ML 1000 Assignment 2

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To do list:

- **Add Pie charts! - by sub_category, region** # (done)
- **Create a Month variable - to see the change of sales/profits by month?**
- **bar charts of profits/sales by region** #(done)
- **Output the characteristics of the orders with the highest and lowest profits/sales - e.g. what made the order? when? bought what product? in which city/state/region? Any discount?**
- **relationship between discount & sales, discount & profits, sales & profits, and the role of region?**
- **from someone's analysis - there is no significant change between the four discount categories when it comes to Sales**
- **sales/profits by month, rather than by date? color by region?**

Abstract

Anomaly detection or Outlier detection identifies data points, events or observations that deviate from dataset's normal behavior. Anomalous data indicate critical incidents or potential opportunities. In order to take advantage of opportunities or fix costly problems anomaly detection has to be done in real time. Unsupervised machine learning models can be used to automate anomaly detection. Unsupervised anomaly detection algorithms scores data based on intrinsic properties of the dataset. Distances and densities are used to give an estimation what is normal and what is an outlier. Anomaly detection monitor is a tool developed for an online retailer to check product quality issues like profit opportunities and sales glitches. The application is built using R and Shinyapp following CRISP-DM framework.

Business Case

Objective

Detect point anomalies from superstore dataset using K-NN and clustering methods.

Data Understanding

US Superstore dataset is sourced from US uperstore dataset . The dataset have online orders for Superstores in U.S. from 2014-2018. Tableau community is the owner of the dataset. The dataset has 9994 records and 21 attributes.

Import data

```
superstore<- read_excel("US_Superstore_data.xls")
```

```
## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L2236 / R2236C12: '05408'

## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L5276 / R5276C12: '05408'

## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L8800 / R8800C12: '05408'

## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L9148 / R9148C12: '05408'

## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L9149 / R9149C12: '05408'

## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L9150 / R9150C12: '05408'

## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L9388 / R9388C12: '05408'

## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L9389 / R9389C12: '05408'

## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L9390 / R9390C12: '05408'

## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L9391 / R9391C12: '05408'

## Warning in read_fun(path = enc2native(normalizePath(path)), sheet_i = sheet, :
## Coercing text to numeric in L9743 / R9743C12: '05408'
```

```
data_superstore
```

Table 1: Dataset description

Attribute	Data Type	Description
Row ID	numeric	row number
Order ID	character	unique order number
Order Date	numeric	order placed date
Ship Date	numeric	order shipping date
Ship Mode	character	shipping mode of order
Customer ID	character	unique customer id for order

Attribute	Data Type	Description
Customer Name	character	name of customer
Segment	character	section of product
Country	character	country based on order
City	character	city based on order
State	character	state based on order
Postal Code	numeric	pin code
Region	character	region based on order
Product ID	character	product id of product
Category	character	category of product
Sub-Category	character	sub-category of product
Product Name	character	name of product
Sales	numeric	selling price of product
Quantity	numeric	order quantity
Discount	numeric	discount on product
Profit	numeric	profit from product

```
##  [1] "ï..Row.ID-0 missing values"     "Order.ID-0 missing values"
##  [3] "Order.Date-0 missing values"    "Ship.Date-0 missing values"
##  [5] "Ship.Mode-0 missing values"     "Customer.ID-0 missing values"
##  [7] "Customer.Name-0 missing values" "Segment-0 missing values"
##  [9] "Country-0 missing values"       "City-0 missing values"
## [11] "State-0 missing values"         "Postal.Code-0 missing values"
## [13] "Region-0 missing values"        "Product.ID-0 missing values"
## [15] "Category-0 missing values"      "Sub.Category-0 missing values"
## [17] "Product.Name-0 missing values"  "Sales-0 missing values"
## [19] "Quantity-0 missing values"      "Discount-0 missing values"
## [21] "Profit-0 missing values"        "diff_in_days-0 missing values"
```

Get a general idea of the data set.

```r
length(unique(data$Customer.ID))
```

```
## [1] 793
```

```r
#793 unique customer IDs
length(unique(data$Customer.Name))
```

```
## [1] 793
```

```r
#793 unique customer names - drop one of these two vars


length(unique(data$Order.Date))
```

```
## [1] 1237
```

```r
#1237 unique order dates
length(unique(data$Ship.Date))
```

```
## [1] 1334
```

```r
#1334 unique ship dates - more unique ship dates than order dates - orders made on the same day were sh
length(unique(data$Segment))
```

```
## [1] 3
```

```r
unique(data$Segment)
```

```
## [1] "Consumer"    "Corporate"   "Home Office"
```

```r
#"Consumer"    "Corporate"   "Home Office"
unique(data$Country)
```

```
## [1] "United States"
```

```r
#all are from US - could drop this variable due to no-variation introduced by it
length(unique(data$City))
```

```
## [1] 531
```

```r
#531 different cities
length(unique(data$State))
```

```
## [1] 49
```

```r
#49 states
length(unique(data$Postal.Code))
```

```
## [1] 631
```

```r
#631 postal code - 793 unique customer IDs - some customers live very close!
unique(data$Region)
```

```
## [1] "South"   "West"    "Central" "East"
```

```r
#only 4 regions
unique(data$Category)
```

```
## [1] "Furniture"       "Office Supplies" "Technology"
```

```r
#only 3 categories - "Furniture" "Office Supplies" "Technology"

length(unique(data$Sub.Category))
```

```
## [1] 17
```

```r
unique(data$Sub.Category)
```

```
##  [1] "Bookcases"   "Chairs"      "Labels"      "Tables"      "Storage"
##  [6] "Furnishings" "Art"         "Phones"      "Binders"     "Appliances"
## [11] "Paper"       "Accessories" "Envelopes"   "Fasteners"   "Supplies"
## [16] "Machines"    "Copiers"
```

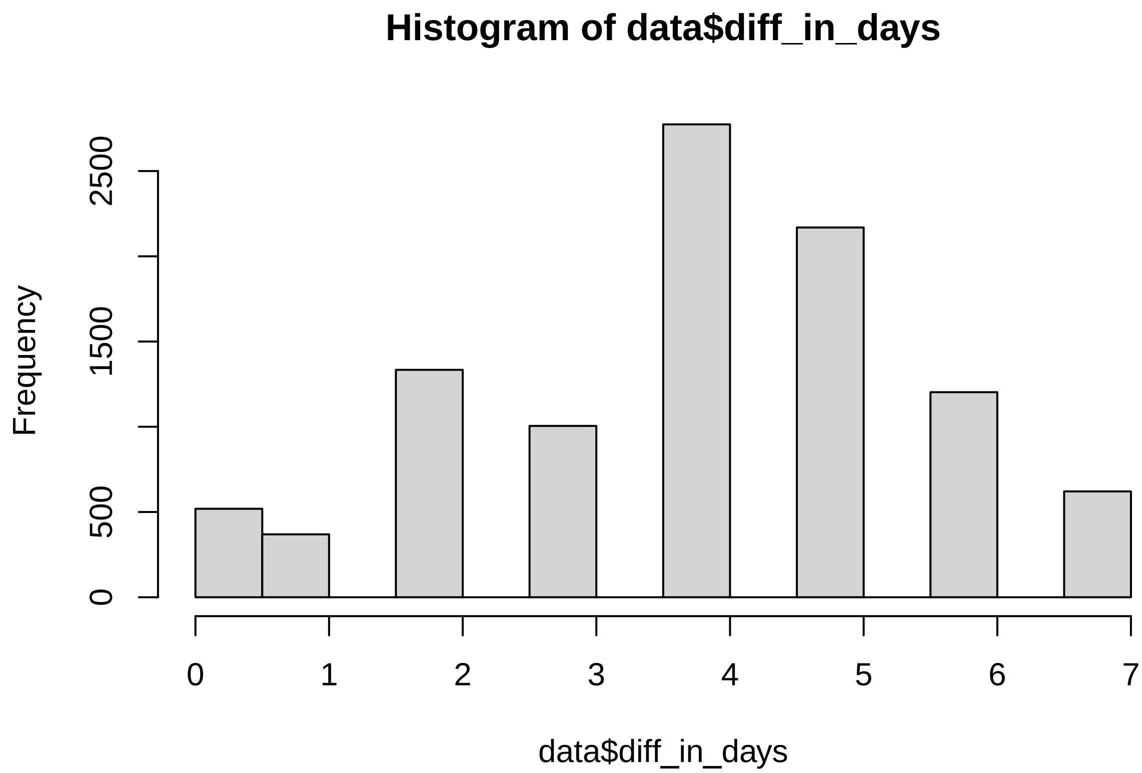
```r
#17 sub-categories

length(unique(data$Product.Name))
```

```
## [1] 1850
```

```r
#1850 product names
length(unique(data$Product.ID))
```

```
## [1] 1862
```

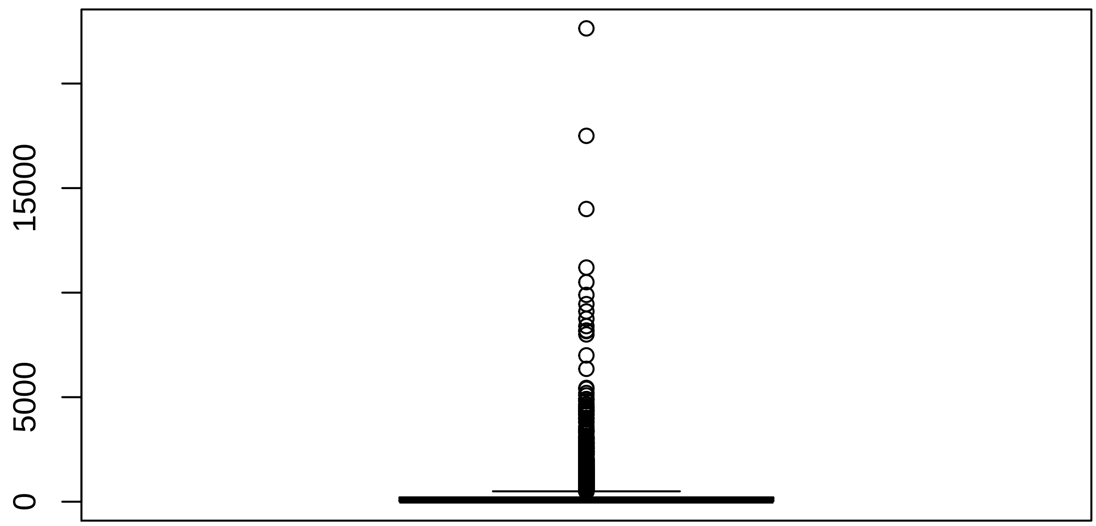
```r
#1862 product IDs - potential redundant variables!

hist(data$diff_in_days)
```



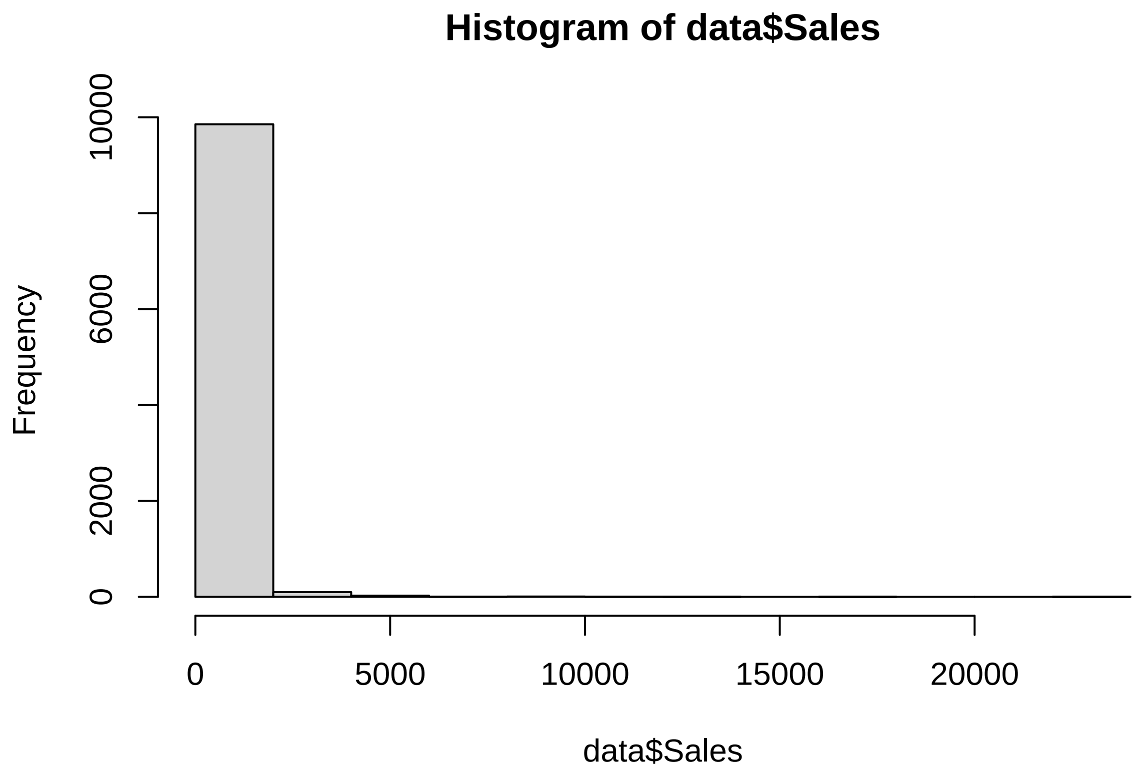

```r
#The time difference between order date and ship date typically takes 4 days.

summary(data$Sales)
```

```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
##     0.444    17.280    54.490   229.858   209.940 22638.480
```

```r
boxplot(data$Sales)
```



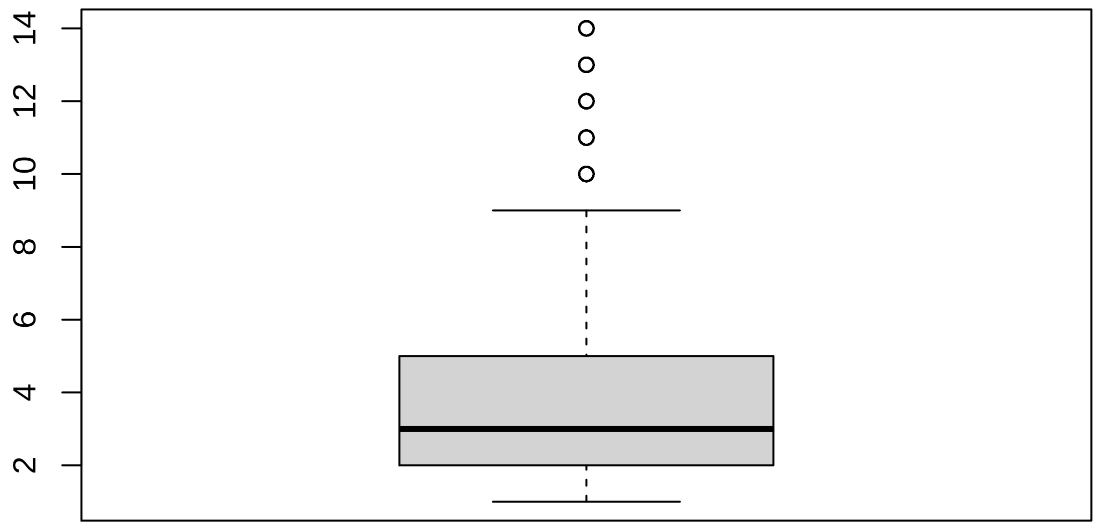

```r
hist(data$Sales)
```



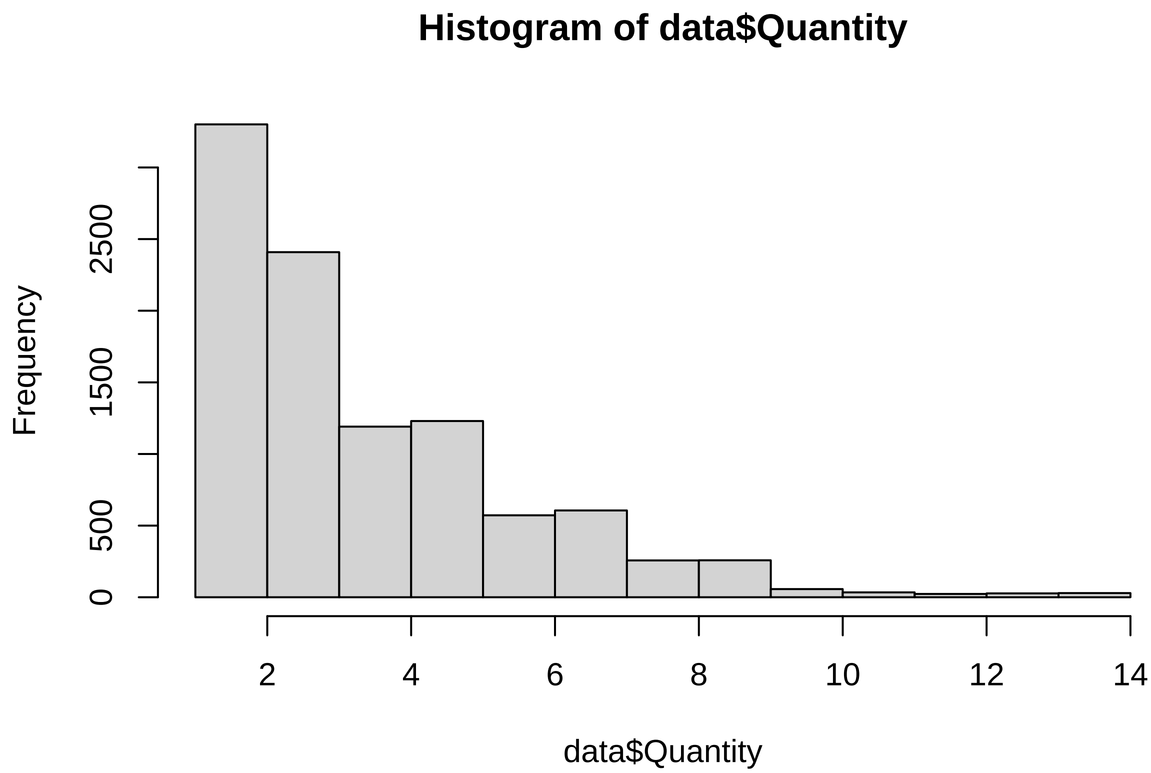

```r
#a large amount of orders with very small Sales!


summary(data$Quantity)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    1.00    2.00    3.00    3.79    5.00   14.00
```

```r
boxplot(data$Quantity)
```



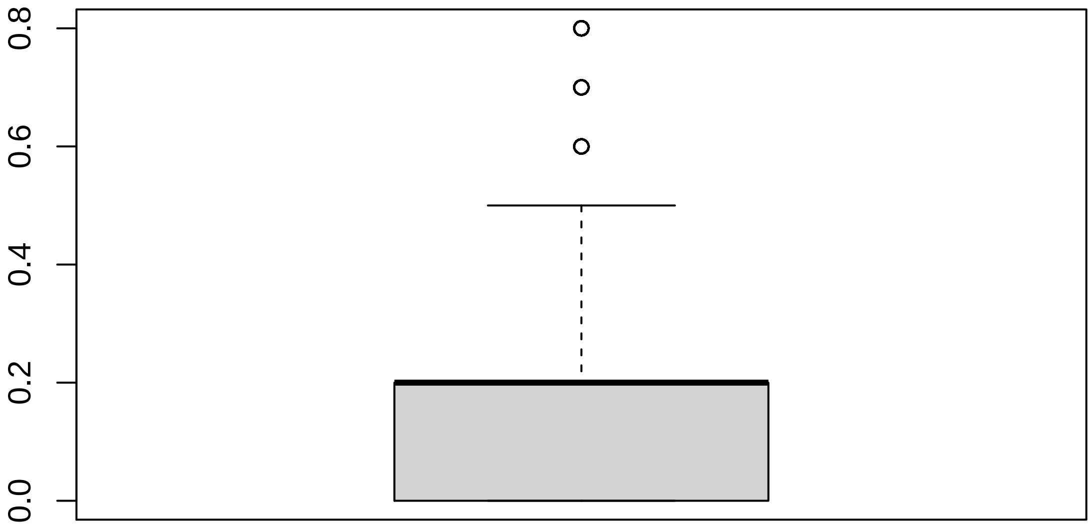

```
#not many outliers - the #of products in each order is stable?
hist(data$Quantity)
```



