Week 9 Module 4 – Scatterplots

CSCI E-5a: Programming in R

Let's clear the global computing environment:

```
rm( list = ls() )
```

Module Overview and Learning Objectives

Hello! And welcome to Module 5: Scatter Plots.

In this module we'll learn about a data visualization method called a *scatter plot*.

- In Section 1, we'll discuss the basic concept behind a scatter plot, and see how to construct this graph in R and add a grid to it.
- In Section 2, we'll explore the concept of a "least-squares regression line", and learn how to draw a regression line on a scatterplot.
- In Section 3, we'll learn more about linear model objects, and see how to select the regression coefficients from such objects.

When you've completed this module, you should be able to:

- Construct a scatter plot to display the relationship between two numeric variables.
- Add a grid to the scatter plot.
- Add a least-squares regression line to the graph.
- Select the slope and y-intercept regression coefficients from a linear model object.

There are three new built-in R functions in this module:

- `grid()`
- `lm()`
- `abline()`

Section 1: The Scatter Plot

> **Main Idea:** *We can use a scatter plot to visualize the relationship between two variables*

In this section, we'll discuss the basic concept behind a scatter plot, and see how to construct this graph in R and add a grid to it.

Scatter plots enable us to visualize the relationship between two variables.

In order to use a scatter plot, the two variables must be *coordinated*: that means that the corresponding entries have to be related.

The data in the `cars` data frame is coordinated: it consists of a speed measurement and a stopping distance, and corresponding values of the two variables are related, because they both come from the same experimental replication.

To visualize the relationship between the `speed` and `dist` variables, we then plot a point for each pair of corresponding values:

- The x-coordinate of the point will be the value of the `speed` variable.
- The y-coordinate of the point will be the value of the `dist` variable.

Let's recall some of the values in the `cars()` dataset:

```
head( cars )
```

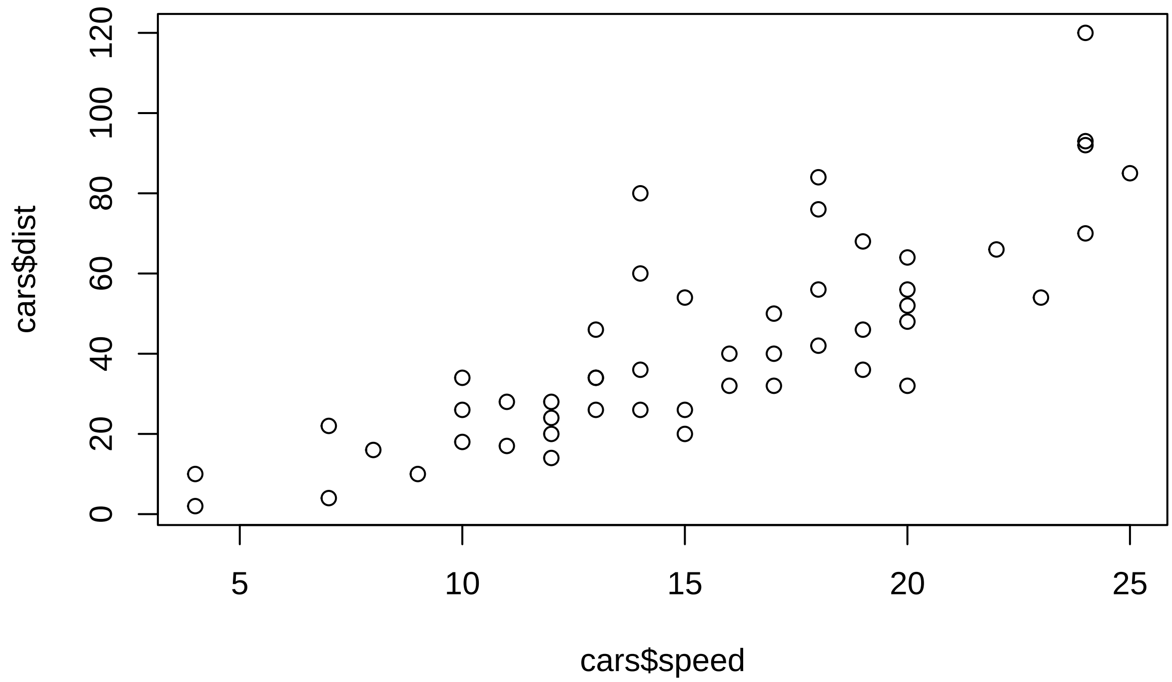
```
##   speed dist
## 1     4    2
## 2     4   10
## 3     7    4
## 4     7   22
## 5     8   16
## 6     9   10
```

