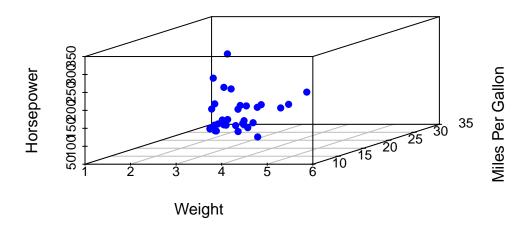
- The code provided simulates a 3D plot by exploiting visual cues and perceptual aspects of human vision. It uses the following strategies to simulate depth and give the perception of a three-dimensional plot on a two-dimensional surface:
- Size Encoding: The size = hp aesthetic in the aes() function maps the hp (horse-power) variable to the size of the points in the scatter plot. Points representing cars with higher horsepower appear larger, while those with lower horsepower appear smaller. This varying point size provides a depth cue, simulating the z-axis on a 2D surface.
- Color Encoding: The color = hp aesthetic assigns different colors to the points based on their horsepower values. The scale\_color\_gradient(low = "blue", high = "red") function further specifies that lower horsepower should be represented with blue, transitioning to red for higher horsepower. The gradient color scale serves as another depth cue, indicating that points of different colors are at different 'depths'.
- Alpha Transparency: The alpha = 0.6 parameter in the geom\_point() function adjusts the transparency of the points. This transparency allows for better visibility of overlapping points, giving a sense of depth where points are clustered.
- Axis Mapping: The x = wt and y = mpg within the aes() function map the weight of the cars to the x-axis and the miles per gallon to the y-axis. These two axes represent the spatial dimensions on the plotting surface.

- This plot has similarities to the classic bubble plot. The application of a color gradient gives the illusion of 3D.
- By combining these elements, the plot employs size, color gradient, and transparency to introduce visual cues of depth, effectively simulating a 3D effect on a 2D plotting surface. This enables the viewer to infer relationships among wt, mpg, and hp, even though the plot itself is inherently two-dimensional. [1]

### 3D Plots using scatterplot3d

The \*scatterplot3d\*\* package can be used on the mtcars data to demonstrate visualization in 3 dimensions.

#### 3D Scatter Plot of mtcars



#### Discussion:

- x = tb\$wt, y = tb\$mpg, and z = tb\$hp are used to map the wt, mpg, and hp columns from the tb tibble to the x, y, and z axes of the 3D scatter plot respectively.
- The xlab, ylab, and zlab parameters are used to label the x, y, and z axes.
- pch = 16 specifies the type of point to be used in the plot.
- color = "blue" sets the color of the points to blue.
- main is used to set the title of the plot.
- Overall, this code visualizes a 3D scatter plot demonstrating the relationships between wt, mpg, and hp in the mtcars dataset. [2]

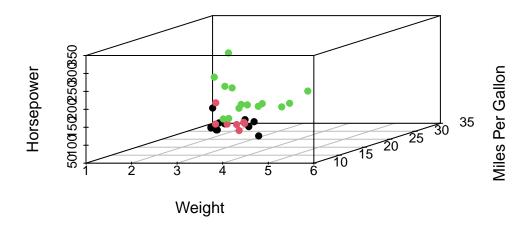
#### Variations of 3D Plots using scatterplot3d

Here are some variations and extensions of the original scatterplot3d code to demonstrate the versatility of 3D visualizations:

#### Color by a Variable:

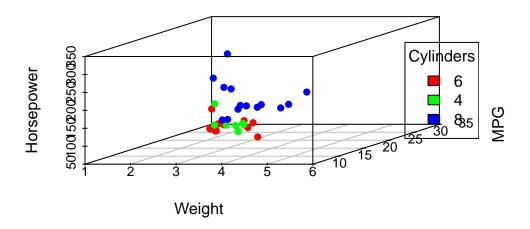
We can color points by a variable, for example, by the number of cylinders (cyl), which can reveal additional patterns in the data.