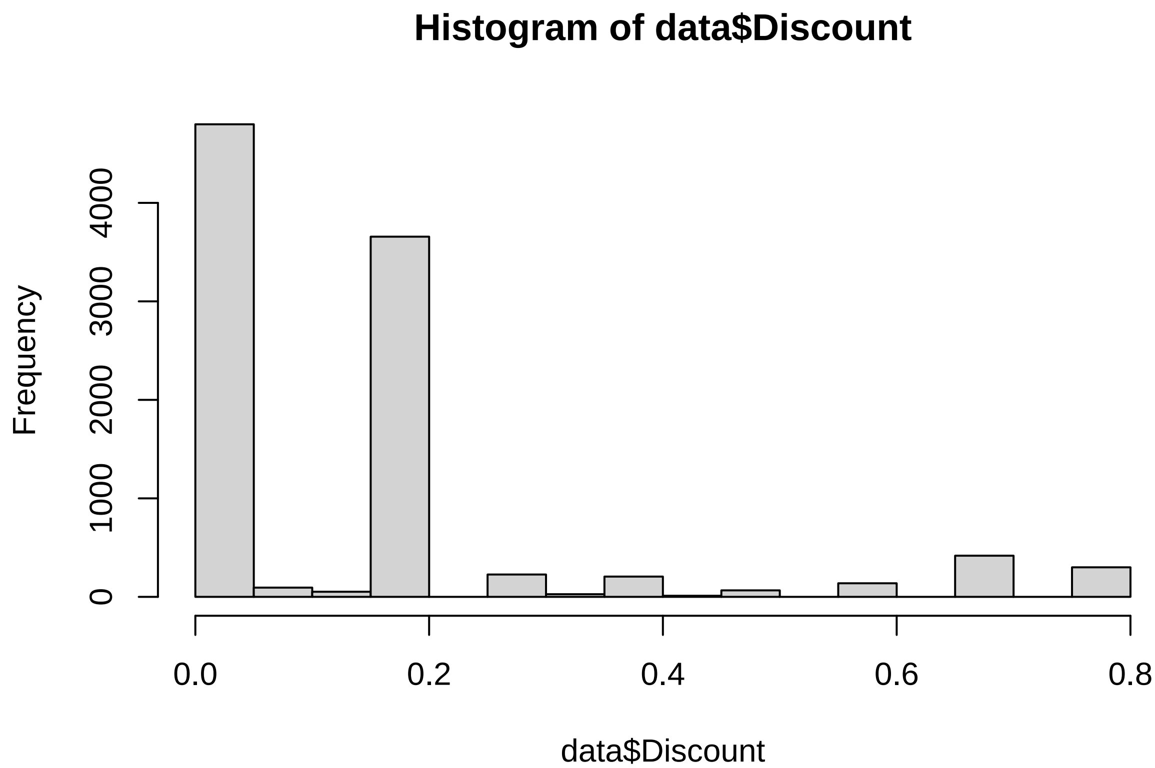

```r
#very skewed distribution - most of the orders have small #of items

summary(data$Discount)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##  0.0000  0.0000  0.2000  0.1562  0.2000  0.8000
```

```r
boxplot(data$Discount)
```



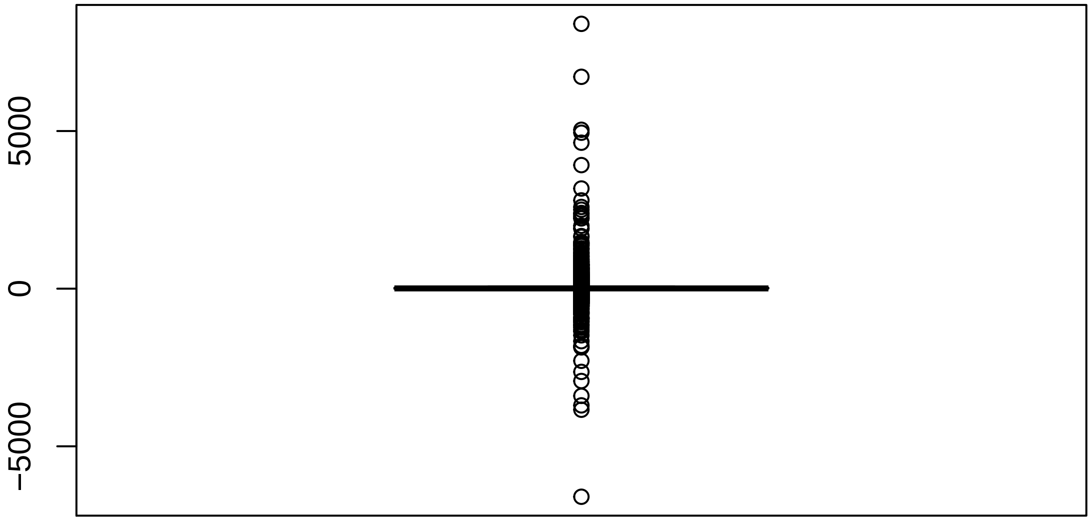

```
#a strange looking box dataplot? - median & 3rd quantile are the same (0.2) - not many orders have high
hist(data$Discount)
```



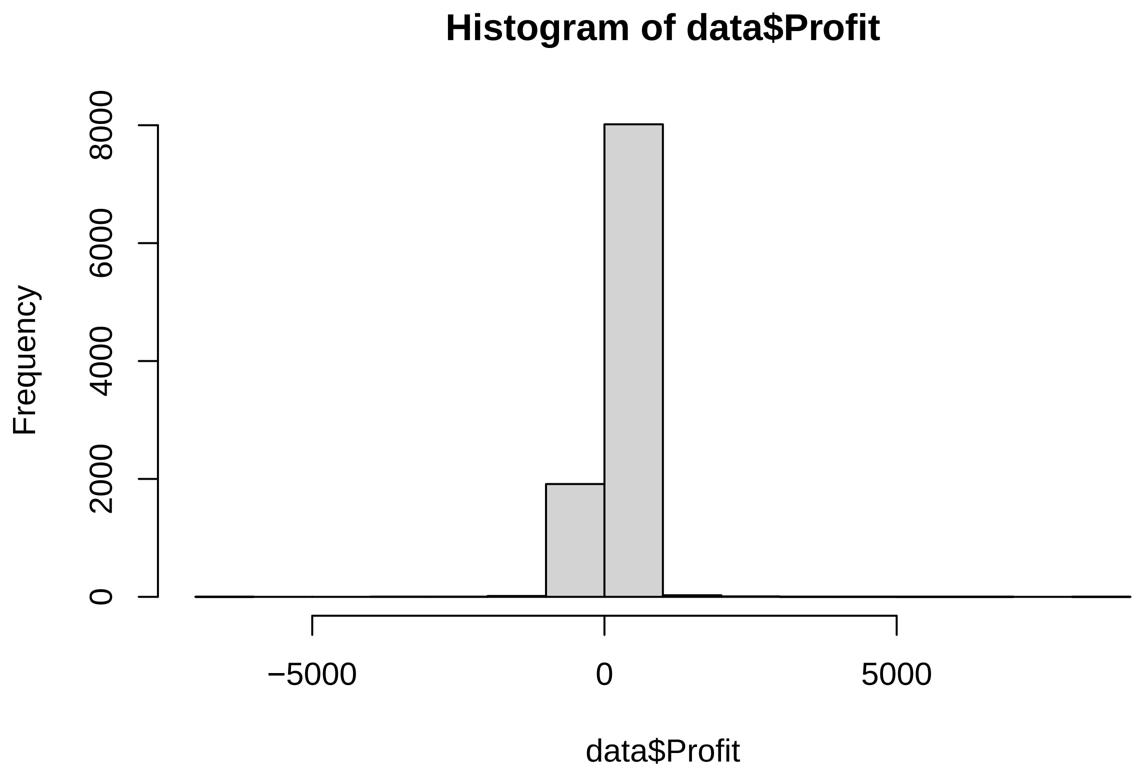

```r
#most of the orders were placed without any discounts or with 20% off

summary(data$Profit)
```

```
##      Min.   1st Qu.    Median      Mean   3rd Qu.      Max.
## -6599.978     1.729     8.666    28.657    29.364  8399.976
```

```r
boxplot(data$Profit)
```




```
#most of the profits are outside of the box - but most of them clustered close to the box(not with so e
hist(data$Profit)
```



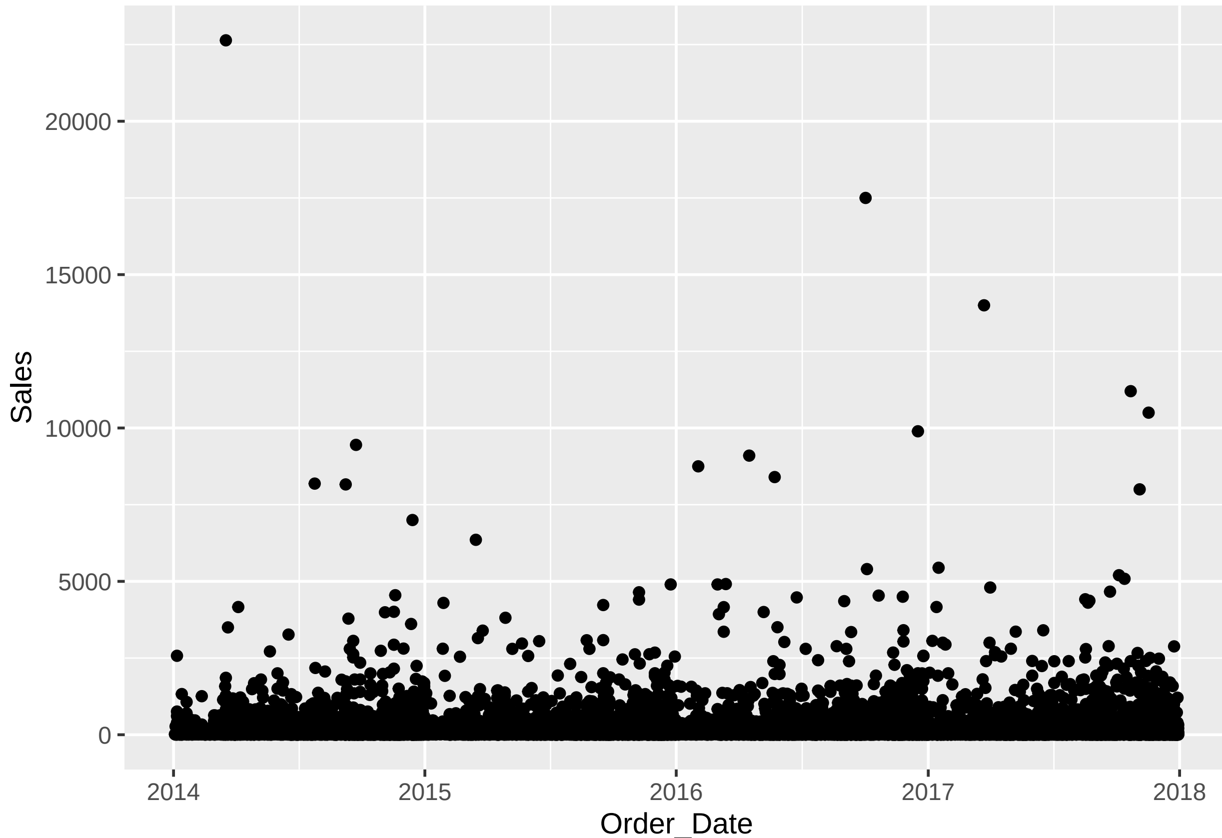

```
#most of the orders have profits ~1000 (or ~800?), and ~ -800
```

Remove the dot in the column names and replace with "_" to make variable names easier to handle:

```
##  [1] "ï__Row_ID"     "Order_ID"      "Order_Date"    "Ship_Date"
##  [5] "Ship_Mode"     "Customer_ID"   "Customer_Name" "Segment"
##  [9] "Country"       "City"          "State"         "Postal_Code"
## [13] "Region"        "Product_ID"    "Category"      "Sub_Category"
## [17] "Product_Name"  "Sales"         "Quantity"      "Discount"
## [21] "Profit"        "diff_in_days"
```

Exploratory Data Analysis

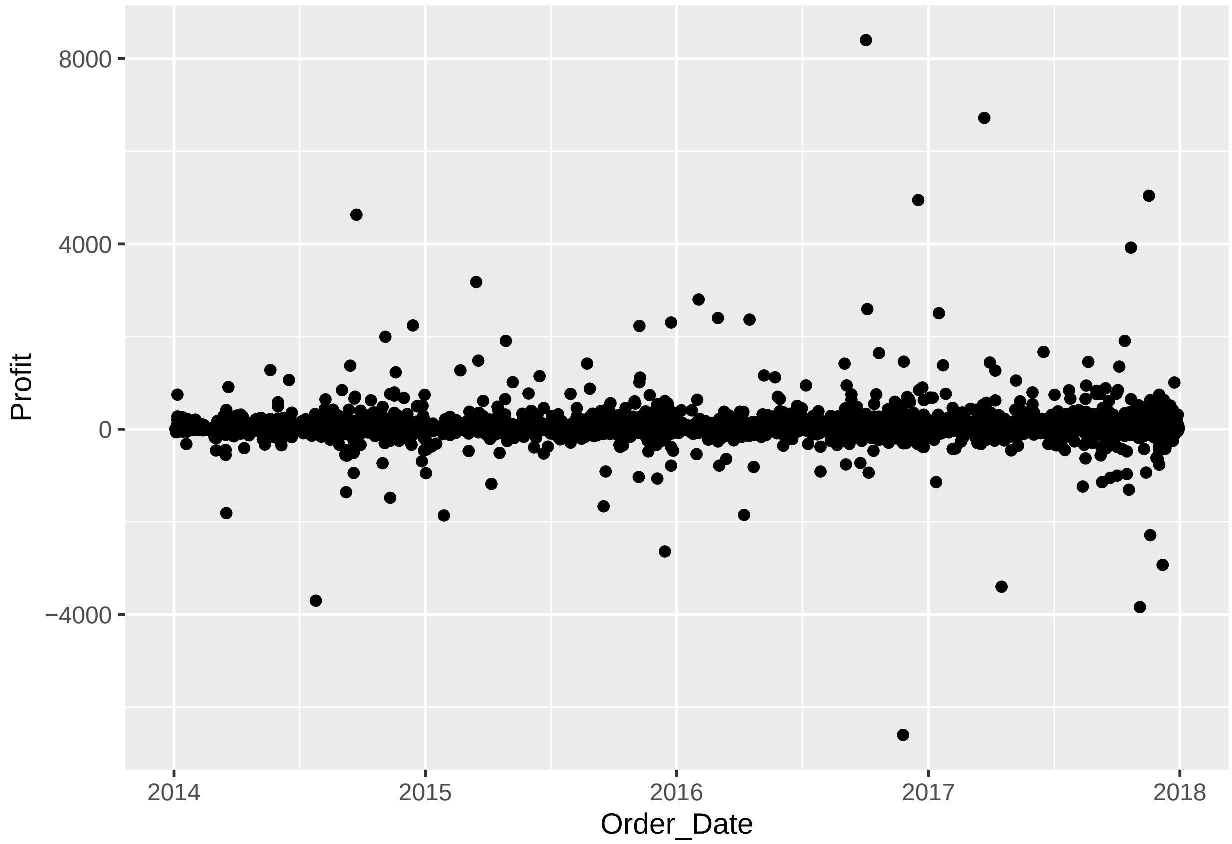
Plot Sales in relation to Order Date:



Plot Profit in relation to Order Date:

```r
ggplot(data = data) +
  geom_point(mapping = aes(x = Order_Date, y = Profit), xlab="Order Date", ylab="Profit")
```

```
## Warning: Ignoring unknown parameters: xlab, ylab
```



Some outliers for certain days

```
table(data$`Sub_Category`)
```

```
##
## Accessories  Appliances         Art     Binders   Bookcases      Chairs
##         775         466         796        1523         228         617
##     Copiers   Envelopes   Fasteners Furnishings      Labels    Machines
##          68         254         217         957         364         115
##       Paper      Phones     Storage    Supplies      Tables
##        1370         889         846         190         319
```

look at the time range for these transactions, ie. start date for Order_Date column:

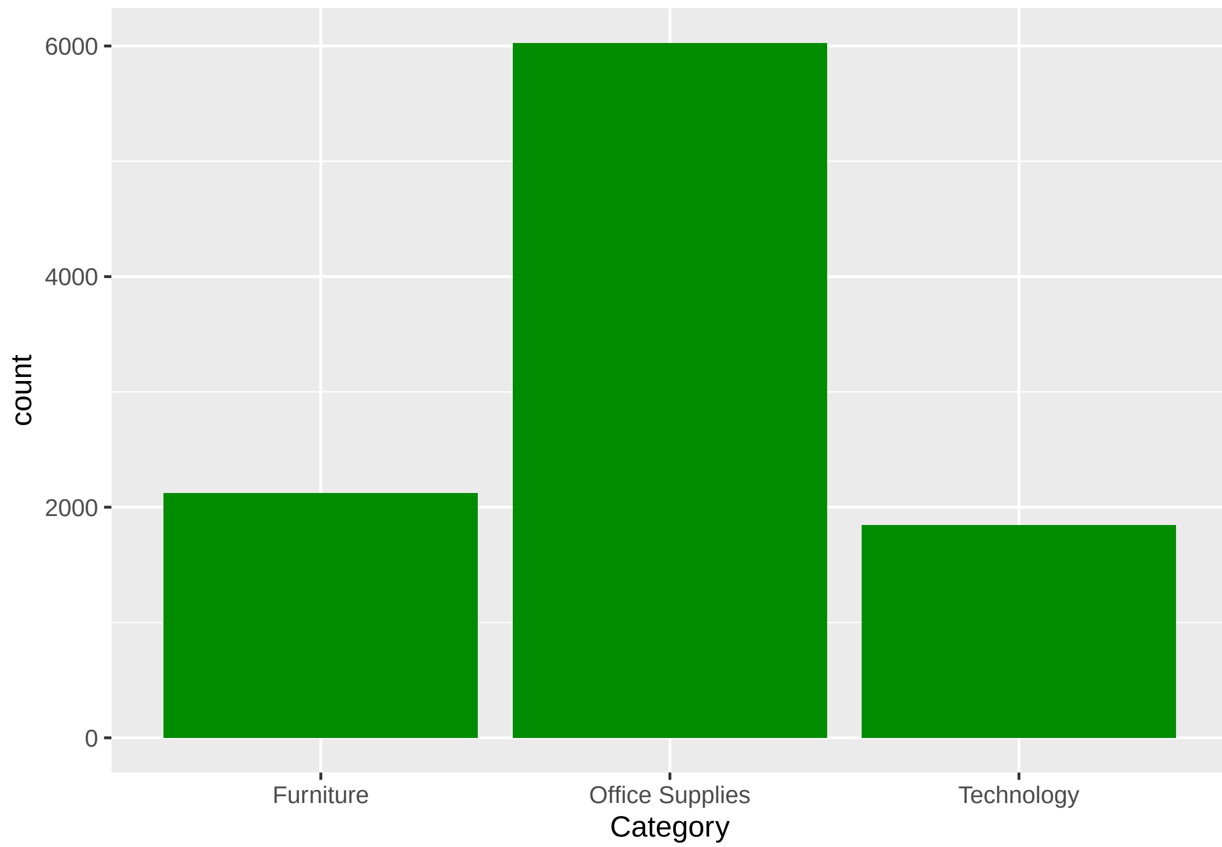
```
summary(data$Order_Date)
```

```
##         Min.      1st Qu.       Median         Mean      3rd Qu.         Max.
## "2014-01-03" "2015-05-23" "2016-06-26" "2016-04-30" "2017-05-14" "2017-12-30"
```

```
#[1] min "2014-01-03", max "2017-12-30"
```

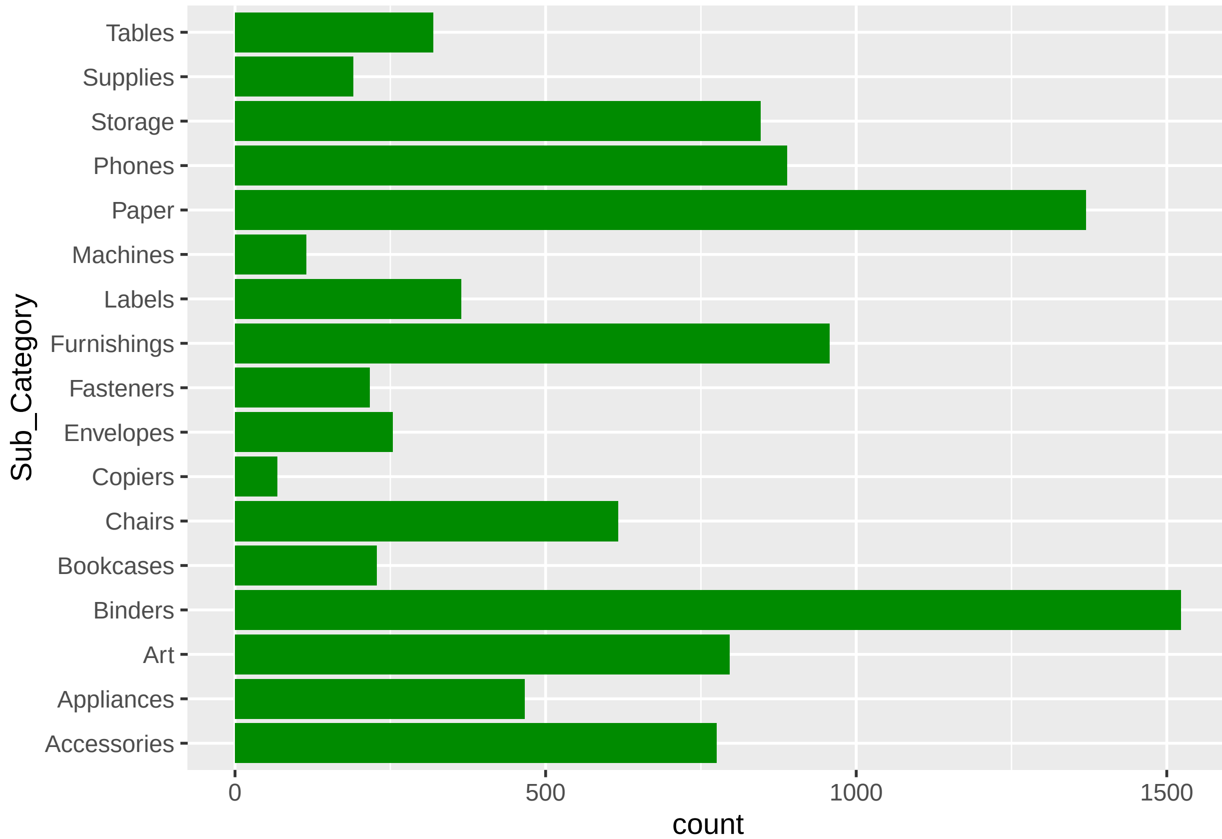
Basically this dataset covers transactions ranging from 2014-01-03 to 2017-12-30.

```r
ggplot(data = data) +
  geom_bar(mapping = aes(x = Category),fill="green4")
```