To construct a scatter plot, we use the `plot()` function.

If you go back to the very beginning of the course, the first plot that we made was a scatter plot with one point, using the `plot()` function.

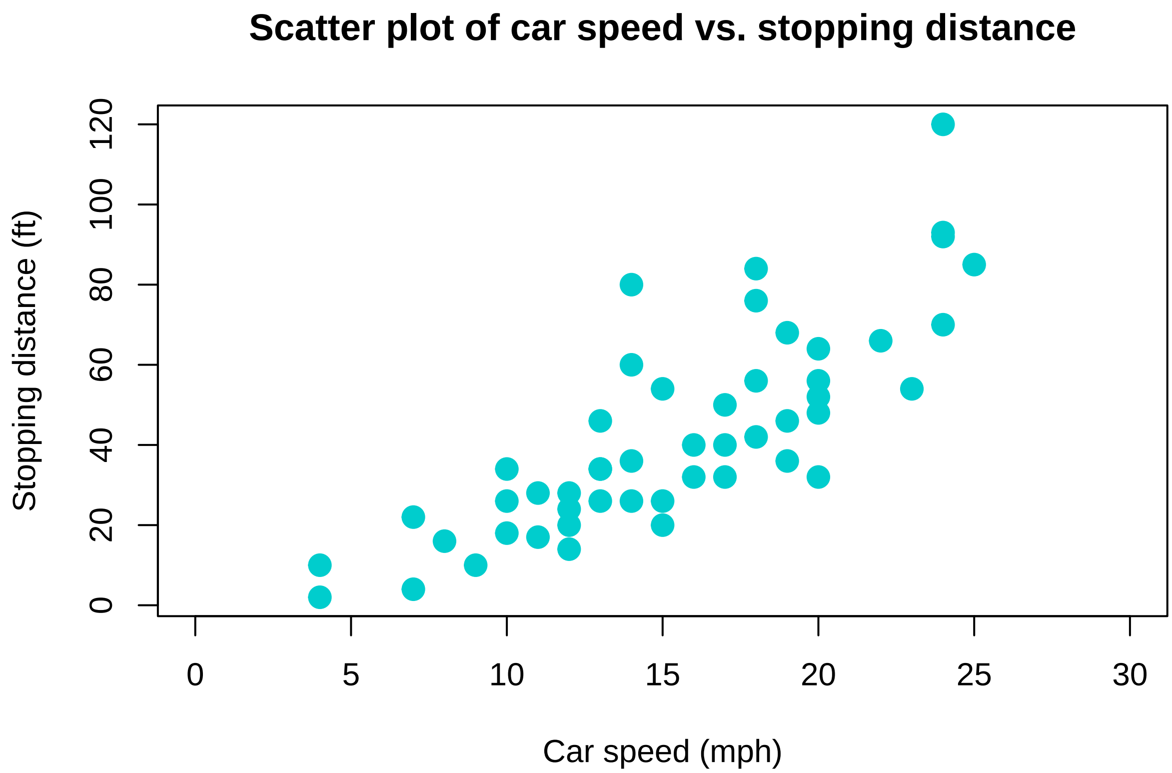
We'll start by making the simplest possible scatter plot:

```
plot(
    x = cars$speed,
    y = cars$dist
)
```



Let's make this look a little nicer:

