

# ML 1000 Assignment 2

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## 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

The Superstore is a chain of stores all over the United States with an online website where customers can view and order products. The Superstore company would like to understand more about customer preferences such as the types of products ordered, category, shipping service, quantity of items bought and whether customers use discounts. With a greater understanding of customer needs by location (city), the Superstore can then use this information to update their website. In particular, when customers select their city on the Superstore website, the site may show more products of a certain category which is commonly ordered by customers located in that area. By conducting clustering on transaction data which spans over 3 years, the Superstore company find out groupings of transactions which may share similarities. For example, if a group of transactions indicate customers from a certain location are similar in typically using discounts, the Superstore may offer more promotional offers on their site for customers at that location. Another example would be if a cluster of transactions indicate typical sales are higher than other groupings, then the Superstore may display more expensive items on their site for customers in that location.

## Objective

Detect point anomalies from superstore dataset using K-NN and clustering methods. The objective is to detect point anomalies from superstore dataset using K-NN and clustering methods. Another objective is to use clustering methods to find commonalities in the transactions in order to offer more relevant products to customers based on their location and typical sales transactions. The clustering methods used are K-means, K-medoids and the principal components method using Factor Analysis of Mixed Data (FAMD).

## Data Understanding

US Superstore dataset is sourced from US uperstore dataset . The dataset has 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

```
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 |
| 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          |

## Exploratory Data Analysis

```
#check duplicates
#data %>% distinct()
data_nodup=distinct(data,data[,1:21], keep_all=TRUE) [,-22]
#dim did not change - no dup

#check missing values
n=c()
for (i in 1:ncol(data)) {
  n[i]=sum(is.na(data[,i]))
}
missing_values=paste0(colnames(data),rep("-",ncol(data)),n,rep(" missing values",))
#cat("The number of missing values for each variable are:")
missing_values

## [1] "i..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"

#no missing values
data_miss=data[!complete.cases(data),]

```

There are no missing values in the dataset.

Get a general idea of the data set.

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

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

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

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

*#793 unique customer names - We can drop one of these two variables since they are redundant.*

```
length(unique(data$Segment))
```

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

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

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

*"Consumer" "Corporate" "Home Office"*

```
unique(data$Country)
```

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

*#all are from US - could drop this variable due to no-variation introduced by it*

```
length(unique(data$City))
```

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

```

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

## [1] 49

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

## [1] 631

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

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

#only 4 regions
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"

#17 sub-categories
length(unique(data$Product.Name))

## [1] 1850

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

## [1] 1862

#1862 product IDs - potential redundant variables!

hist(data$diff_in_days)

summary(data$Sales)