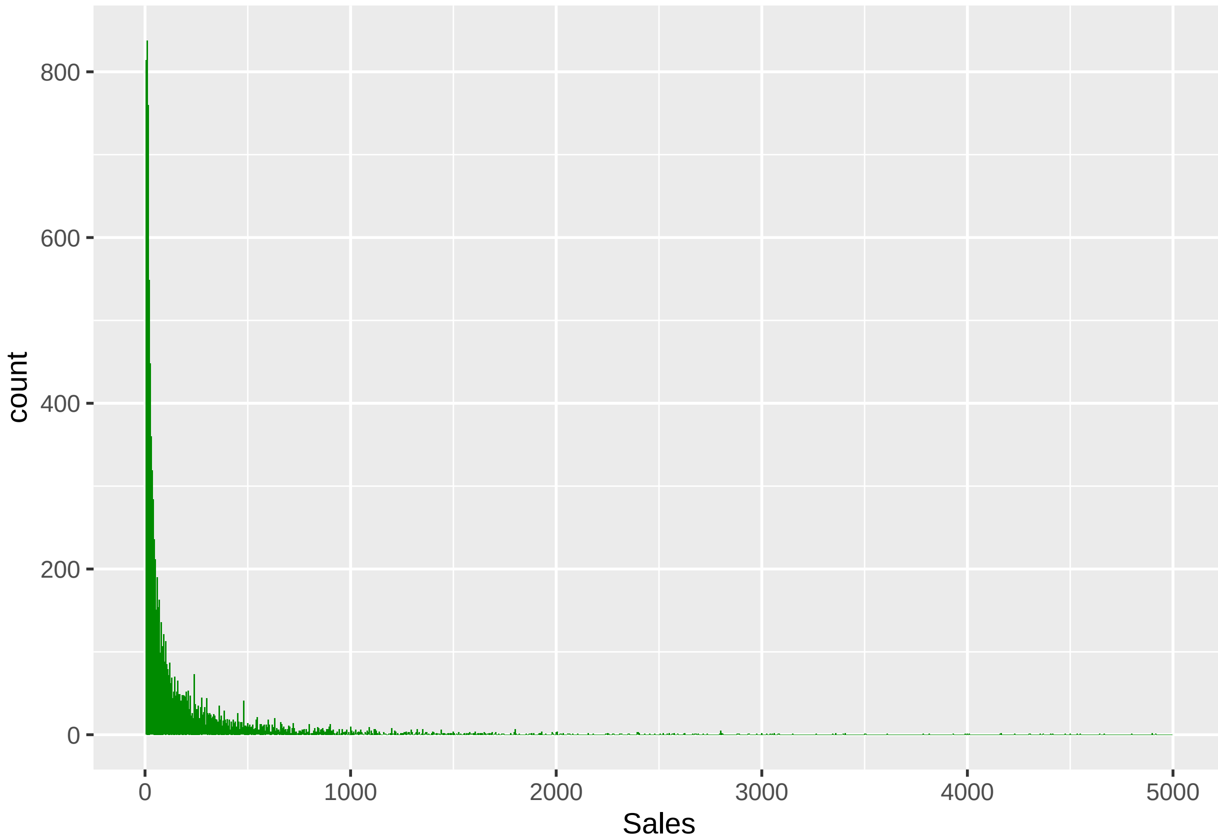
Most type of products sold belong to the Office supplies category.

```r
ggplot(data = data) +
  geom_bar(mapping = aes(y = `Sub_Category`), fill="green4")
```



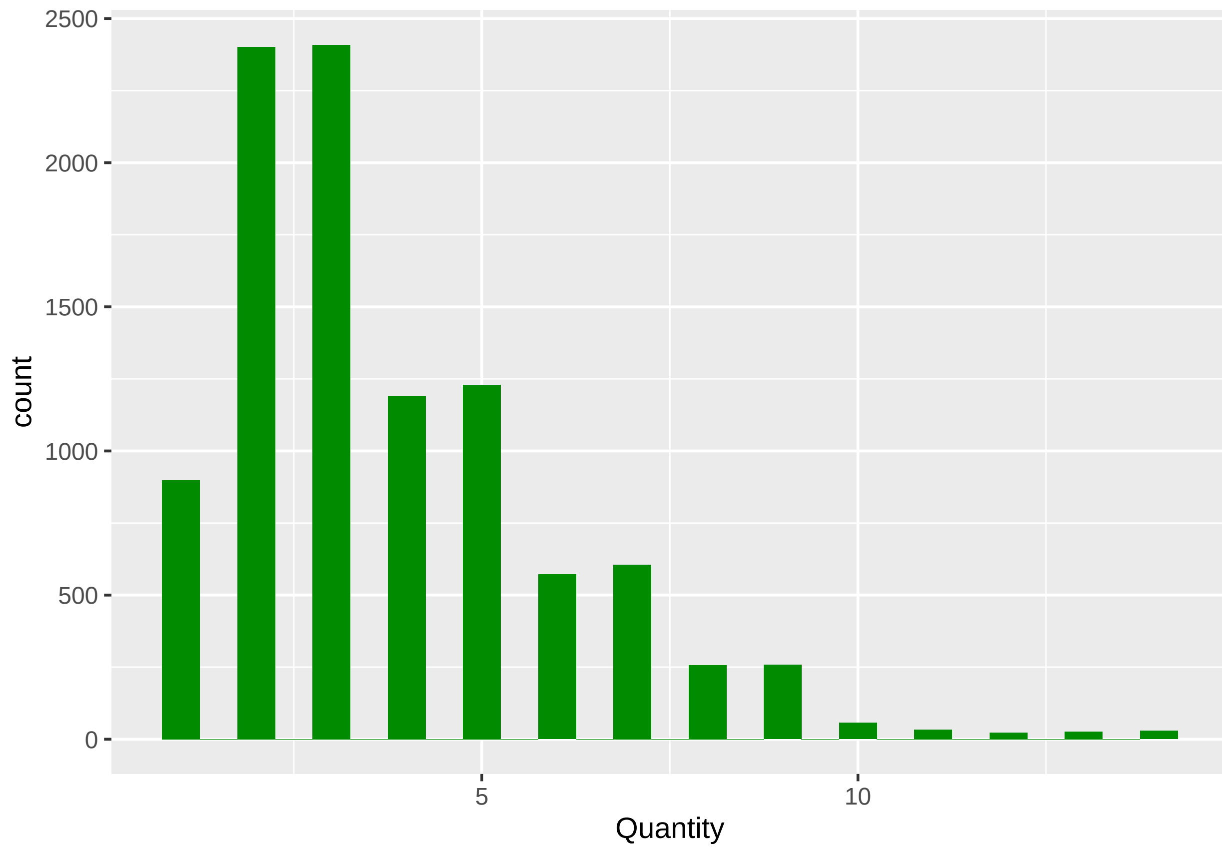

```r
ggplot(data = data, mapping = aes(x = Sales)) +
  xlim(0, 5000) +
  geom_histogram(binwidth = 5,fill="green4")
```

```
## Warning: Removed 19 rows containing non-finite values (stat_bin).

## Warning: Removed 2 rows containing missing values (geom_bar).
```



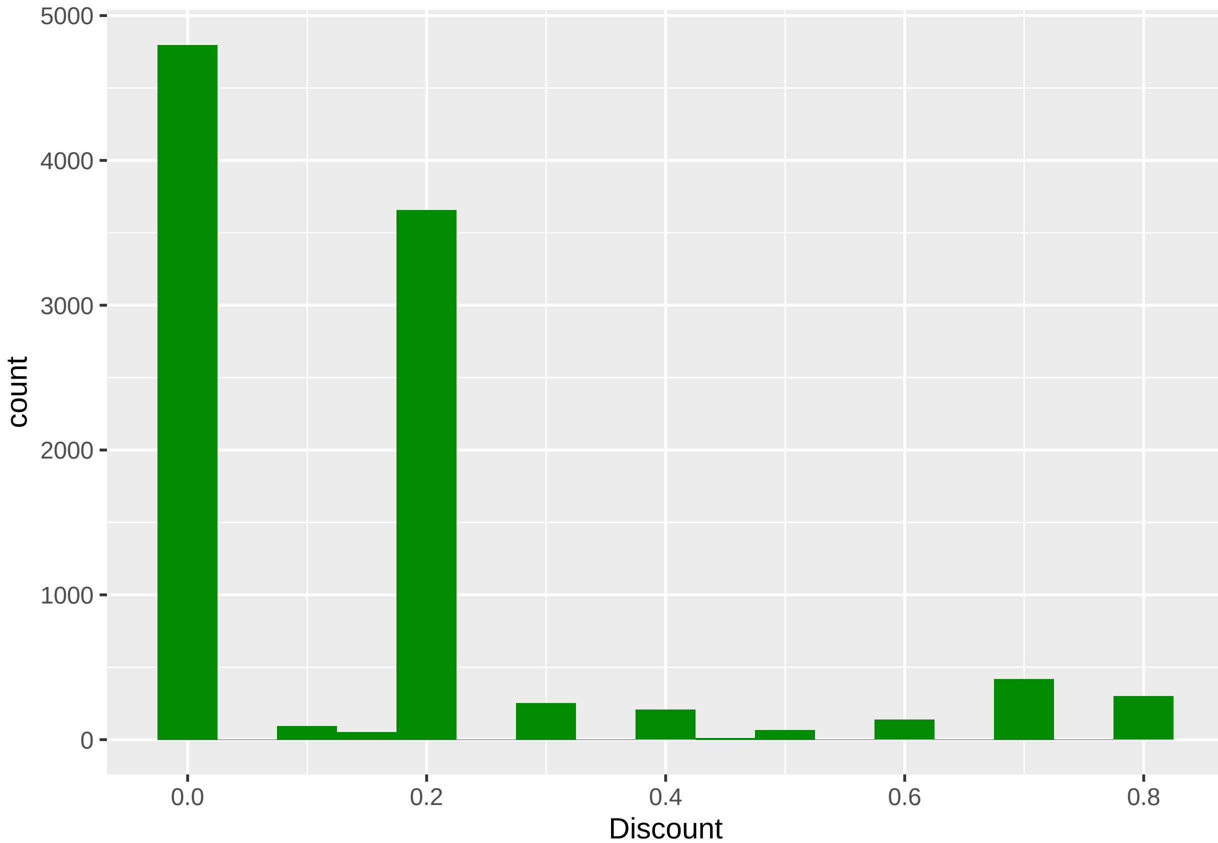
Most sales are very few items (<500).

```
ggplot(data = data, mapping = aes(x = Quantity)) +
  geom_histogram(binwidth = 0.5,fill="green4")
```




```
ggplot(data = data) +
  geom_histogram(mapping = aes(x = Discount),
                 binwidth = 0.05,
                 xlab="Discount",
                 fill="green4")
```

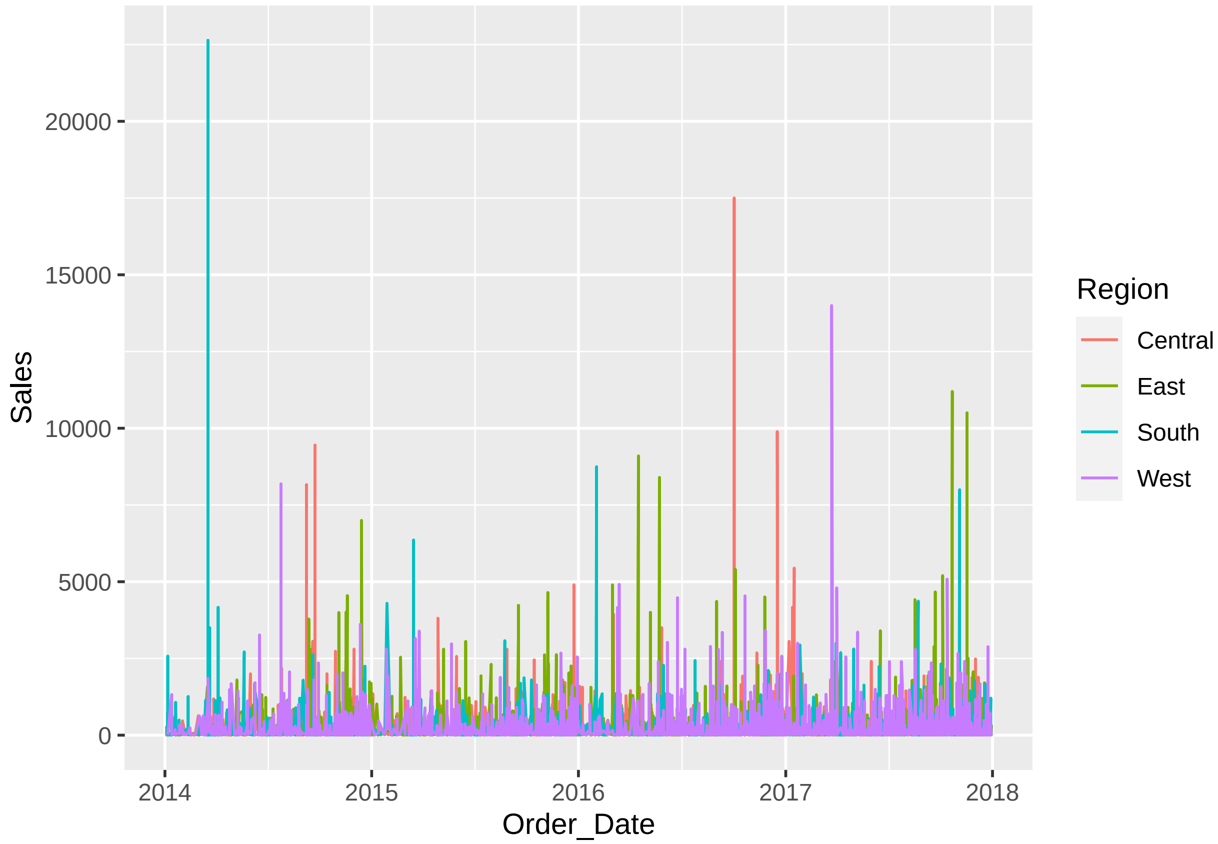
```
## Warning: Ignoring unknown parameters: xlab
```



Sales transactions mostly do not involve discounts.

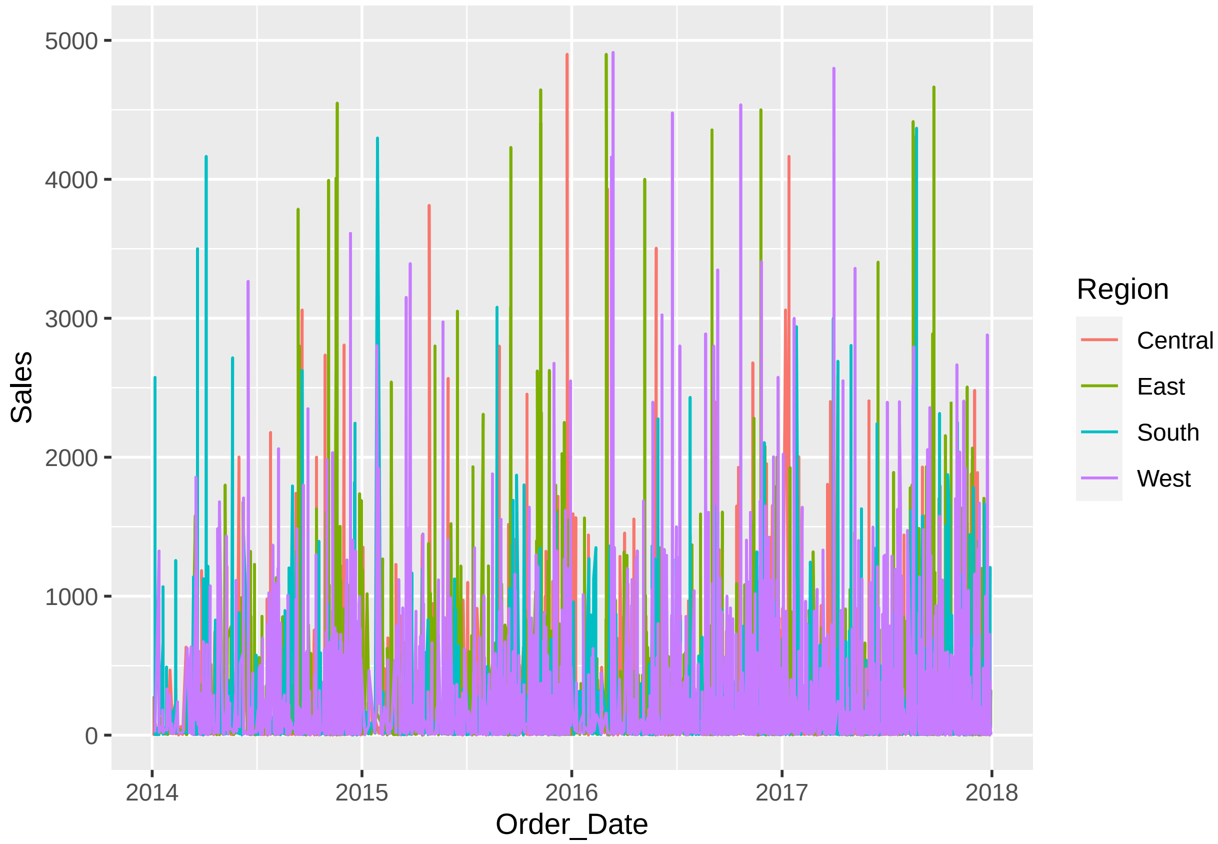
Visualise sales transactions by Region over time (order date).

```
ggplot(data, aes(Order_Date, Sales,color=Region)) +
     geom_line()
```



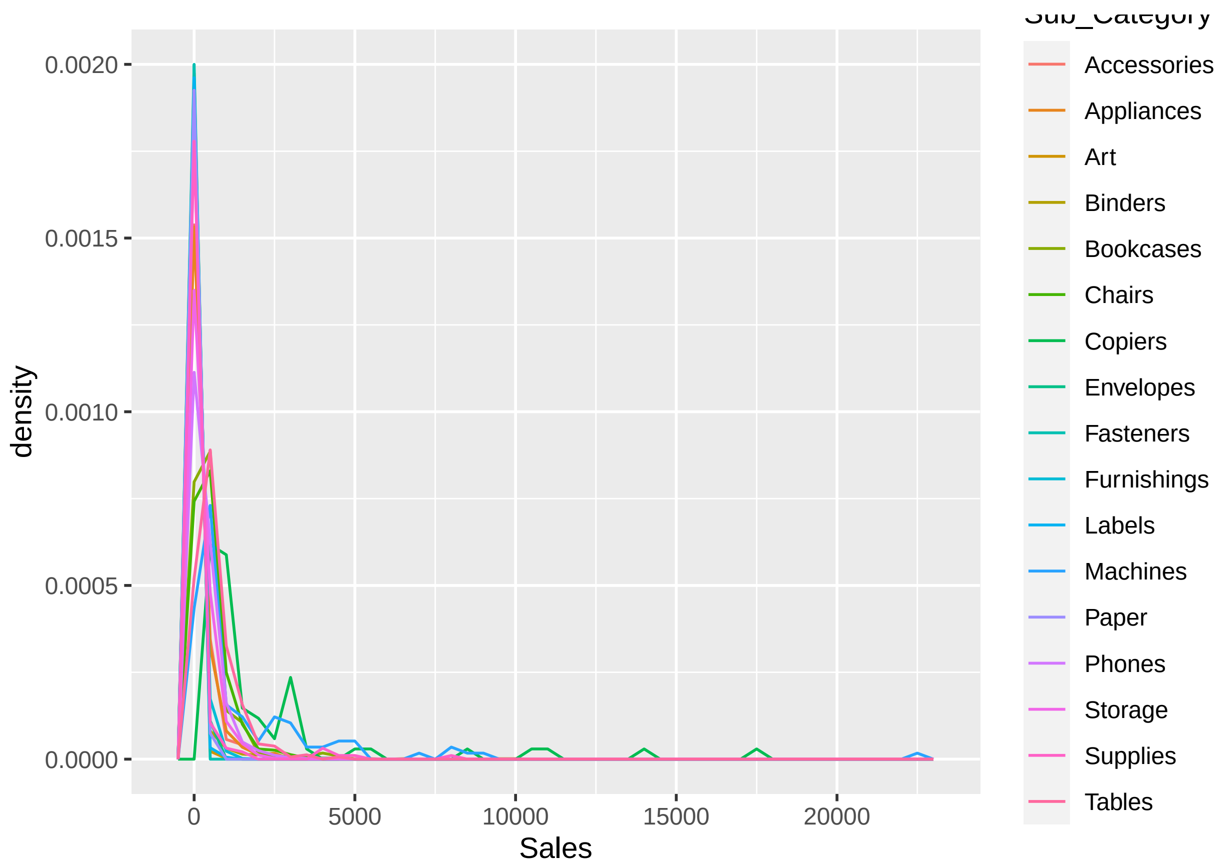
Let's zoom in a little bit - Visualise sales transactions by Region over time (order date).

```
ggplot(data, aes(Order_Date, Sales,color=Region)) +
     geom_line() +
     ylim(0,5000)
```



How does profit change with sub-category?