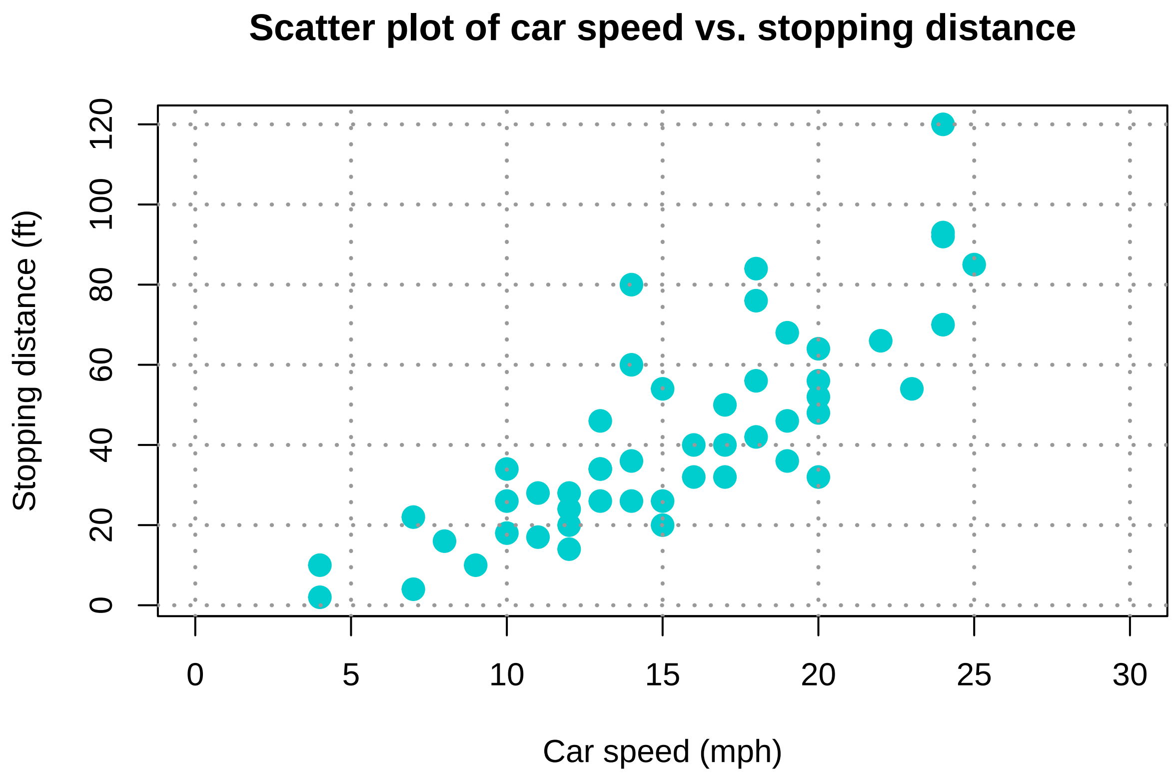
```
plot(
    x = cars$speed,
    y = cars$dist,
    xlim = c(0, 30),
    main = "Scatter plot of car speed vs. stopping distance",
    xlab = "Car speed (mph)",
    ylab = "Stopping distance (ft)",
    pch = 19,
    cex = 1.5,
    col = "cyan3"
)
```



We can add a grid to our scatter plot:

```
plot(
    cars$speed,
    cars$dist,
    xlim = c(0, 30),
    main = "Scatter plot of car speed vs. stopping distance",
    xlab = "Car speed (mph)",
    ylab = "Stopping distance (ft)",
    pch = 19,
    cex = 1.5,
    col = "cyan3"
)


grid(
    col = "gray60",
    lwd = 2
)
```



So that's how to construct a scattplot to visualize the relationship between two numeric variables.

Now let's see how to construct a least-squares regression line through our the points of the scatter plot.

Section 2: Adding a Least-Squares Regression Line

> **Main Idea:** *We can add a least-squares regression line to a scatter plot*

In this section, we'll explore the concept of a "least-squares regression line", and learn how to draw a regression line on a scatter plot.

A popular statistical method for visualizing the relationship between two numeric variables such as the `dist` and `speed` variables in the `cars` data frame is to construct what is called a "regression line", or sometimes a "least-squares regression line".