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

```

**Histogram of data\$diff\_in\_days**

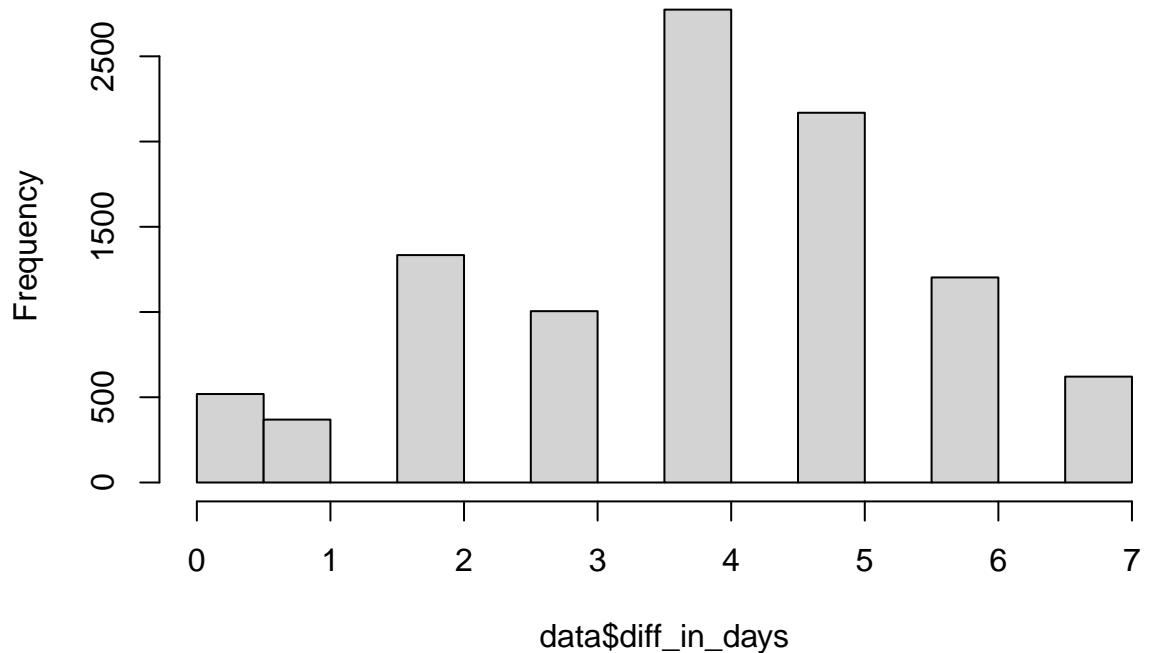


Figure 1: Histogram of time difference between order date and ship date. The time difference between order date and ship date typically takes 4 days.

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

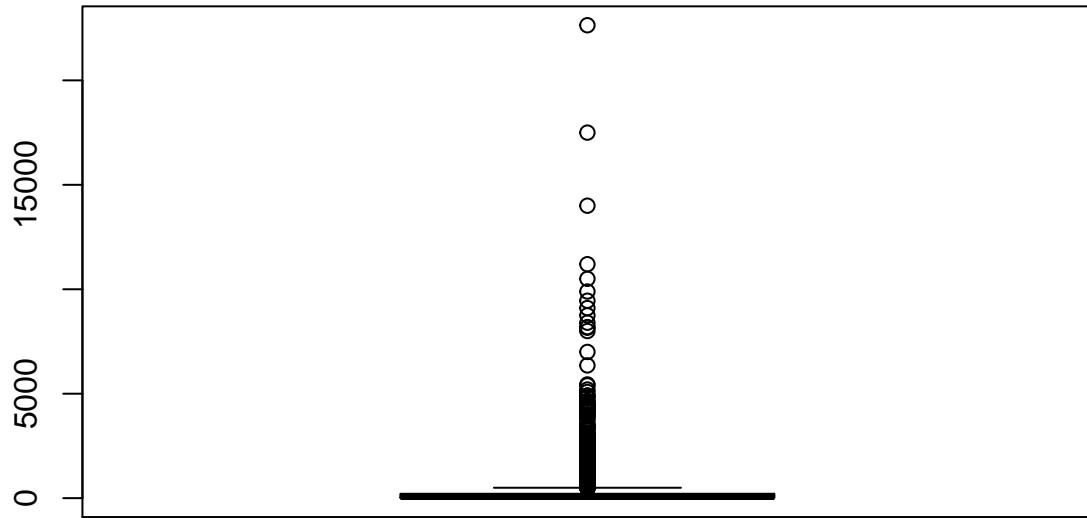


Figure 2: Boxplot of sales showing many outliers.

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