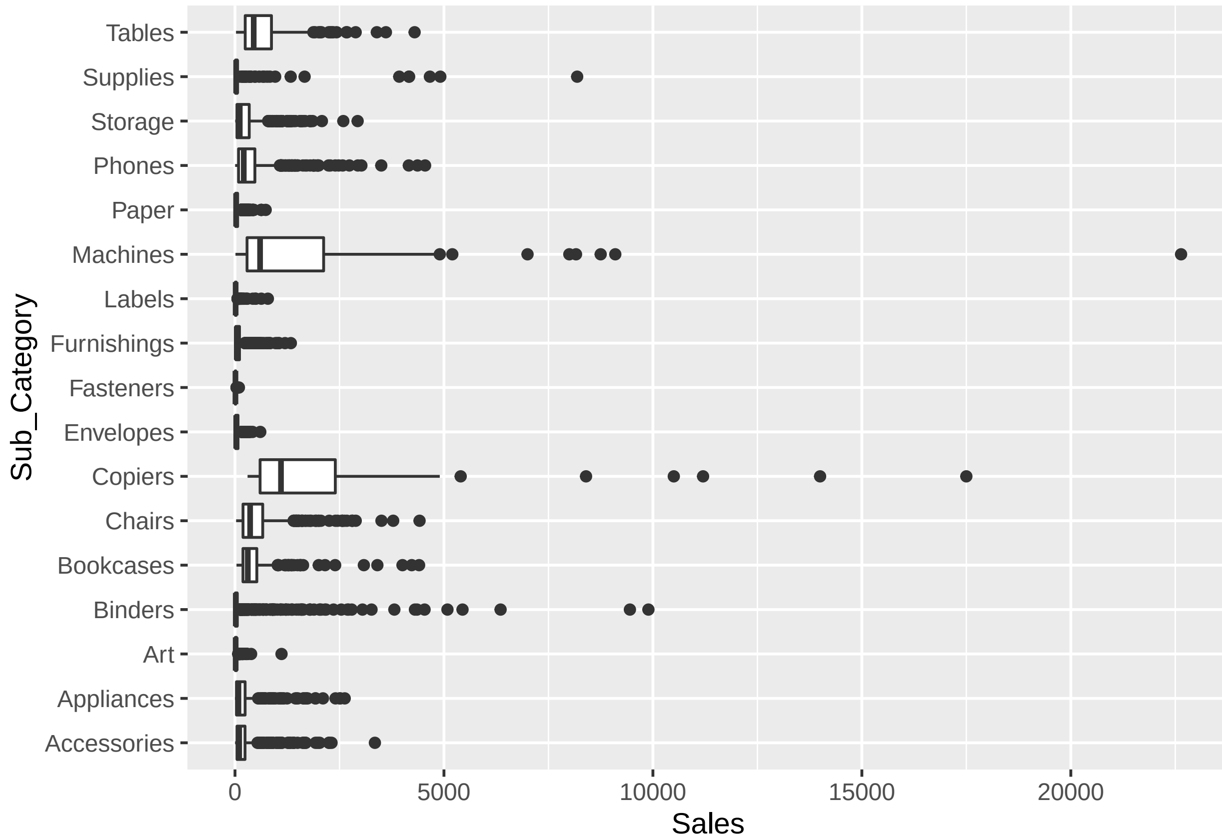
```
#density plot where the count is standardized,area under each frequency is 1
ggplot(data = data, mapping = aes(x = Sales, y = ..density..)) +
  geom_freqpoly(mapping = aes(colour = Sub_Category), binwidth = 500)
```



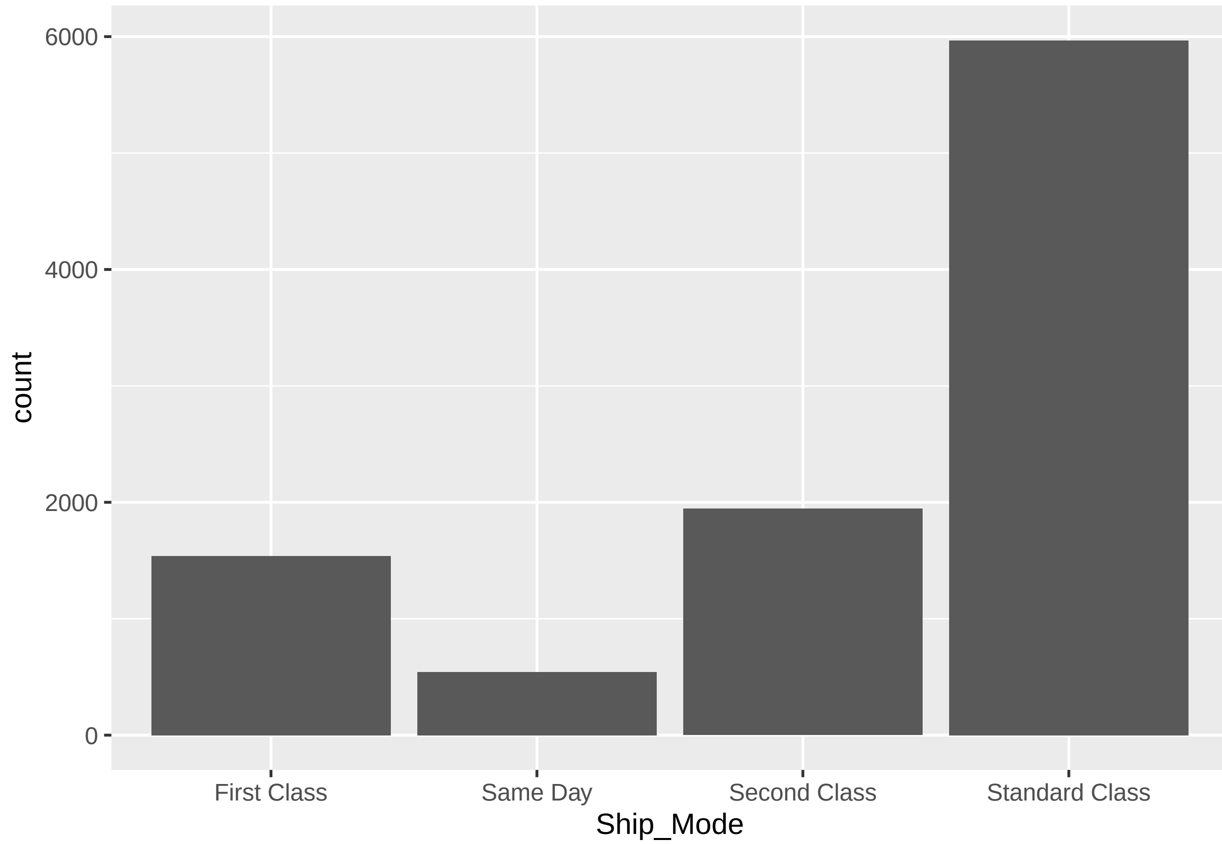
It looks like some categories of items ie. supplies or accessories have negative sales values.

How does sales vary across sub category?

```
ggplot(data = data, mapping = aes(x = Sales, y = `Sub_Category` )) +
  geom_boxplot()
```



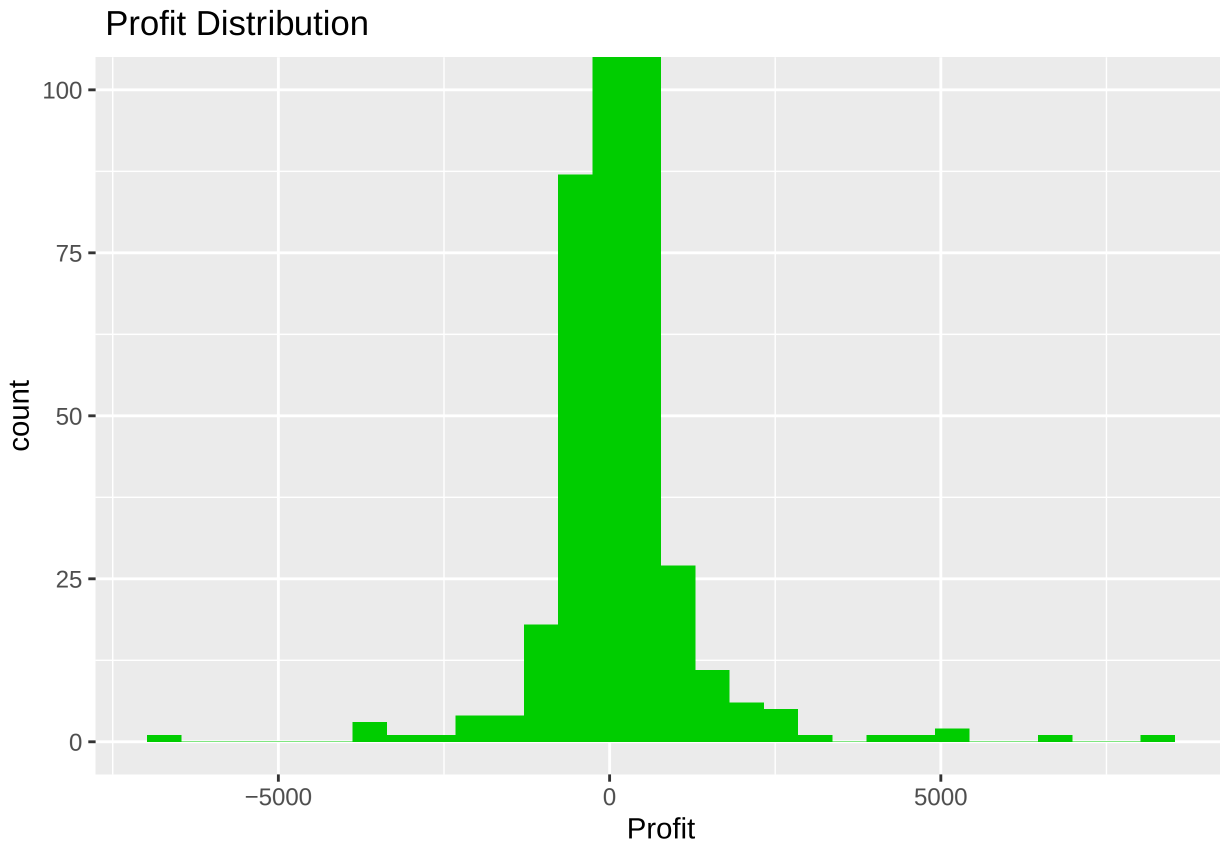

```
ggplot(data =data, mapping = aes(x = Ship_Mode)) +
  geom_bar()
```



Most transactions are shipped via Standard Class method.

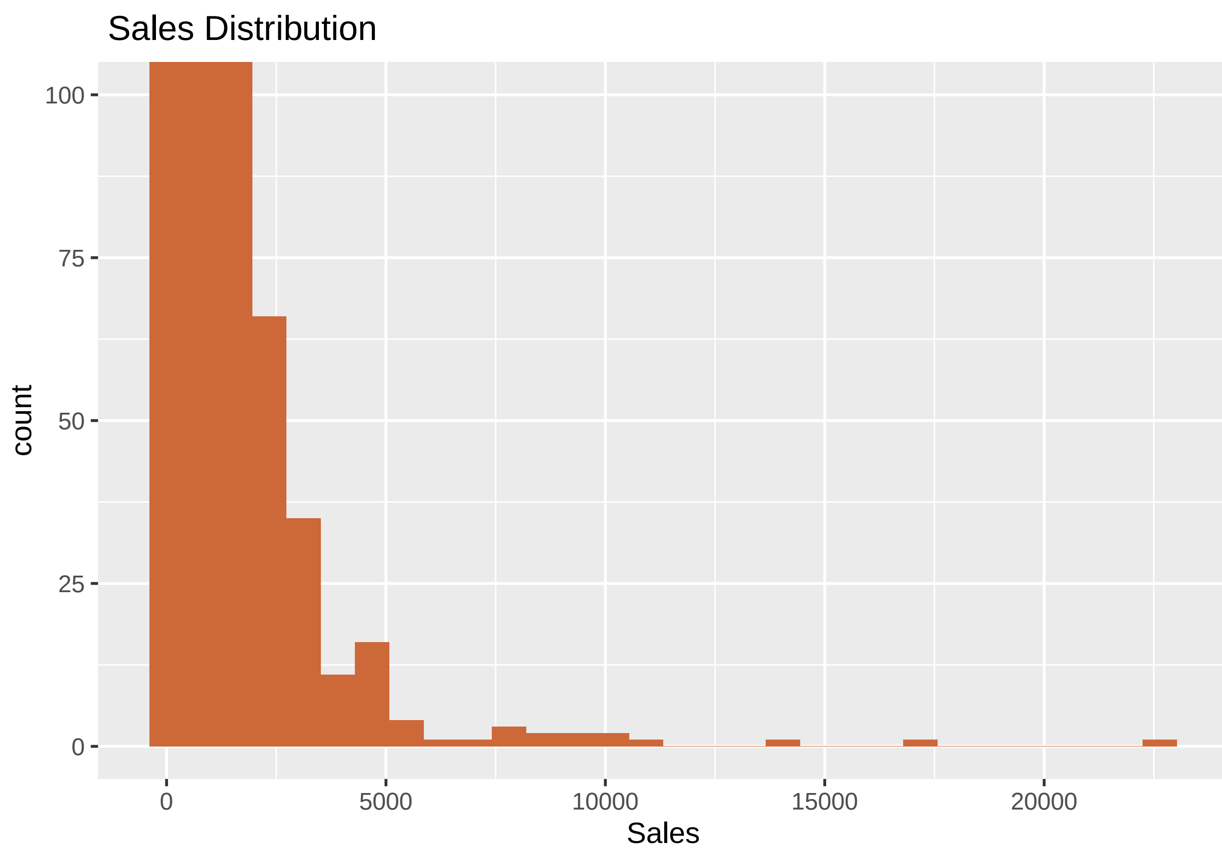
```
ggplot(data)+
geom_histogram(mapping=aes(x=Profit),fill="green3")+
coord_cartesian(ylim = c(0, 100))+
labs(title=" Profit Distribution")
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

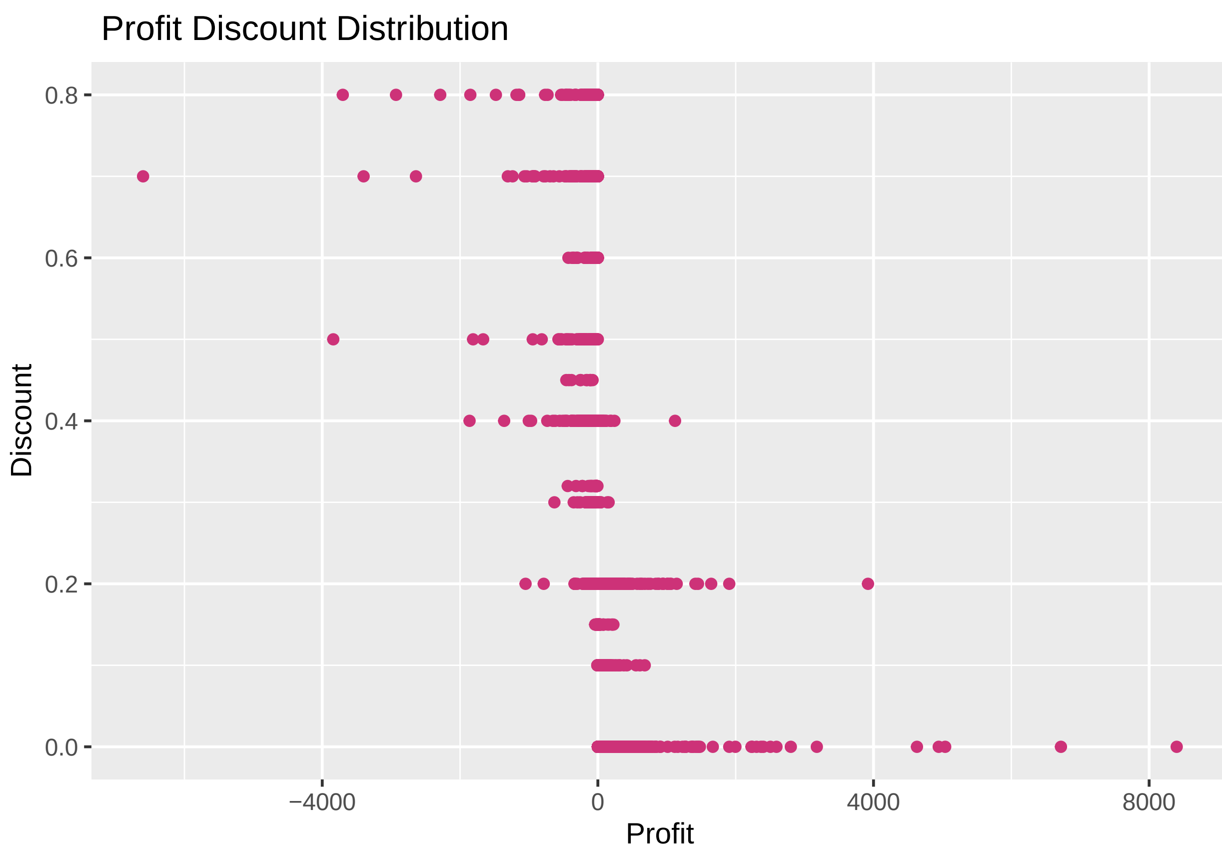



```r
ggplot(data)+
geom_histogram(mapping=aes(x=Sales),fill="sienna3")+
coord_cartesian(ylim = c(0, 100))+labs(title=" Sales Distribution")
```

```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```

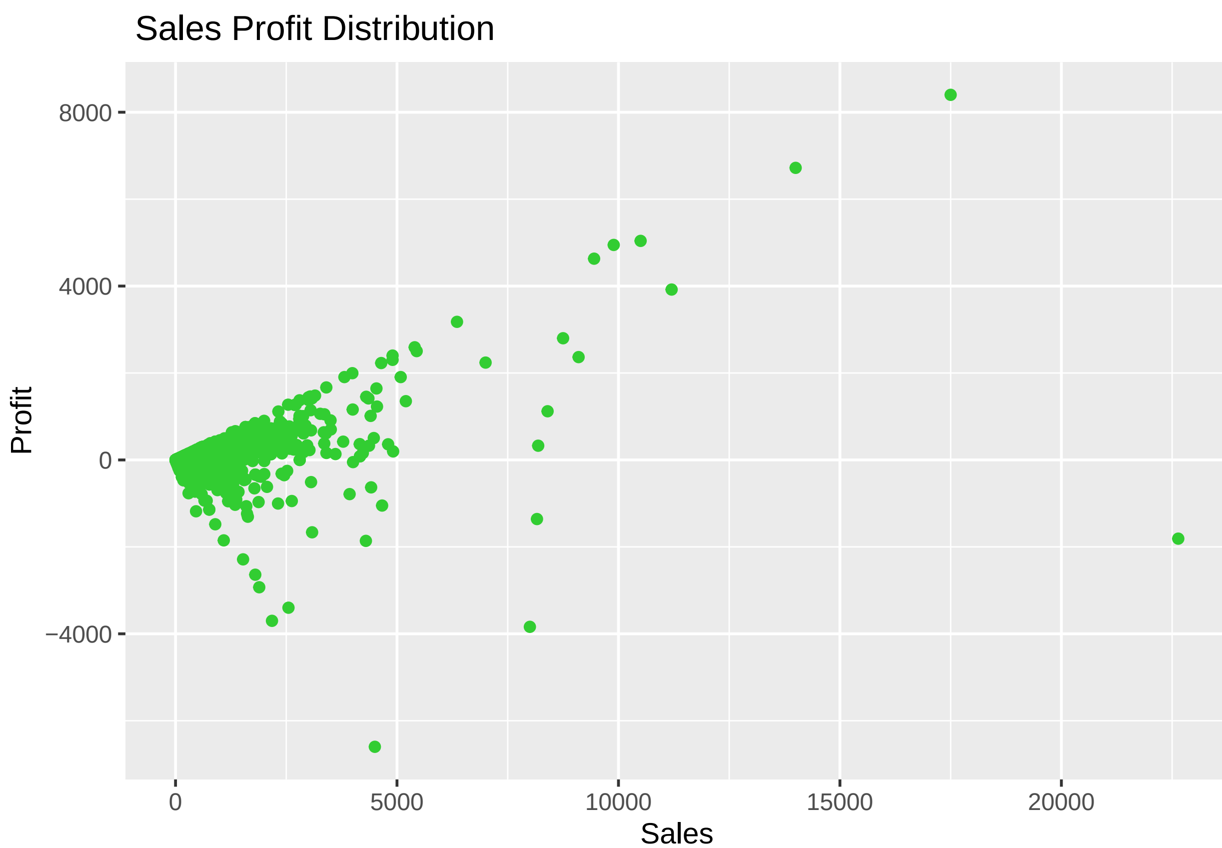



```
ggplot(data) +
geom_point(mapping = aes(x = Profit, y = Discount),colour="violetred3")+
labs(title=" Profit Discount Distribution")
```