We won't get into the statistical theory of what this means, or how to calculate it, but the basic idea is to draw the "best-fitting" line through our two-dimensional display of points in the scatter plot.

To draw this "best-fitting least-squares regression line", we first have to run what's called a "linear model", and then we can use the output of this procedure to draw the regression line.

To do this, we construct what's called a "linear model", and to do this we use the `lm()` function:

```
cars.regression.model <-
    lm( cars$dist ~ cars$speed )
```

The `lm()` function has a nice feature: since we're almost always working with data in data frame, we can specify the data frame using the `data` option, and then just refer to the variables using the column names, without the $ notation:

```
cars.regression.model <-
    lm(
      formula = dist ~ speed,
      data = cars
    )
```

Notice the curious notation for the argument of the `lm()` function.

This expression is called a *formula*, and it indicates that we want to determine the least-squares line where the `speed` data is represented by the x-coordinate and the `dist` values are represented by the y-coordinate.

Notice that ~ character in the formula – it's called a "tilde", and you should make sure that you know how to type it on your keyboard.

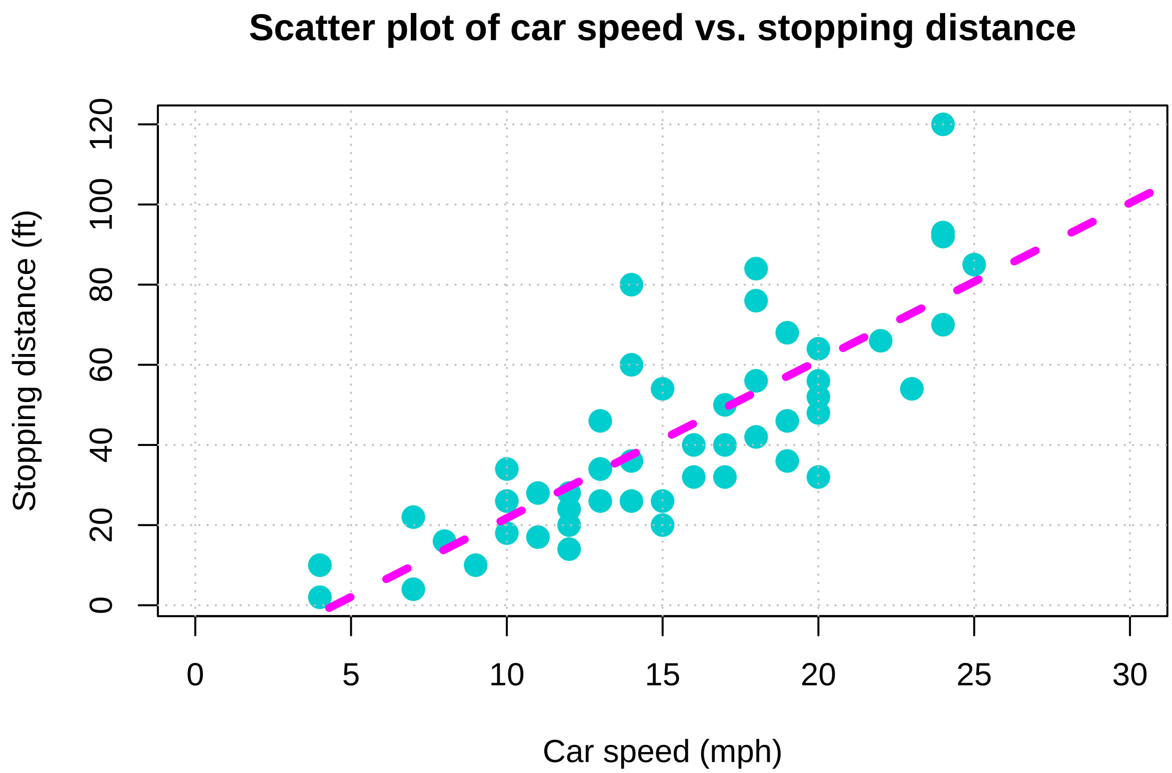
To add a regression line to your scatter plot, we use the `abline()` function with the result of the `lm()` function:

```
plot(
    cars$speed,
    cars$dist,
    xlim = c(0, 30),
    main = "Scatter plot of car speed vs. stopping distance",
    xlab = "Car speed (mph)",
    ylab = "Stopping distance (ft)",
    pch = 19,
    cex = 1.5,
    col = "cyan3"
)

grid( col = "gray75" )

cars.regression.model <-
    lm( cars$dist ~ cars$speed )

abline(
    cars.regression.model,
    col = "magenta",
    lwd = 4,
    lty = "dashed"
)
```