### 3D Scatter Plot Colored by Number of Cylinders



• We can add a legend for the color in the scatterplot3d plot by using a combination of the legend function and the colors argument. [2]

## 3D Scatter Plot Colored by Number of Cylinders



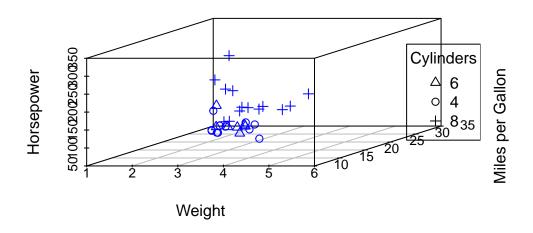
#### Discussion:

- We defined a color palette using the rainbow function based on the number of unique cylinder values in tb\$cyl.
- We then used this color palette to color the points in the scatter plot.
- Finally, we used the legend function to manually add a color legend to the right of the plot. The legend function takes the unique cylinder values as the labels for the legend and the colors from the color palette as the fill colors. The title of the legend is set to "Cylinders". [2]

#### Change Point Style:

We can change the point style to better distinguish between data points. [2]

### 3D Scatter Plot with Different Point Styles



#### Discussion:

- This R code visualizes relationships among the wt, mpg, and hp columns from the tb tibble, with points having different shapes based on the number of cylinders (cyl).
- Creation of 3D Scatter Plot
  - sp34 <- scatterplot3d(...): This line initializes the creation of a 3D scatter plot and stores the result in the s3d variable.
  - -x = tb%wt, y = tb\$mpg, z = tb\$hp: These arguments define the variables that will be plotted on the x, y, and z axes, respectively.
  - pch = as.numeric(tb\$cyl): This argument specifies the point shape (pch) to vary based on the cyl column, with different cylinders represented by different shapes.
  - color = "blue": All points are colored blue.
  - xlab, ylab, zlab: These arguments label the axes of the plot.
  - main: This argument provides the main title of the plot.
- Determination of Unique Cylinder Values and Shapes

- cylinders <- unique(tb\$cyl): This line identifies the unique values in the cylinders variable.</li>
- shapes <- as.numeric(cylinders): The unique cylinder values are converted to numeric form to determine the corresponding point shapes, which are stored in shapes.

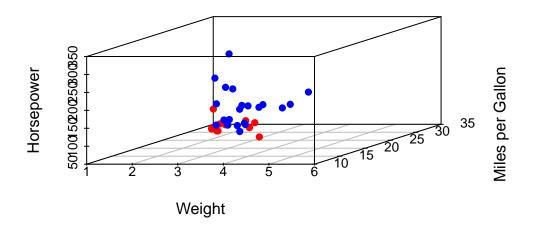
#### • Addition of Legend

- legend("right", ...): This function is used to add a legend to the right of the plot.
- legend = as.character(cylinders): This argument defines the labels of the legend, which are the unique cylinder values converted to character strings.
- pch = shapes: The point shapes corresponding to the unique cylinder values are used in the legend.
- title = "Cylinders": The title of the legend is set as "Cylinders".
- By executing this code, we get a 3D scatter plot with points having different shapes based on the number of cylinders, and a corresponding legend clarifying the representation of each shape. [2]

#### **Highlight Specific Points:**

We can can highlight specific points, for example, cars with 4 cylinders, by changing their color or size. [2]

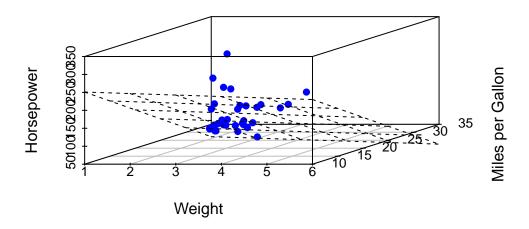
# **3D Scatter Plot Highlighting Specific Points**