Sales Profit

```
ggplot(data) +
geom_point(mapping = aes(x = Sales, y = Profit),colour="limegreen")+
labs(title=" Sales Profit Distribution")
```




```r
#product name and product id mismatch
data %>%
  distinct(Product_Name,Product_ID) %>%
  group_by(Product_ID) %>%
  filter(n()>1) %>%
  select(Product_ID)
```

```
## # A tibble: 64 x 1
## # Groups:   Product_ID [32]
##    Product_ID
##    <chr>
##  1 FUR-FU-10004848
##  2 FUR-CH-10001146
##  3 OFF-BI-10004654
##  4 FUR-CH-10001146
##  5 OFF-PA-10002377
##  6 OFF-AR-10001149
##  7 OFF-PA-10000659
##  8 TEC-MA-10001148
##  9 FUR-FU-10004017
## 10 TEC-AC-10003832
## # ... with 54 more rows
```

```r
#total category and subcategory
```

```r
count_category<-unique(data$Category)
length(count_category)
```

```
## [1] 3
```

```r
count_subcategory<-unique(data$Sub_Category)
length(count_subcategory)
```

```
## [1] 17
```

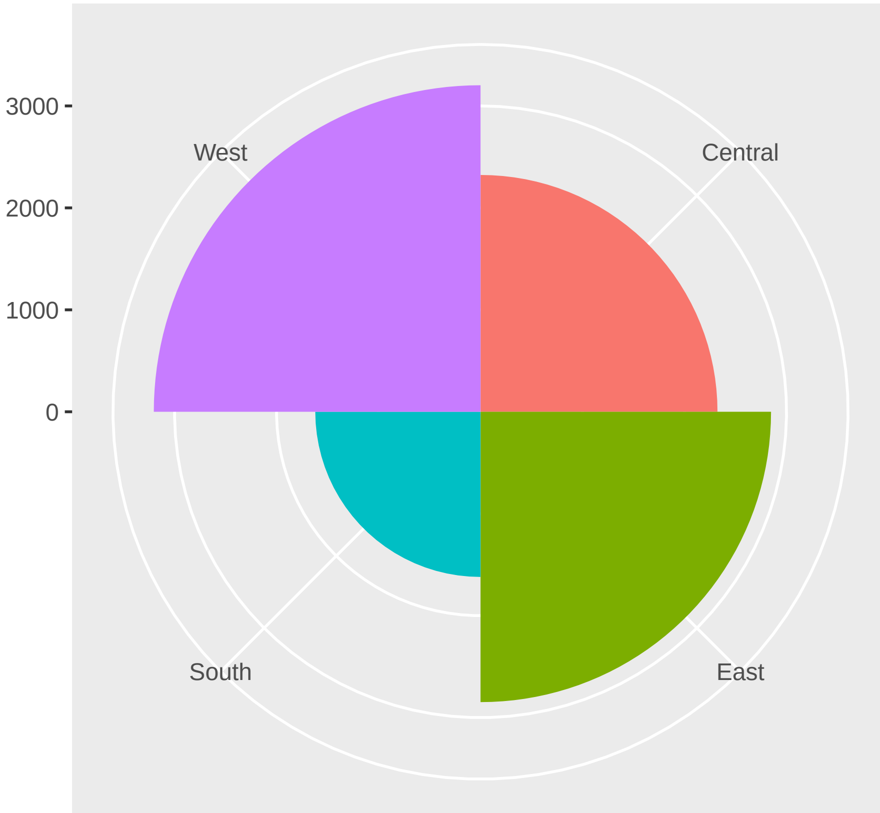
```r
data %>%
  distinct(Category, Sub_Category)
```

```
##           Category Sub_Category
## 1        Furniture    Bookcases
## 2        Furniture       Chairs
## 3  Office Supplies       Labels
## 4        Furniture       Tables
## 5  Office Supplies      Storage
## 6        Furniture  Furnishings
## 7  Office Supplies          Art
## 8       Technology       Phones
## 9  Office Supplies      Binders
## 10 Office Supplies   Appliances
## 11 Office Supplies        Paper
## 12      Technology  Accessories
## 13 Office Supplies    Envelopes
## 14 Office Supplies    Fasteners
## 15 Office Supplies     Supplies
## 16      Technology     Machines
## 17      Technology      Copiers
```

```r
superstore_sales<-data %>%
                  select(Order_Date,Sales)


superstore_sales<-as_tibble(superstore_sales)
```

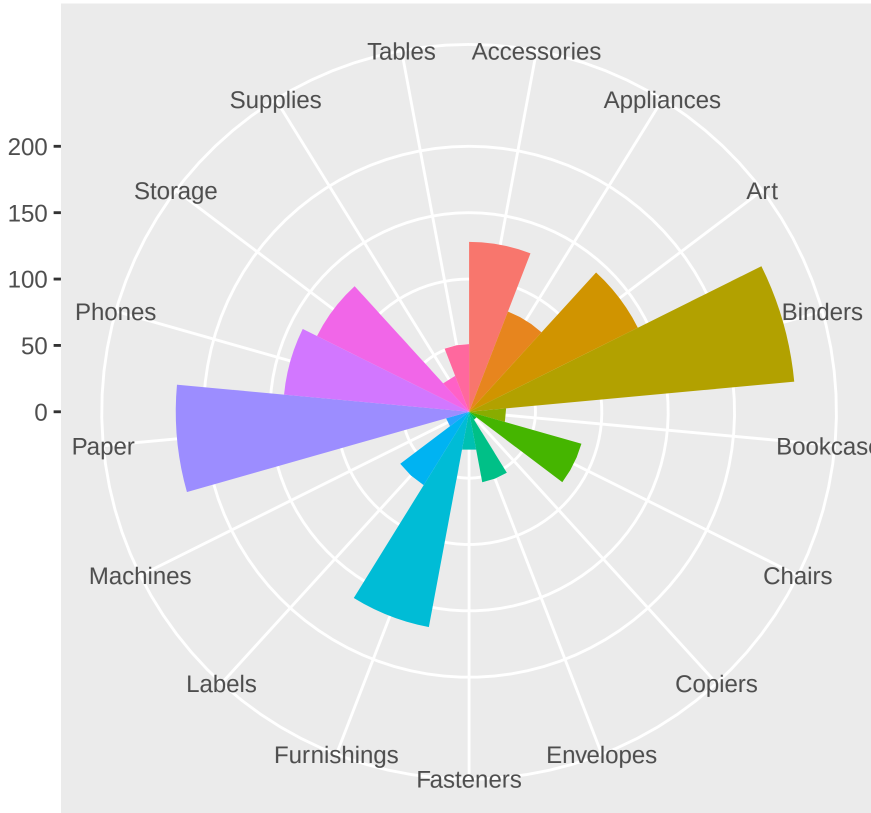
Transactions by region:

```r
bar <- ggplot(data = data) +
  geom_bar(
    mapping = aes(x = Region, fill = Region),
    show.legend = FALSE,
    width = 1
  ) +
  theme(aspect.ratio = 1) +
  labs(x = NULL, y = NULL)

bar + coord_polar()
```



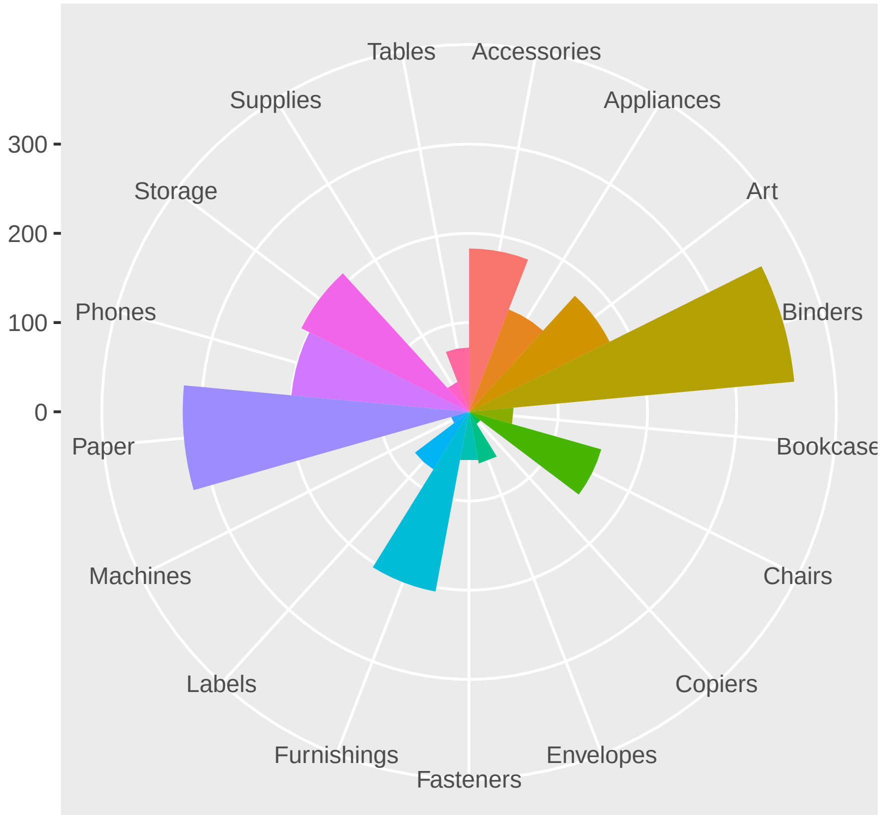
The above chart shows proportions of transactions from the different regions.

```
#Extracting the rows for South region, and sub-categories:
South <- data %>%
  select(Region, Sub_Category) %>%
  filter(Region == "South")

bar <- ggplot(data = South) +
  geom_bar(
    mapping = aes(x = Sub_Category, fill = Sub_Category),
    show.legend = FALSE,
    width = 1
  ) +
  theme(aspect.ratio = 1) +
  labs(x = NULL, y = NULL)

bar + coord_polar()
```

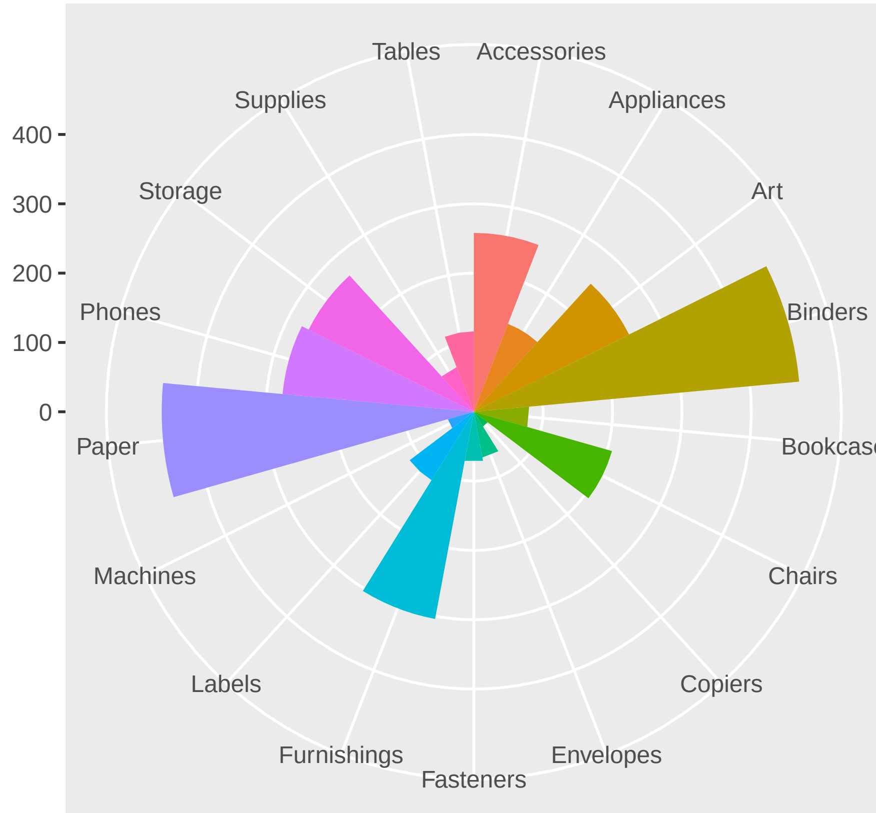


In the South, most transactions are Binders, Paper, or Furnishings.

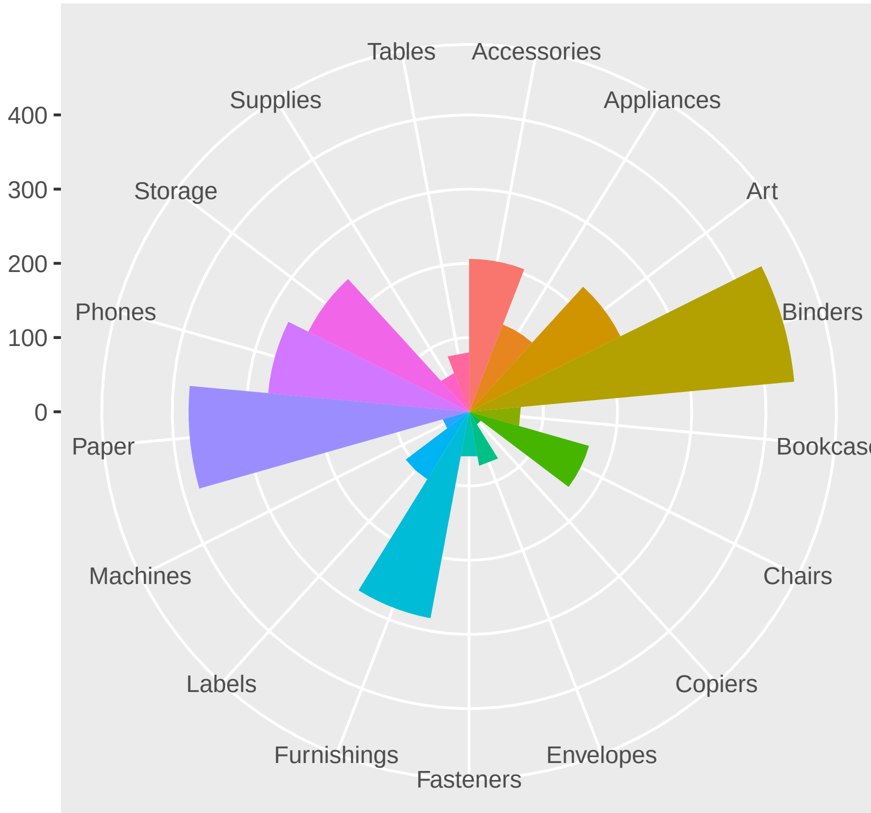
```
#Extracting the rows for Central region, and sub-categories:
Central <- data %>%
  select(Region, Sub_Category) %>%
  filter(Region == "Central")

bar <- ggplot(data = Central) +
  geom_bar(
    mapping = aes(x = Sub_Category, fill = Sub_Category),
    show.legend = FALSE,
    width = 1
  ) +
  theme(aspect.ratio = 1) +
  labs(x = NULL, y = NULL)

bar + coord_polar()
```




```
#Extracting the rows for West region, and sub-categories:
West <- data %>%
  select(Region, Sub_Category) %>%
  filter(Region == "West")

bar <- ggplot(data = West) +
  geom_bar(
    mapping = aes(x = Sub_Category, fill = Sub_Category),
    show.legend = FALSE,
    width = 1
  ) +
  theme(aspect.ratio = 1) +
  labs(x = NULL, y = NULL)

bar + coord_polar()
```

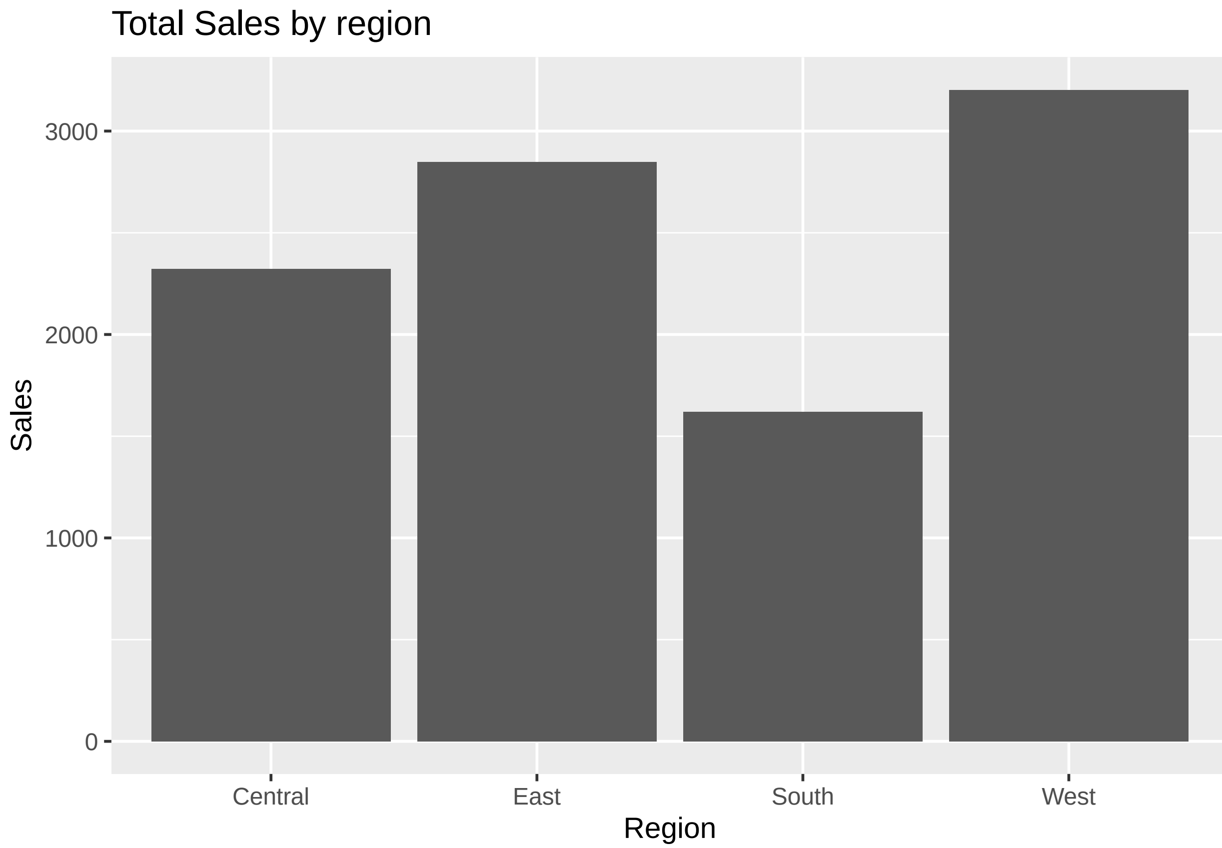



```r
#Extracting the rows for East region, and sub-categories:
East <- data %>%
  select(Region, Sub_Category) %>%
  filter(Region == "East")

bar <- ggplot(data = East) +
  geom_bar(
    mapping = aes(x = Sub_Category, fill = Sub_Category),
    show.legend = FALSE,
    width = 1
  ) +
  theme(aspect.ratio = 1) +
  labs(x = NULL, y = NULL)

bar + coord_polar()
```