So that's how to add a least-squares regression line to a scatter plot.

Now let's see how to extract the regression coefficients from the linear model.

Section 3: Regression Coefficients

> **Main Idea:** *We can determine the coefficients of the linear model*

In this section, we'll learn more about linear model objects, and see how to select the regression coefficients from such objects.

When we just want to draw the least-squares regression line for a scatter plot, we don't actually have to worry about the details.

We just run the `lm()` function, and then pass the result to the `abline()` function, and the line gets drawn.

In particular, the regression line has a slope and a y-intercept, but we never had to deal with the actual values.

Instead, all of that information was bundled up in the complex object returned by the `lm()` function, and then `abline()` unpacked and drew the line for us.

Sometimes however you *do* want to know the actual numerical values of the slope and the y-intercept.

How can we extract that information from the linear model object returned by the `lm()` function?

The output of the `lm()` function is a complicated object, and it has its own special class:

```r
class( cars.regression.model )
```

```
## [1] "lm"
```

```r
is.list( cars.regression.model )
```

```
## [1] TRUE
```

If you want to see a report of the regression analysis of `cars.regression.model`, you can use the `summary()` function:

```r
summary( cars.regression.model )
```

```
##
## Call:
## lm(formula = cars$dist ~ cars$speed)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -29.069  -9.525  -2.272   9.215  43.201
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -17.5791     6.7584  -2.601   0.0123 *
## cars$speed    3.9324     0.4155   9.464 1.49e-12 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 15.38 on 48 degrees of freedom
## Multiple R-squared:  0.6511, Adjusted R-squared:  0.6438
## F-statistic: 89.57 on 1 and 48 DF,  p-value: 1.49e-12
```

That's nice, and if you take a statistics class I hope it's useful for you.

But we want to actually extract the values for the slope and y-intercept, and then store them in variables.

To do this, we first select the vector of coefficients from the linear model object.

The linear model object is a named list, so we can just use our standard list indexing method:

```r
regression.coefficients <-
    cars.regression.model$coefficients

regression.coefficients
```

```
## (Intercept)  cars$speed
##  -17.579095    3.932409
```

Do you see what that is?

It's just a named numeric vector.

The y-intercept always has the name `(Intercept)`, regardless of the variables that you used to construct the regression:

```
y.intercept <-
    regression.coefficients[ "(Intercept)" ]

cat(
    "Y-intercept of least-squares regression line:",
    formatC(
        y.intercept,
        format = "f",
        digits = 5
    )
)
```

```
## Y-intercept of least-squares regression line: -17.57909
```

The name of the slope coefficient *will* be different for different regression models, but it always be the name of the variable on the right-hand side of the formala that you used to construct the linear model.

For our example, we used the variable `cars$speed`, and so that's name of the slope coefficient:

```
slope <-
    regression.coefficients[ "cars$speed" ]

cat(
    "Slope of least-squares regression line:",
    formatC(
        slope,
        format = "f",
        digits = 5
    )
)
```

```
## Slope of least-squares regression line: 3.93241
```

So that's how to obtain the regression coefficients from a linear model object.

Now let's review what we've learned in this module.

Module Review

In this module we learned about a data visualization method called a *scatter plot*.

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There were three new built-in R functions in this module:

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- `lm()`
- `abline()`

Allright, that's it for Module 5: Scatter Plots, and in fact that's the end of the material for Unit 9: Data Frames.

Now let's move on to Unit 10: Managing Data.

See you there!