### Add Regression Plane:

We can fit a linear regression model and add the regression plane to the scatter plot. [2]

### 3D Scatter Plot with Regression Plane



#### Discussion:

- This code snippet is used to create a 3D scatter plot and then fit a linear regression plane to the plotted data points.
- Fit a Linear Model
  - model <- lm(hp ~ wt + mpg, data = tb): A linear model is fitted using the lm function with hp as the dependent variable and wt and mpg as the independent variables. The resulting model object is stored in the variable model.</p>

#### • Add a Regression Plane to the Plot

- sp36\$plane3d(model): The plane3d function is accessed from the s3d object and is used to add a regression plane to the existing 3D scatter plot. The plane is based on the coefficients of the linear model stored in model.
- The resulting output will be a 3D scatter plot visualizing the relationships among weight (wt), miles per gallon (mpg), and horsepower (hp), with a regression plane fitted to these points, representing the linear relationship between the dependent and independent variables. [2], [4]

# Summary of Chapter 16 – Three Dimensional (3D) Data

This chapter provides an insightful exploration into the creation of 3D plots using R, focusing on the ggplot2 and scatterplot3d packages.

ggplot2: The chapter begins by highlighting that ggplot2, primarily known for 2D plots, can be used to simulate 3D effects. This is demonstrated through a scatter plot example where

visual cues like point size and color gradients are employed to give an illusion of depth. By mapping variables such as horsepower to these visual elements in the 'mtcars' dataset, the plot achieves a 3D-like effect on a 2D plane.

scatterplot3d: The scatterplot3d package, specifically designed for 3D scatter plots, is explored next. The chapter illustrates its straightforward application in creating 3D plots with the mtcars data, considering variables like weight, miles per gallon, and horsepower. It delves into various enhancements like coloring points based on categorical variables (e.g., the number of cylinders), changing point styles to distinguish data points, highlighting specific points for emphasis, and adding legends for clarity. The chapter also demonstrates how to incorporate a linear regression plane into the scatter plot, adding an analytical dimension to the visual representation.

Throughout the chapter, code examples and discussions are provided to guide the reader on how to effectively use these packages for 3D plotting in R. The focus is on practical application, offering readers the tools to transform standard 2D visualizations into more engaging and informative 3D plots. This approach not only enhances the visual appeal of the data but also allows for a more nuanced understanding of complex relationships within the dataset.

### References

#### ggplot2:

[1] Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York. https://ggplot2.tidyverse.org

Wickham, H., & Grolemund, G. (2016). R for Data Science: Import, Tidy, Transform, Visualize, and Model Data. O'Reilly Media.

Wickham, H. (2020). ggplot2: Create Elegant Data Visualisations Using the Grammar of Graphics (Version 3.3.2) [Computer software]. Retrieved from https://CRAN.R-project.org/package=ggplot2

Wickham, H., et al. (2020). dplyr: A Grammar of Data Manipulation (Version 1.0.2) [Computer software]. Retrieved from https://CRAN.R-project.org/package=dplyr

Wilkinson, L. (2005). The Grammar of Graphics (2nd ed.). Springer-Verlag.

Wickham, H., et al. (2020). tibble: Simple Data Frames (Version 3.0.3) [Computer software]. Retrieved from https://CRAN.R-project.org/package=tibble

[2] Ligges, U., Maechler, M., Schnackenberg, S., & Ligges, M. U. (2018). Package 'scatter-plot3d'. Recuperado de https://cran. rproject. org/web/packages/scatterplot3d/scatterplot3d. pdf.

Ligges, U., & Mächler, M. (2002). Scatterplot3d-an r package for visualizing multivariate data (No. 2002, 22). Technical report.

[3] Adler, D., Nenadic, O., & Zucchini, W. (2003, March). Rgl: A r-library for 3d visualization with opengl. In *Proceedings of the 35th symposium of the interface: computing science and statistics, Salt Lake City* (Vol. 35, pp. 1-11).

#### Regression:

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