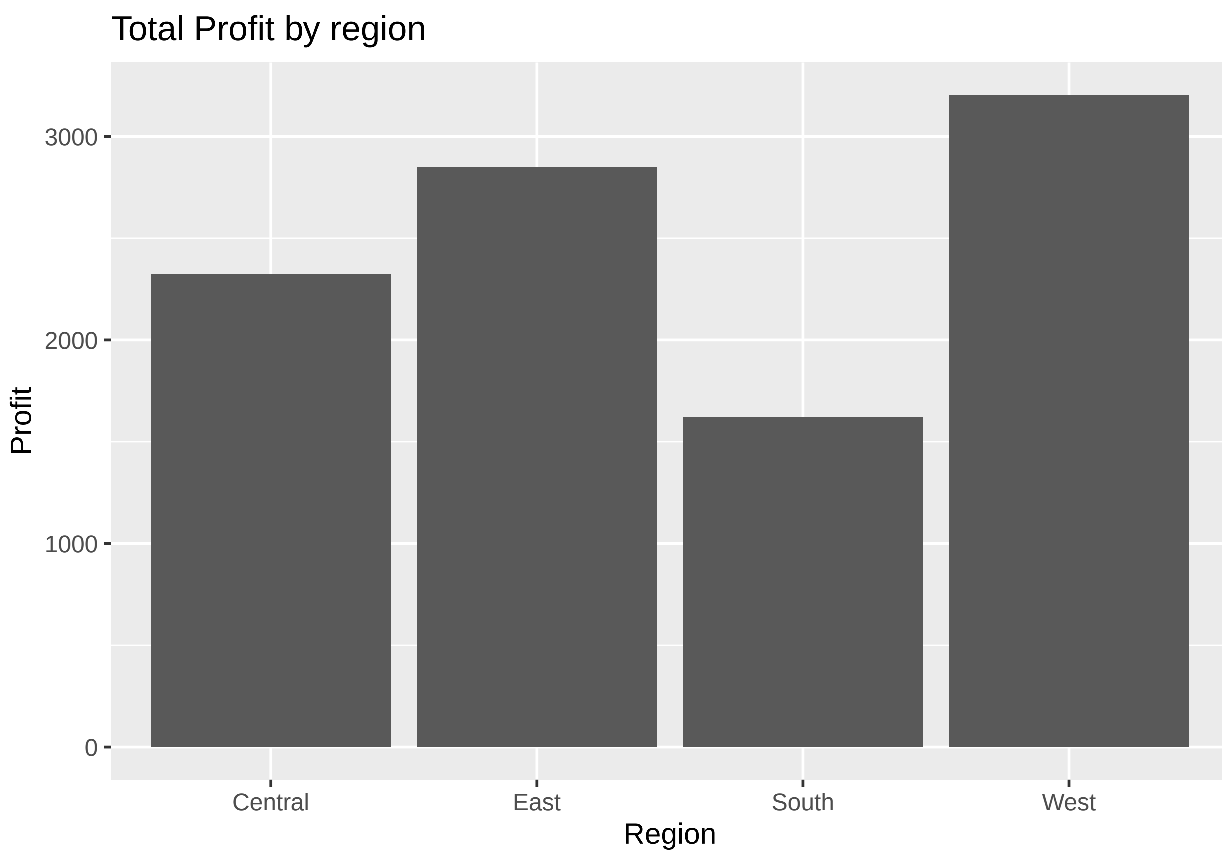
- **bar charts of profits/sales by region**

```
ggplot(data = data) +
  geom_bar(mapping = aes(x = Region, fill = Sales)) +
  ggtitle("Total Sales by region") +
  ylab("Sales")
```



Total sales per region.

```
ggplot(data = data) +
  geom_bar(mapping = aes(x = Region, fill = Profit))+
  ggtitle("Total Profit by region")+
  ylab("Profit")
```



Look at relationship between numeric variables:

```
#subset the numeric variables:
numeric_vars<- c("Sales", "Quantity", "Discount", "Profit", "diff_in_days")
num_data <- data[numeric_vars]
```

We'll use a correlation matrix to look at the relationship between numeric variables:

```
cor(num_data)
```

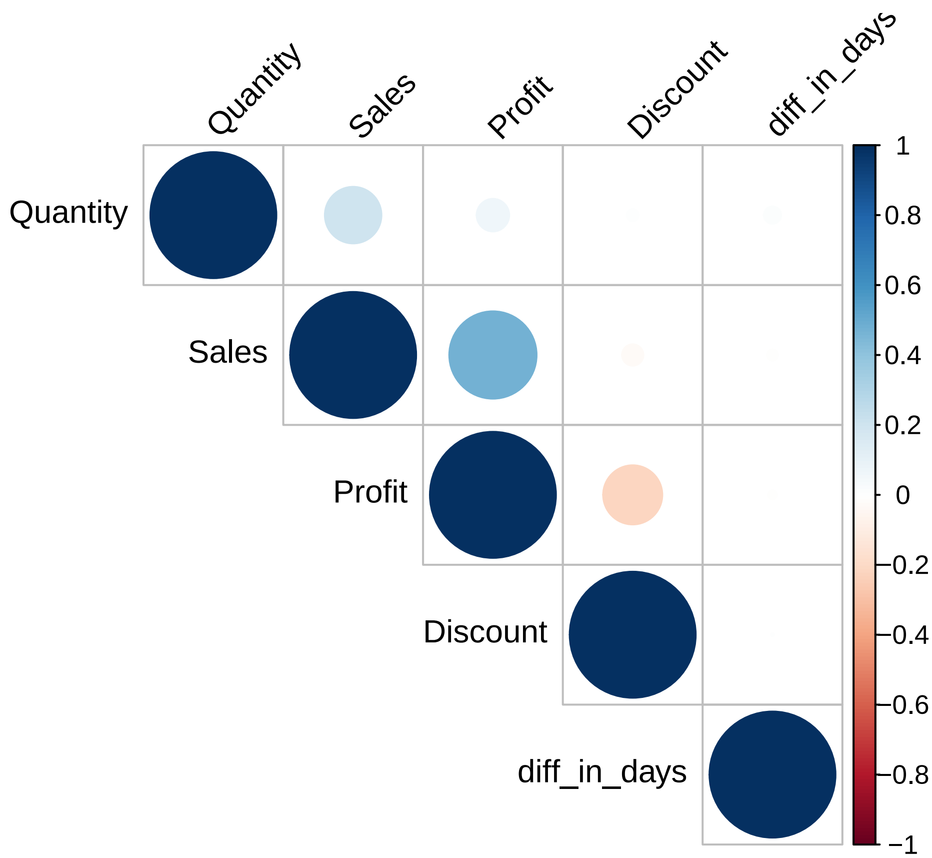
```
##                     Sales   Quantity      Discount       Profit  diff_in_days
## Sales          1.000000000 0.20079477 -0.0281901242  0.479064350 -0.0073535371
## Quantity       0.200794771 1.00000000  0.0086229703  0.066253189  0.0182984399
## Discount      -0.028190124 0.00862297  1.0000000000 -0.219487456  0.0004084856
## Profit         0.479064350 0.06625319 -0.2194874564  1.000000000 -0.0046493531
## diff_in_days -0.007353537 0.01829844  0.0004084856 -0.004649353  1.0000000000
```

```
#correlation matrix with statistical significance
cor_result=rcorr(as.matrix(num_data))

cor_result$r
```

```
##                     Sales   Quantity      Discount       Profit  diff_in_days
## Sales          1.000000000 0.20079477 -0.0281901242  0.479064350 -0.0073535371
## Quantity       0.200794771 1.00000000  0.0086229703  0.066253189  0.0182984399
```

```
## Discount     -0.028190124 0.00862297  1.0000000000 -0.219487456  0.0004084856
## Profit        0.479064350 0.06625319 -0.2194874564  1.000000000 -0.0046493531
## diff_in_days -0.007353537 0.01829844  0.0004084856 -0.004649353  1.0000000000
```

```
corrplot(cor_result$r, type = "upper", order = "hclust", tl.col = "black", tl.srt = 45)  #display only
```



Discount is negatively correlated with profit, whereas sales is positively correlated with profit. The time between order date and ship date (diff_in_days) is not correlated with sales, quantity, discount, or profit.

Since the difference in days between Order date and Ship date has 0 correlation with the other variables, let's drop diff_in_days for the K-means clustering analysis.

Data Preparation

```
#make a copy of the original dataset and copy to data1
data1 <- data
```

drop column Row ID because it is not necessary; it is the row number from the original excel file. The country variable is also not needed because all the values are United states. Customer_Name and Customer_ID give redundant information. So we will drop the Customer_Name column and keep only the Customer_ID column.

```
data1[,c("Row_ID","ï__Row_ID", "Country", "Customer_Name")]<-NULL
```

```r
head(data1)
```

```
##          Order_ID Order_Date  Ship_Date      Ship_Mode Customer_ID   Segment
## 1 CA-2016-152156 2016-11-08 2016-11-11   Second Class    CG-12520  Consumer
## 2 CA-2016-152156 2016-11-08 2016-11-11   Second Class    CG-12520  Consumer
## 3 CA-2016-138688 2016-06-12 2016-06-16   Second Class    DV-13045 Corporate
## 4 US-2015-108966 2015-10-11 2015-10-18 Standard Class    SO-20335  Consumer
## 5 US-2015-108966 2015-10-11 2015-10-18 Standard Class    SO-20335  Consumer
## 6 CA-2014-115812 2014-06-09 2014-06-14 Standard Class    BH-11710  Consumer
##              City      State Postal_Code Region      Product_ID        Category
## 1       Henderson   Kentucky       42420  South FUR-BO-10001798       Furniture
## 2       Henderson   Kentucky       42420  South FUR-CH-10000454       Furniture
## 3     Los Angeles California       90036   West OFF-LA-10000240 Office Supplies
## 4 Fort Lauderdale    Florida       33311  South FUR-TA-10000577       Furniture
## 5 Fort Lauderdale    Florida       33311  South OFF-ST-10000760 Office Supplies
## 6     Los Angeles California       90032   West FUR-FU-10001487       Furniture
##   Sub_Category                                                     Product_Name
## 1    Bookcases                                Bush Somerset Collection Bookcase
## 2       Chairs      Hon Deluxe Fabric Upholstered Stacking Chairs, Rounded Back
## 3       Labels        Self-Adhesive Address Labels for Typewriters by Universal
## 4       Tables                    Bretford CR4500 Series Slim Rectangular Table
## 5      Storage                                   Eldon Fold 'N Roll Cart System
## 6  Furnishings Eldon Expressions Wood and Plastic Desk Accessories, Cherry Wood
##      Sales Quantity Discount    Profit diff_in_days
## 1 261.9600        2     0.00   41.9136            3
## 2 731.9400        3     0.00  219.5820            3
## 3  14.6200        2     0.00    6.8714            4
## 4 957.5775        5     0.45 -383.0310            7
## 5  22.3680        2     0.20    2.5164            7
## 6  48.8600        7     0.00   14.1694            5
```

Model

For this K-means clustering we will use the numeric variables only: which are sales, quantity, discount, profit (columns 15 - 18). K means clustering is affected by the starting assignment points, so we will try with 25 different starting assignments (nstart = 25), and see which ones work the best.

(https://www.datanovia.com/en/blog/k-means-clustering-visualization-in-r-step-by-step-guide/)

```r
#Compute K-means clustering with k=3 (3 initial distinct cluster centres)
set.seed(123)

results_kmeans <- kmeans(scale(data1[,(15:18)]), 3, nstart =25)

#kmeans clusters to show the group of the individuals
results_kmeans$cluster
```

```
##    [1] 2 2 2 1 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 1 2 2 2 1
##   [38] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##   [75] 2 1 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 1 2 2 2 1 2 2 2 2 2
##  [112] 2 2 2 2 2 2 2 1 2 2 2 2 2 2 1 1 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##  [149] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 1 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2
```

```
##   [186] 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 1 2 1 2 2 2 2 2 2 2 2 2 1 1 1 2 2 2 2 2 1
##   [223] 2 1 2 2 2 2 2 2 1 1 1 1 2 2 2 2 1 1 2 1 1 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2
##   [260] 2 2 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 1 2 2 2 2 2 1 2 2 2
##   [297] 1 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 2 2 2 2 2 2 1 2 2 2 1 1 1
##   [334] 1 2 2 2 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##   [371] 2 2 1 2 2 2 2 2 1 2 1 2 2 2 1 2 1 2 2 2 2 2 2 1 2 2 2 2 2 1 2 2 2 2 2 2 2
##   [408] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 1 2 2 2 2 2 2 2 2 2
##   [445] 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 1 1 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2
##   [482] 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 1 1 2 1 2 2 2 2 2 3 2 2 2 2 2 2 2 2
##   [519] 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 1 2 2 2 1 2 2 2 2 2
##   [556] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 1 2 2 2 2 2 1 2
##   [593] 2 2 2 2 2 2 2 1 1 2 2 2 1 1 2 1 2 1 2 2 2 1 1 1 2 2 2 2 2 1 2 2 2 2 2 2 2
##   [630] 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 1 2 2 2 1 2 2 2
##   [667] 2 2 2 1 1 2 2 2 2 2 1 2 1 1 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2
##   [704] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2
##   [741] 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##   [778] 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##   [815] 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##   [852] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 1 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2
##   [889] 2 2 2 2 2 2 2 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2
##   [926] 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 1 2 2 1 2 2 2 2 2 2 2 1 2 2 2 2
##   [963] 2 2 2 2 2 2 2 2 2 1 1 2 2 2 1 2 1 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 2 2
##  [1000] 2 2 2 1 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 1 1
##  [1037] 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 1 2 2 1 2 2 2
##  [1074] 1 1 2 2 2 2 2 2 2 1 2 2 3 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 1 1 2 2 1 1 2 2
##  [1111] 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##  [1148] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2
##  [1185] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 1 2
##  [1222] 2 2 2 2 2 2 2 2 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 1
##  [1259] 2 2 2 1 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2
##  [1296] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 1 2 2 2 2 1 2
##  [1333] 1 1 2 2 2 2 2 2 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 1 1 1 2 2 2 2
##  [1370] 1 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 1 2 2 1
##  [1407] 2 2 2 1 2 2 2 2 2 2 2 2 1 2 1 2 1 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2
##  [1444] 2 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2
##  [1481] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2
##  [1518] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 1 2 2 2
##  [1555] 2 2 2 2 2 2 2 2 1 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2
##  [1592] 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##  [1629] 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2
##  [1666] 2 2 2 2 1 2 2 2 2 1 1 2 2 2 1 2 1 2 2 2 1 1 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2
##  [1703] 2 2 1 1 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2
##  [1740] 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 1 1 2 1 2 2 2 2 2
##  [1777] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 1 2 2 2
##  [1814] 2 2 2 2 2 1 1 1 2 2 2 1 2 2 2 2 1 2 2 2 1 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2
##  [1851] 2 2 2 2 2 2 2 1 2 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2
##  [1888] 1 2 1 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 1 1 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2
##  [1925] 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 1 2 2 2 1 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2
##  [1962] 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 1 1 2
##  [1999] 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##  [2036] 2 2 2 2 1 1 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2
##  [2073] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2
##  [2110] 2 2 2 2 2 2 2 1 2 2 2 1 2 2 2 2 1 2 2 2 2 2 2 2 1 2 1 1 1 2 2 2 1 2 1 2 2
##  [2147] 1 2 2 2 2 2 2 2 1 2 2 2 2 1 2 2 2 2 2 1 2 1 2 2 1 2 2 1 2 2 2 2 2 2 2 2 2
```

```
## [2184] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2
## [2221] 2 1 2 2 2 1 2 2 1 2 2 2 2 2 2 2 2 2 1 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [2258] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [2295] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [2332] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 1 1 1 2 2 1 2 2 2 2 2
## [2369] 2 2 2 1 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [2406] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 1 1 1 2 2 2 2 2 2 2 1 2 2 2 2
## [2443] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [2480] 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 2 2 2 2 2 2 2 1 1 2 2 3 2 1 2 2 2 2 1 2 2 2
## [2517] 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [2554] 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [2591] 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 3 2 2 2
## [2628] 2 1 1 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [2665] 1 1 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 1 1 2 2 1 2 2 2 2 2 1 3 2 2 2
## [2702] 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 1 2 2 2 2 2 1 1 1 1 2 2 2 2 2 2 2 2 2
## [2739] 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 1 2 2 2 2 2 2
## [2776] 2 2 2 2 2 2 2 2 1 1 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [2813] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 1 2 2
## [2850] 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2
## [2887] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1
## [2924] 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2
## [2961] 2 2 2 2 2 2 1 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2
## [2998] 2 2 1 2 1 2 2 2 2 2 2 2 2 1 1 1 1 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [3035] 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [3072] 2 2 2 2 2 1 2 2 2 2 2 2 2 1 2 1 1 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 1 2 2 2 2
## [3109] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 1 2 2 2 2 2 2 2 1 2 2 2 2 1 2 1 2 2 2
## [3146] 2 2 2 2 2 2 1 1 2 2 2 1 2 2 2 1 2 2 2 2 2 2 2 2 2 2 1 2 2 2 1 2 2 2 2 2 2
## [3183] 2 2 2 1 2 2 2 2 2 2 1 1 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2
## [3220] 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2
## [3257] 2 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2
## [3294] 2 1 2 1 2 2 1 2 1 2 1 2 2 2 1 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 1 1 2 2 2 2
## [3331] 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 1 2 2
## [3368] 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 1 1 2 2 2 1 2 2 2 2 2 2 2 2 1 1
## [3405] 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 1 1 1 2 2 2
## [3442] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [3479] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 1 2 2 2 2
## [3516] 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2
## [3553] 2 1 2 2 2 2 2 2 2 1 1 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2
## [3590] 2 2 2 2 1 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2
## [3627] 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 1 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [3664] 2 2 1 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 1 2 2 2 2 2 2 2 2 2
## [3701] 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2
## [3738] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2
## [3775] 2 2 2 2 2 2 2 1 2 2 2 1 2 2 2 2 2 1 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 1 1 2 2
## [3812] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [3849] 2 2 2 2 1 2 2 1 2 2 2 1 2 2 2 2 1 2 2 2 2 2 2 2 2 2 1 2 2 1 2 2 2 2 2 2 2
## [3886] 1 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 1 2 1 1 2 1 2 2 2 1 2 2 1 2 2 2 2
## [3923] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2
## [3960] 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [3997] 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 1 2 2 2 2
## [4034] 2 1 2 2 2 2 2 2 2 2 2 2 1 1 2 2 2 2 2 1 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 1
## [4071] 1 2 2 2 2 2 2 2 2 2 2 1 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 1 1 2 2 2 2 1
## [4108] 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 1 2 2 2 2 2 2 2 1 2 2 2 2 2
## [4145] 2 2 2 1 2 2 2 2 2 2 1 1 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1
```

```
## [4182] 2 2 2 2 2 1 1 2 2 3 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
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##              Length Class  Mode
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## totss           1   -none- numeric
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## betweenss       1   -none- numeric
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## iter            1   -none- numeric
## ifault          1   -none- numeric
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results_kmeans
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## K-means clustering with 3 clusters of sizes 1136, 8831, 27
##
## Cluster means:
##         Sales     Quantity   Discount     Profit
## 1 -0.05714414  0.045908572  2.3730228 -0.5928228
## 2 -0.02922217 -0.007823215 -0.3039892  0.0425665
## 3 11.96210167  0.627210176 -0.4157497 11.0200717
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## Clustering vector:
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## [9954] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
## [9991] 2 2 2 2
##
## Within cluster sum of squares by cluster:
## [1]  5207.851 16648.669  3315.203
##  (between_SS / total_SS =  37.0 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

```
# https://towardsdatascience.com/clustering-analysis-in-r-using-k-means-73eca4fb7967

#cluster means are the centroid vectors
#clustering vector is the group that the observation is placed into
#percentage indicates compactness of the clustering or how similar observations are within the same gro
```

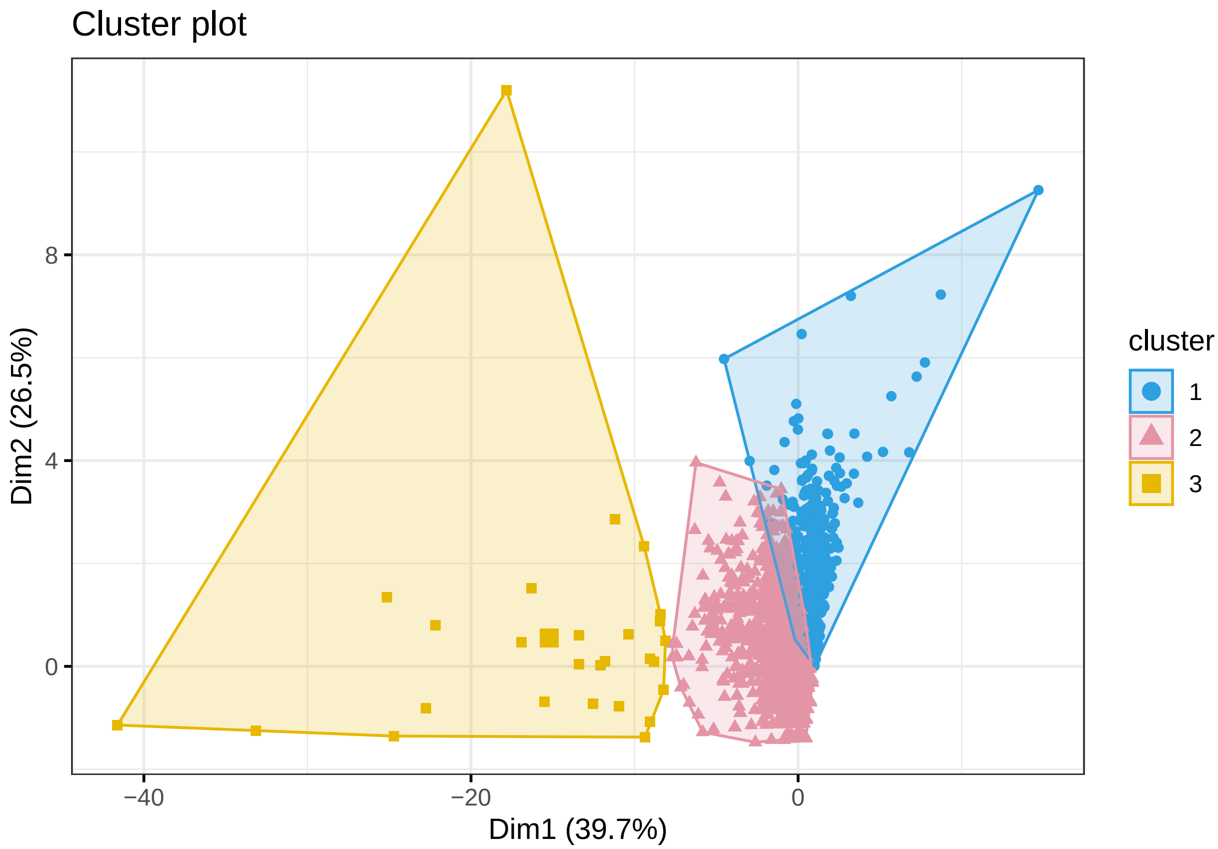
The results of this clustering indicate that the within cluster sum of squares by cluster is 37.0 % which means that the observations within a given group are not very similar to each other.

Plot K-means

The factoextra package contains a function called fviz_cluster() which can be used to visualize kmeans clusters. The input required is the original dataset, and the kmeans results. These are used to produce plots which show points that represent observations.