```
# 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
```

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

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

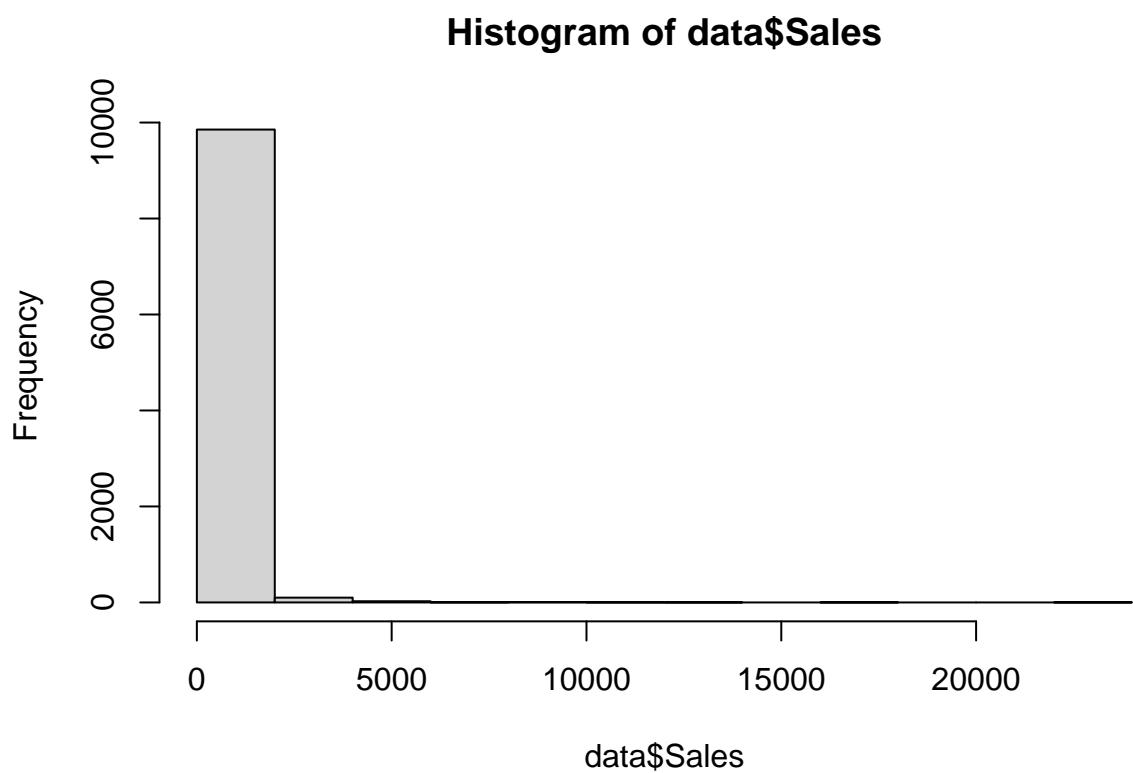


Figure 3: Histogram of sales values.

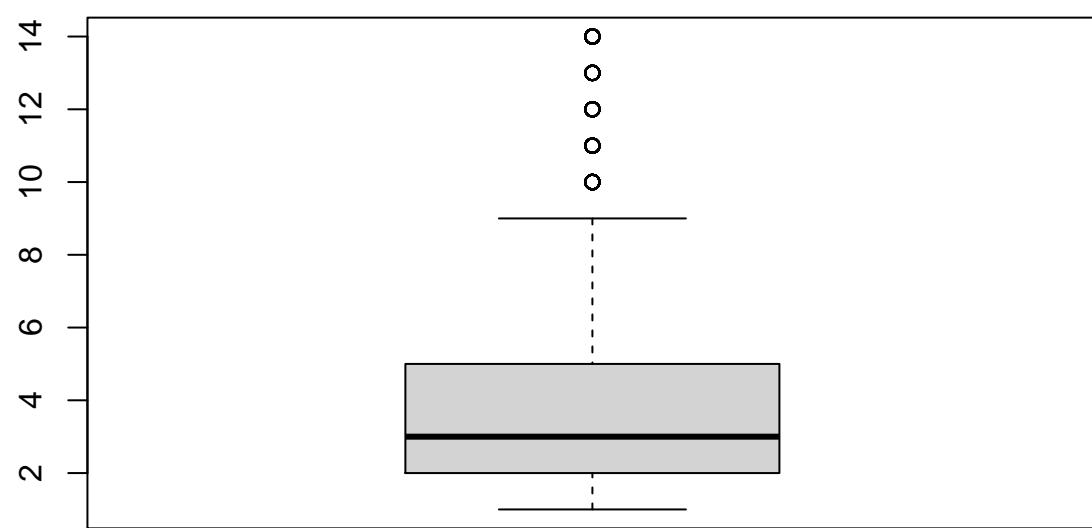


Figure 4: Boxplot of quantity values

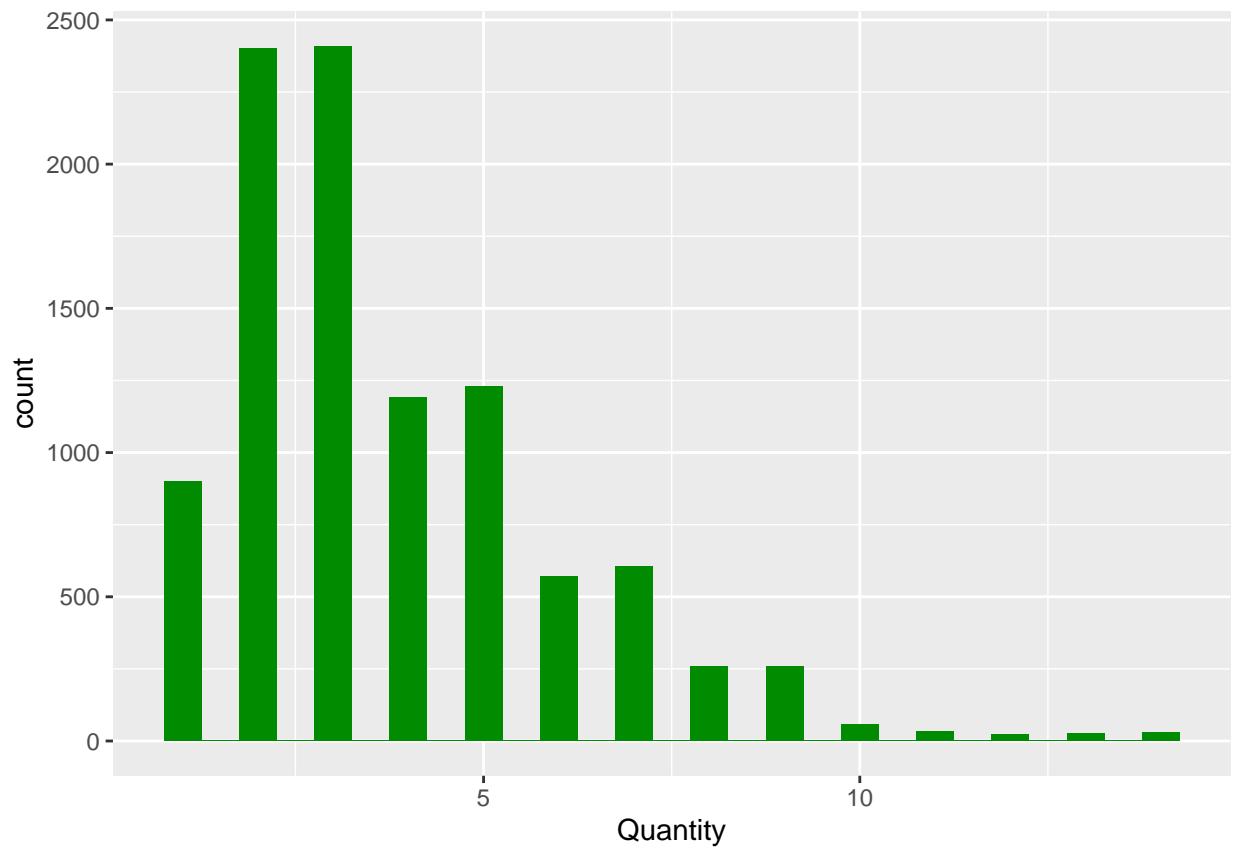


Figure 5: Plot of quantity distribution of transaction. There is a very skewed distribution where most of the orders have small number of items and there are not a lot of outliers