```
fviz_cluster(results_kmeans, data = data1[,(15:18)],
             palette = c("#2E9FDF", "#E495A5", "#E7B800"),
             geom = "point",
             ellipse.type = "convex",
```

```r
            ggtheme = theme_bw()
            )
```



Reduce dimensions using Principal Component Analysis.

```r
results_pca <- prcomp(data1[,(15:19)], scale=TRUE)

#Coordinates of individual observations
indiv_coordinates <- as.data.frame(get_pca_ind(results_pca)$coord)

#Add clusters obtained through the Kmeans algorithm
indiv_coordinates$cluster <- factor(results_kmeans$cluster)

#Add region from the dataset
indiv_coordinates$Region <- data1$Region

#look at the first few rows of individual coordinates
head(indiv_coordinates)
```

```
##          Dim.1       Dim.2      Dim.3         Dim.4       Dim.5 cluster Region
## 1  0.04520418 -1.13666870  0.3612739  0.0807637427  0.30768311       2  South
## 2  1.15718390 -0.84275631  0.4252513  0.1851981706  0.21856052       2  South
## 3 -0.31072375 -1.08484635 -0.2274155 -0.0007838382  0.15040037       2   West
## 4 -0.63620673  2.24187253 -1.2663321  0.5805617103  1.55922466       1  South
## 5 -0.58444157 -0.08714015 -1.6947210  0.7880697439 -0.05040709       2  South
## 6  0.39080002  0.44622564 -0.7312599 -1.4739348647 -0.19665673       2   West
```

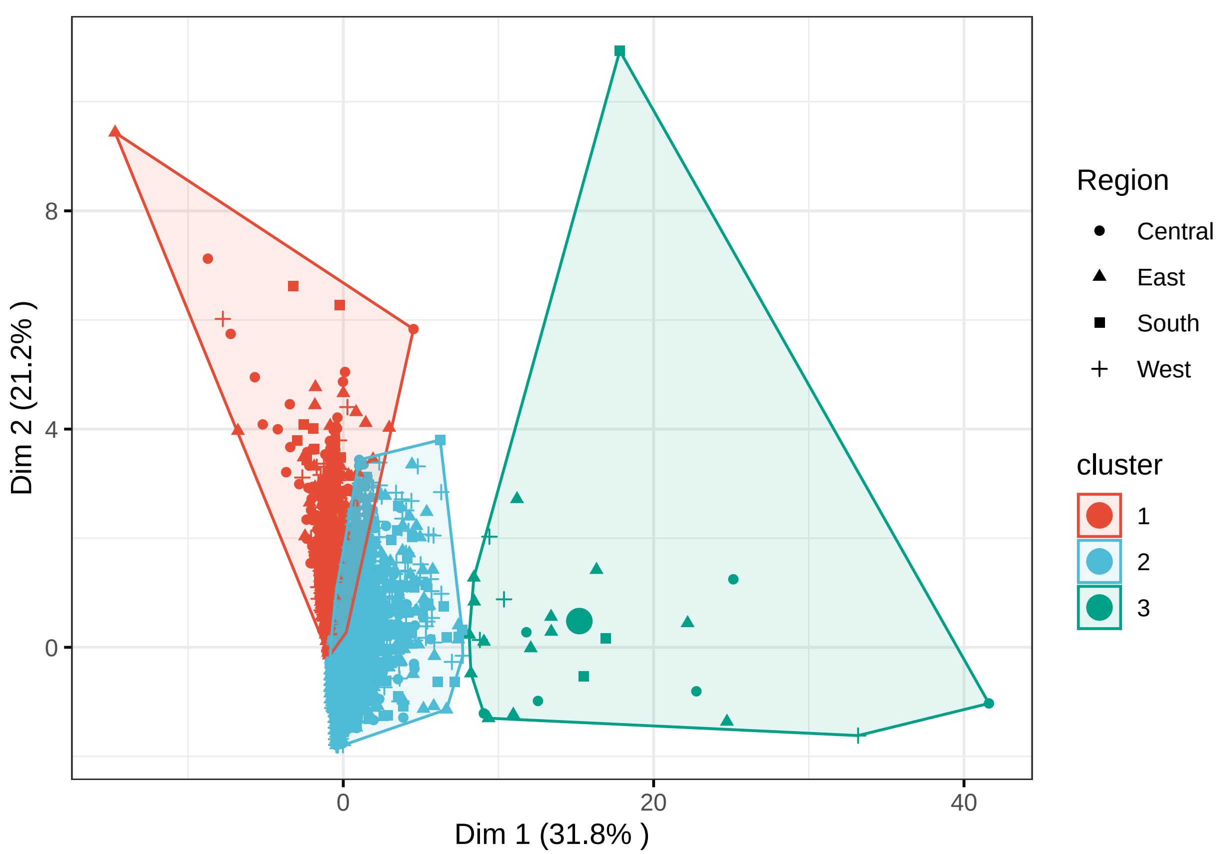
Percentage of variance explained by dimensions.

```
eigenvalue <- round(get_eigenvalue(results_pca), 1)
variance.percent <- eigenvalue$variance.percent
head(eigenvalue)
```

```
##       eigenvalue variance.percent cumulative.variance.percent
## Dim.1        1.6             31.8                        31.8
## Dim.2        1.1             21.2                        53.0
## Dim.3        1.0             20.0                        73.0
## Dim.4        0.9             17.6                        90.6
## Dim.5        0.5              9.4                       100.0
```

Variance of a group indicates how different members of a group are. Higher variance means greater dissimilarity within a group.

```
#To visualize the k-means clusters:

ggscatter(
  indiv_coordinates, x = "Dim.1", y = "Dim.2",
  color = "cluster", palette = "npg", ellipse = TRUE, ellipse.type = "convex",    #adding the concentra
  shape = "Region", size = 1.5,  legend = "right", ggtheme = theme_bw(),
  xlab = paste0("Dim 1 (", variance.percent[1], "% )" ),
  ylab = paste0("Dim 2 (", variance.percent[2], "% )" )
) +
  stat_mean(aes(color = cluster), size = 4)      #stat_mean is used for adding the cluster centroid
```



The clustering plot shows that the groups are very close together, and overlap slightly. The clusters could be further apart with some tuning by changing the number of clusters (k).

Evaluation

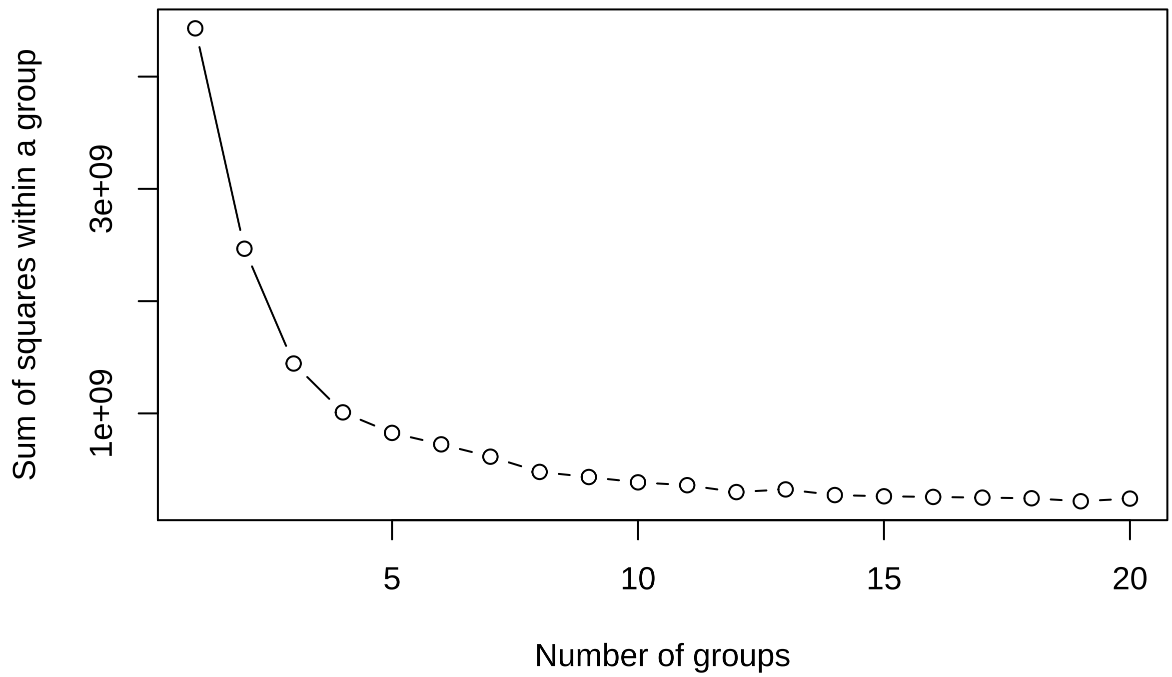
(https://towardsdatascience.com/clustering-analysis-in-r-using-k-means-73eca4fb7967)

The within sum of squares (Withinss) is a value that represents the level of dissimilarity within a group. The higher the withinss, the greater the dissimilarity within the group.

(Foncesca, 2019)

```
#To plot a within sum of squares plot for a range of different number of initial K-means centroids:

#This function is from:  (https://towardsdatascience.com/clustering-analysis-in-r-using-k-means-73eca4f

#data is the input dataset, nc is the maximum number of initial centres

wssplot <- function(data, nc=25, seed=123){
               wss <- (nrow(data)-1)*sum(apply(data,2,var))
               for (i in 2:nc){
                    set.seed(seed)
                    wss[i] <- sum(kmeans(data, centers=i)$withinss)}
                plot(1:nc, wss, type="b", xlab="Number of groups",
                     ylab="Sum of squares within a group")}

wssplot(data1[,(15:18)], nc = 20)
```

```
## Warning: did not converge in 10 iterations

## Warning: did not converge in 10 iterations

## Warning: did not converge in 10 iterations

## Warning: did not converge in 10 iterations

## Warning: did not converge in 10 iterations

## Warning: did not converge in 10 iterations

## Warning: did not converge in 10 iterations

## Warning: did not converge in 10 iterations

## Warning: did not converge in 10 iterations
```



From the Within sum of squares plot, the optimal number of clusters is around 5. when the number of groups (k) initially increases 1 to 6, the error measures (sum of squares within a group) starts to decrease. When the number of groups is 7 or 8, the error measure starts to flatten.

The main purpose is to find a number of initial groups which achieves some fair amount of compactness (or similarity) between observations within a group. When k is too high, each cluster starts to represent individual points, whereas when k is too low, the observations may not be in the right cluster.

We can try re-running the k-means model with the number of groups, k = 4

```
set.seed(123)
clustering_results_4 <- kmeans(scale(data1[,(15:18)]), centers = 4, nstart = 25)
clustering_results_4
```

```
## K-means clustering with 4 clusters of sizes 27, 1044, 2838, 6085
##
## Cluster means:
##        Sales    Quantity   Discount      Profit
## 1 11.9621017  0.62721018 -0.4157497 11.02007172
## 2 -0.1222964  0.02095769  2.4788189 -0.58466503
## 3  0.2856822  1.19688927 -0.2981228  0.17558930
## 4 -0.1653353 -0.56459922 -0.2844025 -0.03048054
##
## Clustering vector:
##    [1] 4 4 4 2 4 3 4 3 4 3 3 3 4 4 2 2 3 4 4 4 4 3 3 4 4 4 4 2 2 4 4 3 2 4 4 3 2
##   [38] 3 4 4 4 4 4 4 4 4 4 4 4 3 3 4 4 3 3 3 3 3 4 4 4 4 4 3 4 4 3 3 4 4 4 4 3 4
##   [75] 4 2 2 4 2 4 4 3 4 3 4 4 4 4 3 4 4 4 4 4 4 2 3 4 3 3 4 2 4 3 4 2 3 4 4 3 4
```

```
##   [112] 4 3 3 4 4 3 4 2 4 4 3 3 3 4 2 2 3 4 4 2 4 3 4 4 4 4 4 3 3 4 4 4 4 4 3 4 3
##   [149] 4 3 3 3 4 3 4 3 4 4 4 3 4 4 3 4 4 3 4 3 3 2 4 4 4 3 2 4 2 3 3 4 4 3 4 3 4
##   [186] 4 3 4 4 3 3 3 4 3 3 4 4 4 2 4 4 2 4 2 3 4 4 4 4 3 4 4 4 2 2 2 4 3 4 4 3 2
##   [223] 4 2 4 4 3 4 4 3 2 2 2 2 4 4 4 3 2 2 4 2 2 4 3 4 3 3 4 4 4 3 3 4 2 4 3 3 4
##   [260] 4 3 2 2 3 4 4 4 3 4 4 3 3 4 4 4 4 4 4 3 4 2 3 3 3 3 3 2 4 3 3 3 4 2 3 4 4
##   [297] 2 4 3 3 4 4 4 2 4 4 4 3 4 4 4 4 4 4 4 4 4 4 1 3 4 4 4 3 4 4 2 4 4 3 2 4 2
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## [9991] 4 4 4 4
##
## Within cluster sum of squares by cluster:
```

```
## [1] 3315.203 4284.643 7571.058 3614.724
##  (between_SS / total_SS =  53.0 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

The within cluster sum of squares by cluster value is now 53.0%. This represents the compactness of the clustering, or how similar observations are to other observations within the same group.

We can try re-running the k-means model with the number of groups, k = 7

```r
set.seed(123)
clustering_results_7 <- kmeans(scale(data1[,(15:18)]), centers = 7, nstart = 25)
clustering_results_7
```

```
## K-means clustering with 7 clusters of sizes 3317, 200, 12, 914, 2574, 9, 2968
##
## Cluster means:
##         Sales    Quantity   Discount       Profit
## 1 -0.17099202 -0.55401551 -0.7476979   0.01999970
## 2  3.70037129  1.13047292 -0.4332859   2.62598142
## 3  8.36049519  1.14320638  2.0689103 -11.91366497
## 4 -0.21824012  0.05129912  2.6451425  -0.46197164
## 5  0.04223395  1.22666437 -0.2946436   0.03793345
## 6 16.87915324  0.84359568 -0.6489669  19.79865024
## 7 -0.11265862 -0.54381990  0.2993725  -0.10180518
##
## Clustering vector:
##    [1] 1 1 1 4 7 5 1 5 7 5 5 7 7 7 4 4 5 1 1 7 7 5 5 7 1 7 1 3 4 7 7 5 4 7 7 5 4
##   [38] 5 7 7 7 7 1 7 1 1 1 1 1 5 5 1 1 5 5 5 5 5 1 1 7 1 1 5 1 1 7 5 7 1 7 1 5 7
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## [9991] 1 7 1 1
##
## Within cluster sum of squares by cluster:
## [1] 1131.9138 1960.3599 1460.2766 1749.2333 3515.6513  778.7336 1329.8103
##  (between_SS / total_SS =  70.2 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

Re-running k-means with k = 8:

```r
set.seed(123)
clustering_results_8 <- kmeans(scale(data1[,(15:18)]), centers = 8, nstart = 25)
clustering_results_8
```

```
## K-means clustering with 8 clusters of sizes 912, 2114, 2923, 12, 9, 182, 3263, 579
##
## Cluster means:
##         Sales    Quantity   Discount       Profit
## 1 -0.21598994  0.03592803  2.6411836 -0.463442556
## 2  0.06144353  0.84777662 -0.3020867  0.051473515
```

```
## 3 -0.12740261 -0.55718427  0.2964566  -0.102300730
## 4  8.36049519  1.14320638  2.0689103 -11.913664966
## 5 16.87915324  0.84359568 -0.6489669  19.798650239
## 6  3.85740734  0.99833967 -0.4172776   2.749990730
## 7 -0.18963127 -0.56474906 -0.7485896   0.008899425
## 8  0.17956725  2.49300690 -0.2367609   0.083089163
##
## Clustering vector:
##    [1] 7 7 7 1 3 2 7 2 3 2 8 2 3 3 1 1 2 7 7 3 3 2 2 3 7 3 7 4 1 3 3 2 1 3 3 2 1
##   [38] 8 3 3 3 3 7 3 7 7 7 7 7 2 2 7 7 2 2 2 2 2 7 7 3 7 7 2 7 7 2 8 3 7 3 7 8 3
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## [8585] 3 1 2 2 3 3 7 3 3 3 3 7 7 3 3 7 7 3 2 3 3 2 7 7 7 3 7 2 7 7 7 3 7 3 2 7 1
## [8622] 3 3 1 2 3 7 2 3 3 7 1 1 3 1 2 2 2 2 7 1 1 8 3 1 3 3 3 2 1 2 7 7 7 7 7 7 7
## [8659] 1 2 2 1 2 2 2 2 2 3 3 7 3 3 3 3 3 2 1 2 1 2 6 2 7 7 2 2 7 2 7 3 3 3 2 2 7
## [8696] 3 3 3 3 6 8 3 2 3 8 7 7 7 3 3 7 3 3 2 2 1 1 1 8 3 3 8 1 2 2 7 3 3 3 3 2 7
## [8733] 7 7 2 7 7 1 3 3 2 7 3 3 7 7 7 3 3 6 7 3 3 2 1 1 7 8 7 7 6 8 7 7 3 1 1 1 3
## [8770] 3 3 2 3 2 3 3 2 8 3 3 3 2 3 7 3 2 3 3 3 3 8 2 7 2 2 3 7 7 2 6 3 7 7 7 7 3
## [8807] 7 1 3 2 7 7 2 3 7 2 7 7 2 3 3 1 3 3 3 3 2 2 7 7 8 7 3 7 7 7 7 2 7 3 7 7 7
## [8844] 2 1 3 2 3 3 8 1 3 7 2 3 3 2 3 6 3 7 7 7 7 2 7 2 3 3 2 8 7 1 1 1 3 1 7 7 8
## [8881] 7 2 3 3 1 1 1 7 8 7 6 7 6 3 7 7 3 7 7 7 1 3 3 3 7 7 8 2 8 7 3 8 1 3 2 1 1
## [8918] 3 1 7 7 3 3 1 2 1 1 2 3 3 3 2 7 7 3 8 2 3 2 3 3 1 1 3 7 7 7 2 7 2 3 3 2 2
## [8955] 3 7 3 1 2 1 2 3 7 7 2 1 3 2 3 8 3 7 3 2 2 3 3 1 7 1 1 1 1 1 1 3 1 3 3 7 6
## [8992] 2 3 1 2 2 3 3 2 2 1 7 7 2 8 2 7 7 7 3 7 3 2 2 2 3 3 7 3 7 2 8 3 7 7 7 7 7
## [9029] 7 3 7 7 7 6 1 3 7 7 3 5 3 3 7 7 3 2 2 2 7 7 7 7 3 3 7 7 6 2 3 2 3 7 2 8 1
## [9066] 3 7 7 3 7 3 7 7 2 2 1 3 7 7 7 2 7 7 7 2 3 1 2 3 2 8 3 1 7 2 7 2 2 2 3 3 3
## [9103] 3 1 1 3 3 3 2 3 2 7 7 7 2 3 3 3 3 2 2 2 7 1 1 1 7 3 1 1 3 7 7 2 3 3 3 1 2
## [9140] 2 7 7 3 8 2 1 7 2 8 7 2 3 3 2 3 2 7 8 8 1 1 2 7 3 1 6 7 7 8 7 7 7 7 7 3 7
## [9177] 1 7 7 3 3 3 7 7 7 3 6 3 3 2 1 3 1 3 2 3 7 2 2 3 7 7 3 2 8 7 8 3 7 7 7 7 7
## [9214] 7 2 2 1 7 2 1 7 6 7 1 1 1 3 2 7 3 8 1 8 7 2 2 3 3 3 2 1 3 2 3 7 2 7 7 3 2
## [9251] 8 3 2 7 7 7 7 7 7 7 7 3 7 2 1 2 7 7 7 2 6 7 2 6 2 2 3 3 1 3 7 2 3 3 7 3 1
## [9288] 3 2 7 7 7 1 2 3 1 3 3 3 1 3 3 3 3 1 2 7 7 7 2 8 3 3 2 7 3 3 3 7 7 7 1 1 8
## [9325] 3 3 7 3 7 7 7 3 7 7 3 3 2 3 2 7 2 3 2 3 1 3 3 2 8 7 3 3 3 3 7 7 7 2 3 7 2
## [9362] 2 2 7 7 7 3 2 7 7 3 3 2 2 2 7 7 7 3 3 3 3 3 2 7 8 7 7 7 7 2 3 8 2 7 3 2 7
## [9399] 6 2 7 3 3 6 2 3 3 8 7 1 2 3 6 1 3 7 7 3 3 1 1 2 2 3 7 6 2 2 8 2 3 3 3 2 3
## [9436] 3 1 7 3 3 7 2 3 3 3 7 2 2 7 3 8 7 2 7 3 3 3 1 7 3 7 2 7 3 2 7 2 3 7 7 7 3
## [9473] 7 2 3 2 1 1 2 1 1 3 3 2 8 8 3 7 3 2 6 7 8 6 7 2 7 7 7 8 7 7 8 7 2 7 7 2 7
## [9510] 2 8 1 3 6 2 8 3 3 3 7 7 3 3 3 2 2 3 2 3 3 7 3 8 2 7 3 1 3 2 7 2 3 1 3 3 7
## [9547] 7 3 1 3 3 2 7 2 2 3 2 1 2 2 3 3 1 3 7 2 1 3 7 1 3 3 3 2 7 3 3 2 7 7 2 2 2
## [9584] 3 7 3 2 3 3 3 1 1 1 7 7 7 3 3 7 3 8 2 2 3 7 3 3 2 7 7 8 7 3 7 2 6 7 3 3 2
## [9621] 2 3 3 1 3 3 3 7 2 1 3 2 8 7 2 8 7 2 7 4 2 2 2 3 2 3 1 7 7 6 8 7 2 3 1 7 3
## [9658] 7 2 2 6 7 3 7 7 7 7 2 7 7 2 2 3 1 3 7 2 7 7 7 8 7 2 8 7 7 2 1 2 7 7 3 8 2
```
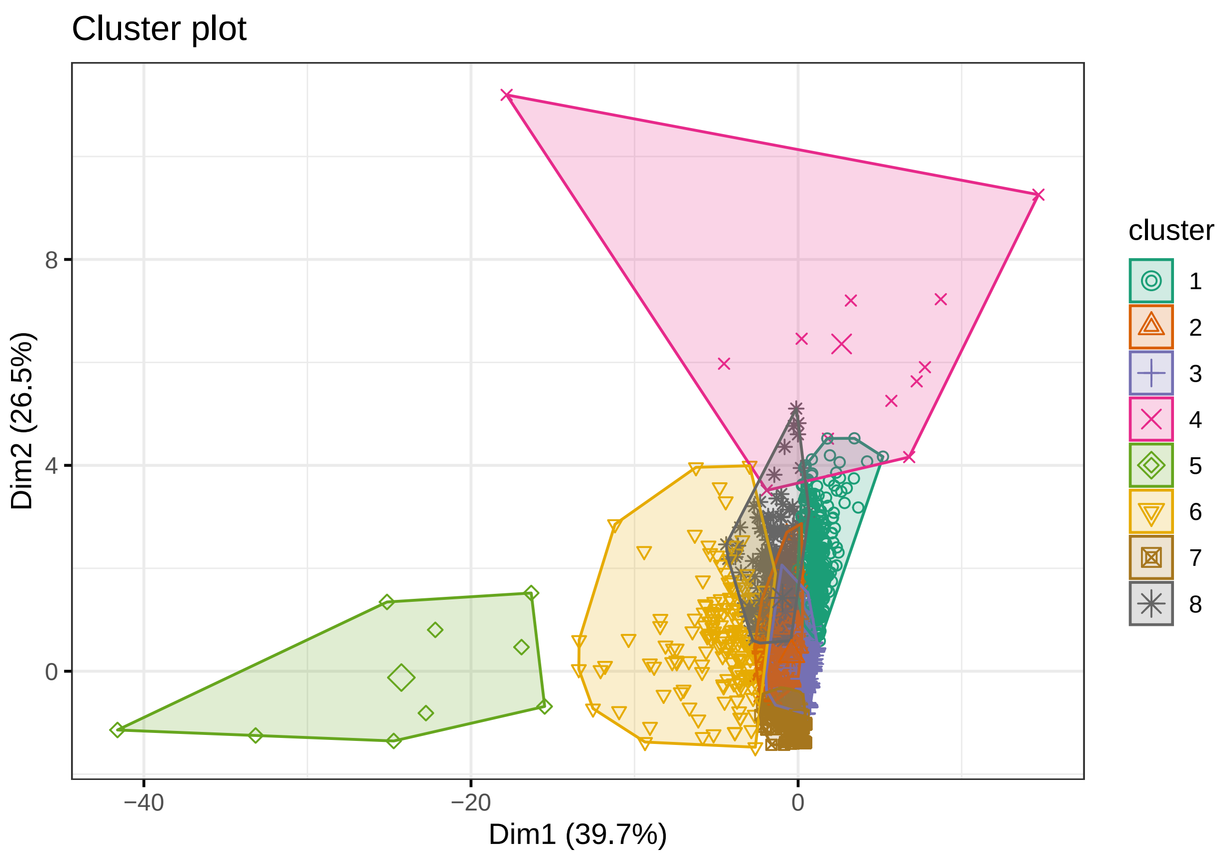

```
## [9695] 7 3 2 3 7 7 3 7 7 2 7 3 3 7 7 7 3 1 2 2 3 3 3 2 2 3 7 7 7 8 3 7 2 2 7 3 2
## [9732] 8 8 7 7 3 7 7 2 2 7 6 2 7 3 3 3 1 3 7 3 3 3 7 7 7 7 2 7 2 7 7 7 7 2 7 7 2
## [9769] 2 2 3 3 2 7 4 1 1 8 1 1 7 3 2 7 7 7 2 2 3 3 3 2 3 3 1 1 3 3 3 3 3 2 3 7 7
## [9806] 3 1 3 1 2 3 7 7 2 2 2 3 2 3 3 8 1 7 7 3 3 3 7 3 3 3 1 3 2 1 1 2 7 7 3 8 7
## [9843] 3 3 1 3 2 2 2 7 7 3 7 2 7 7 2 6 2 7 7 7 7 7 7 7 7 2 7 3 1 1 3 3 7 3 7 3 1 3
## [9880] 2 3 7 8 7 7 7 7 7 7 7 7 2 2 7 2 8 3 3 3 3 3 3 3 1 3 2 3 3 2 7 7 2 3 7 7 2
## [9917] 7 7 7 2 1 1 3 3 7 8 7 7 7 6 3 2 2 7 3 3 7 3 2 7 2 8 8 2 7 3 3 6 6 7 7 7 3
## [9954] 7 3 3 2 7 7 3 7 3 3 3 7 7 2 2 7 2 7 2 3 2 2 7 3 2 3 8 7 2 2 7 8 7 7 7 2 3
## [9991] 7 3 7 7
##
## Within cluster sum of squares by cluster:
## [1] 1692.9327 1850.0638 1220.0787 1460.2766  778.7336 1798.3840  994.1753
## [8]  958.1986
##  (between_SS / total_SS =  73.1 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

The within cluster sum of squares by cluster value is 73.1% for k= 8, which is not very different from the Within cluster sum of square by cluster value for k = 7 (70.2%).

Let's plot the K-means clusters

```r
library(RColorBrewer)
fviz_cluster(clustering_results_8, data = data1[,(15:18)],
             palette = brewer.pal(n = 8, name = "Dark2"),
             geom = "point",
             ellipse.type = "convex",
             ggtheme = theme_bw()
             )
```



There are still some overlaps between cluster groups.

Compute PCA and extract individual components and extract individual components.

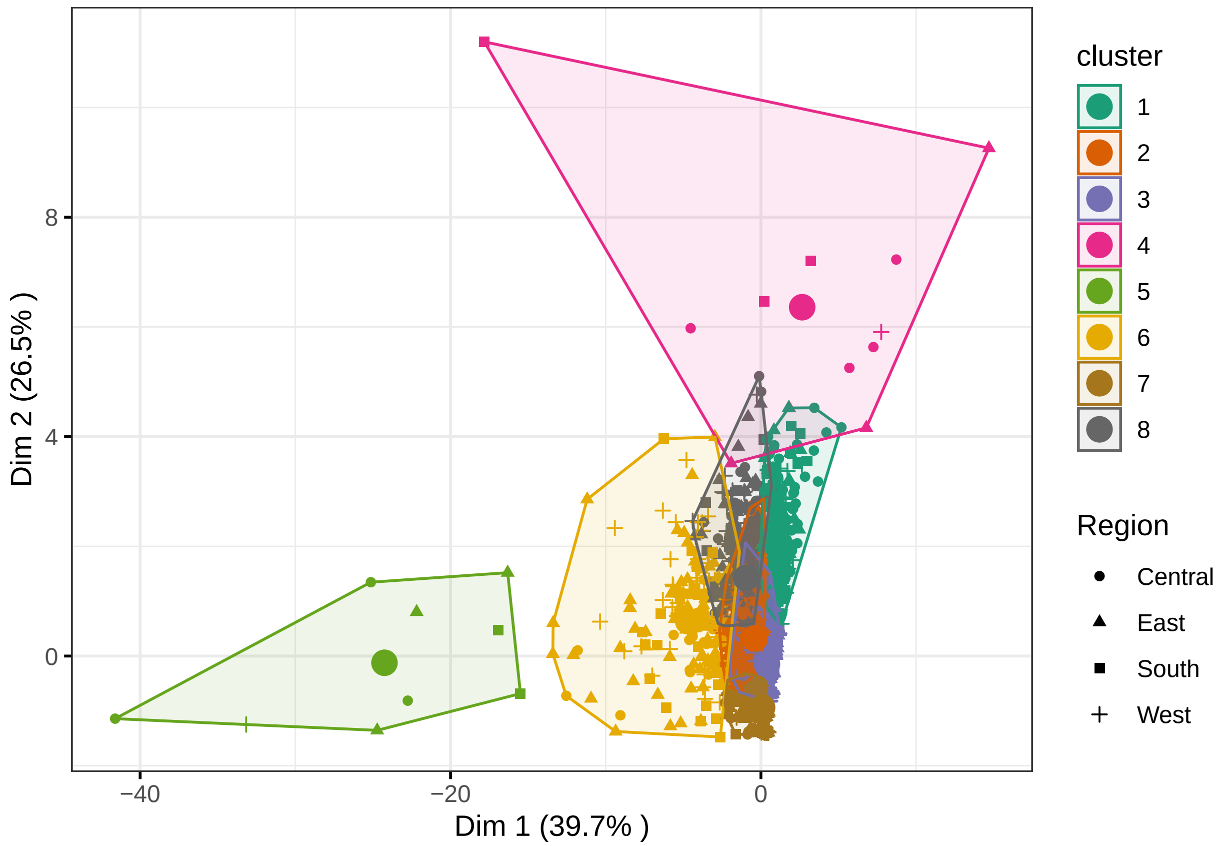
```
# Dimension reduction using PCA
results_pca_8 <- prcomp(data1[,(15:18)],  scale = TRUE)

# Coordinates of individuals
ind.coord <- as.data.frame(get_pca_ind(results_pca_8)$coord)

# Add clusters obtained using the K-means algorithm
ind.coord$cluster <- factor(clustering_results_8$cluster)

# Add Region groups from the original data sett
ind.coord$Region <- data1$Region

#look at the first few rows to double check
head(ind.coord)
```

```
##        Dim.1      Dim.2       Dim.3       Dim.4 cluster Region
## 1 -0.0426607 -1.0508481  0.14635987  0.31244832       7  South
## 2 -1.1546701 -0.7511273  0.25351937  0.22331213       7  South
## 3  0.3107253 -1.1081474 -0.01276717  0.15000936       7   West
## 4  0.6283963  1.9637213  0.37261495  1.54367992       1  South
## 5  0.5768386 -0.4056909  0.55980463 -0.06649362       3  South
## 6 -0.3936310  0.3152509 -1.56442060 -0.20148637       2   West
```

```r
# Percentage of variance explained by dimensions
eigenvalue <- round(get_eigenvalue(results_pca_8), 1)
variance.percent <- eigenvalue$variance.percent
head(eigenvalue)
```

```
##       eigenvalue variance.percent cumulative.variance.percent
## Dim.1        1.6             39.7                        39.7
## Dim.2        1.1             26.5                        66.2
## Dim.3        0.9             22.0                        88.3
## Dim.4        0.5             11.7                       100.0
```

```r
ggscatter(
  ind.coord, x = "Dim.1", y = "Dim.2",
  color = "cluster", palette = brewer.pal(n = 8, name = "Dark2"), ellipse = TRUE, ellipse.type = "conve
  shape = "Region", size = 1.5,  legend = "right", ggtheme = theme_bw(),            #change point s
  xlab = paste0("Dim 1 (", variance.percent[1], "% )" ),
  ylab = paste0("Dim 2 (", variance.percent[2], "% )" )
) +
  stat_mean(aes(color = cluster), size = 4)       #add cluster centroid using stat_mean()
```



Clustering Validation

(https://towardsdatascience.com/clustering-analysis-in-r-using-k-means-73eca4fb7967)

Silhouette coefficient can be used to evaluate the goodness of the clustering. First, for each observation i, it calculates the dissimilarity between i and all the other points within the same cluster. This value is called average dissimilarity Di.

Then calculate the dissimilarity between i and all the other clusters and get the lowest value among them. Find the dissimilarity between i and the next closest cluster, called Ci.

Next find the silhouette width which is the difference between Ci and Di, divided by the maximum difference between Ci and Di. Si = (Ci - Di)/max(Di, Ci)

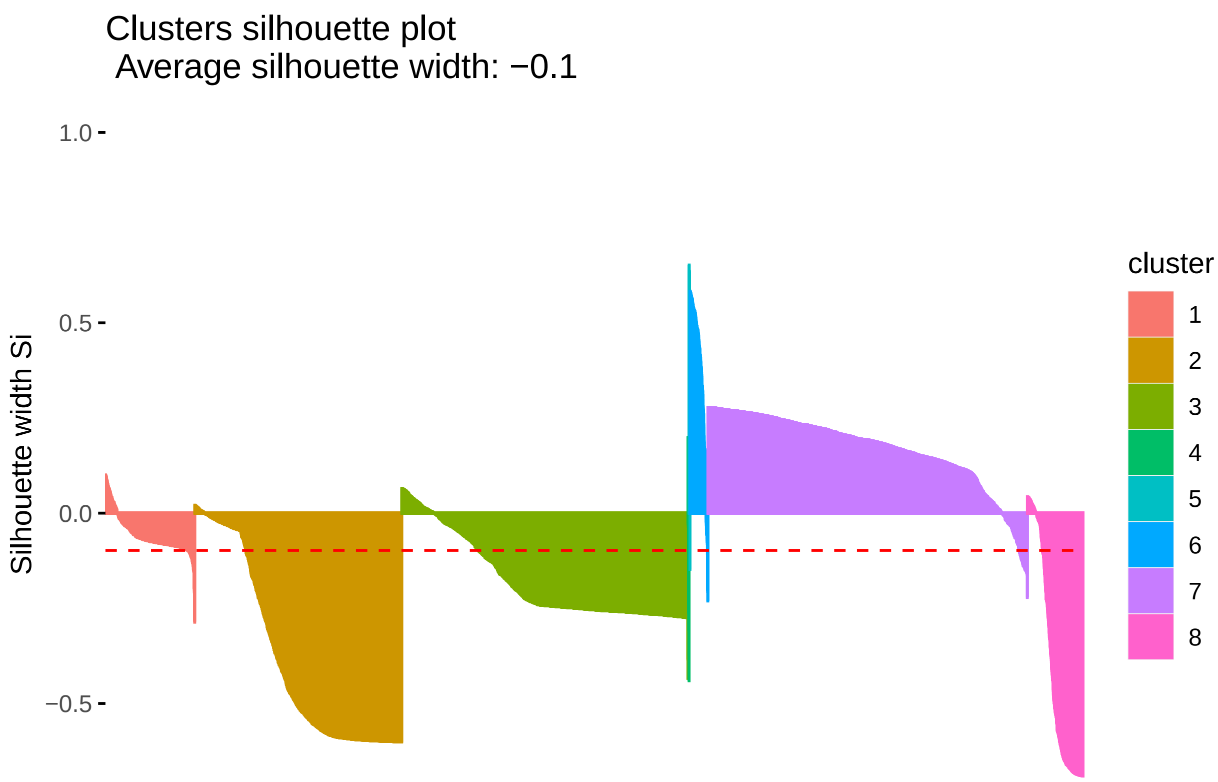
Si>0 means the observation is well clustered. The closer it is to 1 the better it is clustered.

Si <0 means the observation is wrongly clustered.

Si = 0 means the observation is between 2 clusters.

```
library(cluster)
library(factoextra)

sil <- silhouette(clustering_results_8$cluster, dist(data1[,(15:18)]))
fviz_silhouette(sil)
```

```
##   cluster size ave.sil.width
## 1       1  912         -0.06
## 2       2 2114         -0.38
## 3       3 2923         -0.18
## 4       4   12         -0.17
## 5       5    9          0.48
## 6       6  182          0.37
## 7       7 3263          0.17
## 8       8  579         -0.40
```



From the table, 5 of the 8 clusters have a negative silhouette width which means that some observations may be in the wrong cluster, so the clustering is not very good.

Method 2: K-medoids

Following this tutorial: https://towardsdatascience.com/clustering-on-mixed-type-data-8bbd0a2569c3

K-means algorithm is limited in that it can only work with numerical data, whereas our dataset contains both numeric and categorical data.

We will now try the PAM clustering algorithm (Partitioning across medoids). K-medoids is more robust to outliers and noise than K-means. This algorithm uses Gower distance to measure the partial dissimilarity across individuals, and ranges in [0 1]. Standardization is first applied to the features, and the distance between individuals represents the average of all feature specific distances.

Partial dissimilarity is different depending on the type of variable: numeric or categorical.

Numeric features - partial dissimilarity is dependent on absolute difference between 2 observations (x_i and x_j), and the maximum range observed from all individuals. d_ij^f = |x_i - x_j|/|max_N(x) - min_N(x))| where N is the number of individuals in a dataset.

Categorical/Qualitative features - feature dissimilarity is equal to 1 if y_i and y_j do not have the same values, otherwise it is 0.

One method to determine the number of clusters is by using the Silhouette coefficient.

Data Preparation

For this K-medoids analysis we will omit the Region variable because there are only 4 values and the information is too broad.

We will try to cluster transactions according to the following features:

```
data2 <- data1 %>%
              select(Ship_Mode, Segment, City, State, Sub_Category, diff_in_days, Sales, Quantity, Disco

#convert all character data type to factor:
data2[sapply(data2, is.character)] <- lapply(data2[sapply(data2, is.character)],
                                           as.factor)
```

Compute Gower distance

```
gower_dist <- daisy(data2, metric = "gower")

gower_mat <- as.matrix(gower_dist)
```

```
#Print most similar transactions
data2[which(gower_mat == min(gower_mat[gower_mat != min(gower_mat)]), arr.ind = TRUE)[1, ], ]
```

```
##            Ship_Mode  Segment    City State Sub_Category diff_in_days Sales
## 4875 Standard Class Consumer Houston Texas      Binders            4 1.188
## 3326 Standard Class Consumer Houston Texas      Binders            4 1.234
##      Quantity Discount  Profit
## 4875        1      0.8 -1.9602
## 3326        1      0.8 -1.9744
```

Deployment

Responsible ML Framework

Conclusion

References

https://www.datanovia.com/en/blog/k-means-clustering-visualization-in-r-step-by-step-guide/

https://www.tidymodels.org/learn/statistics/k-means/

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