```

summary(data$Discount)

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

boxplot(data$Discount)

```

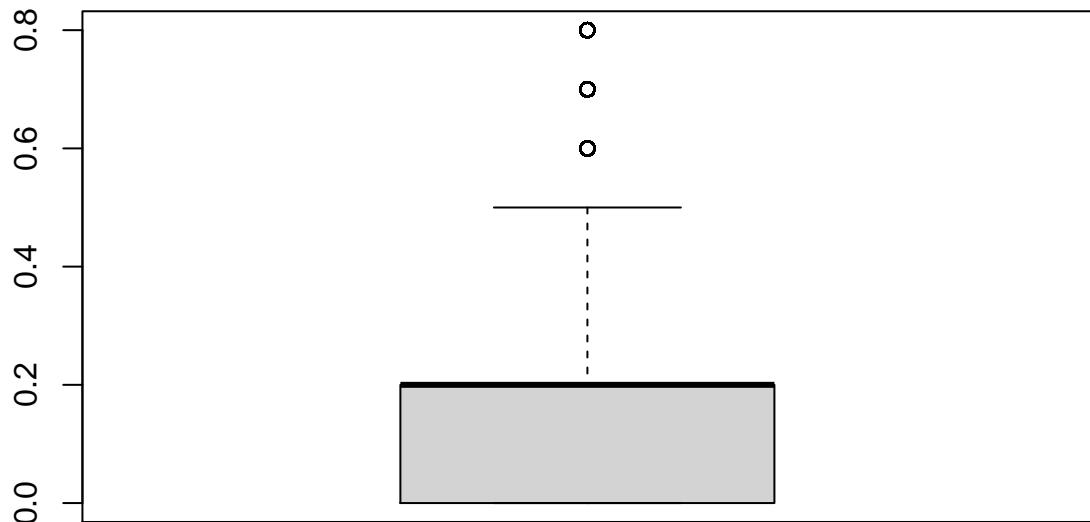


Figure 6: Boxplot of discount values. A strange looking box dataplot - median & 3rd quantile are the same (0.2) and not many orders have high discounts

```

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

## Warning: Ignoring unknown parameters: xlab

boxplot(data$Profit)

```

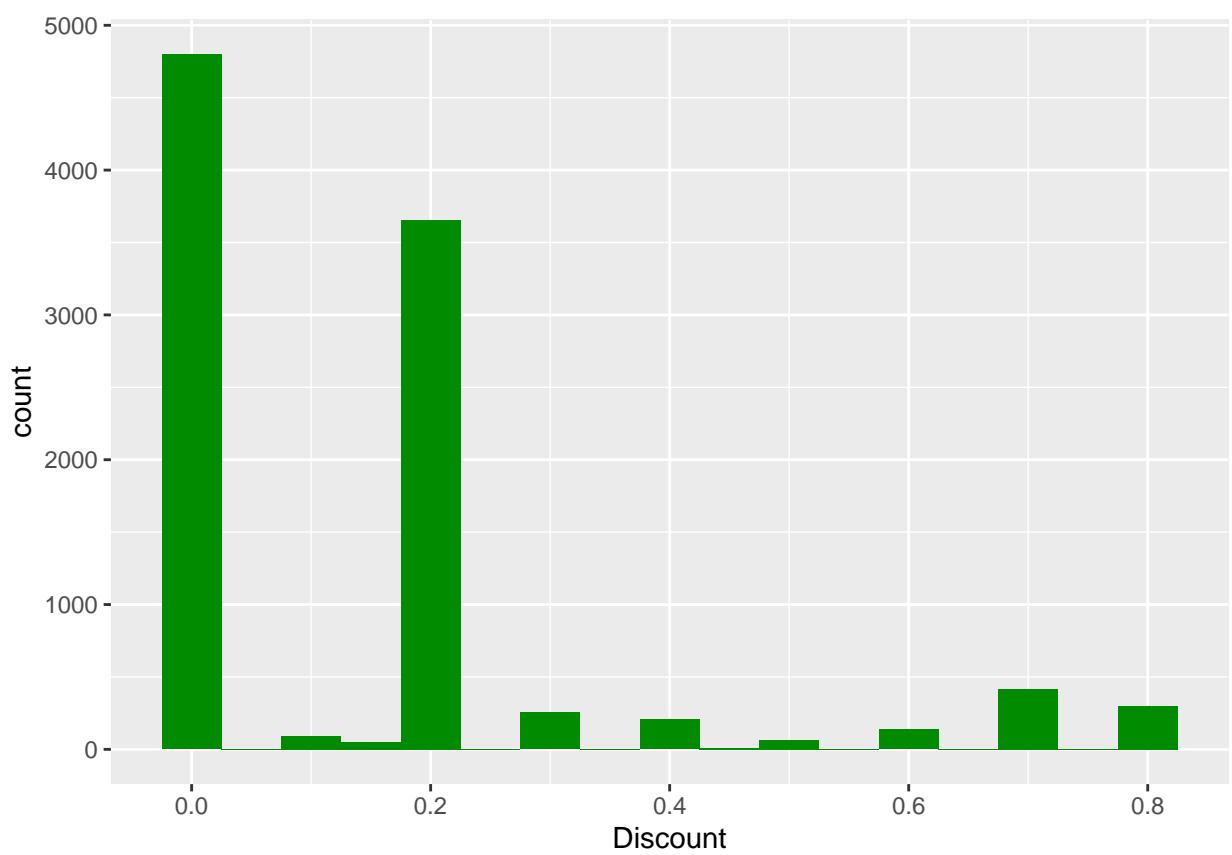


Figure 7: Plot of transactions involving discounts. Sales transactions mostly do not involve discounts.

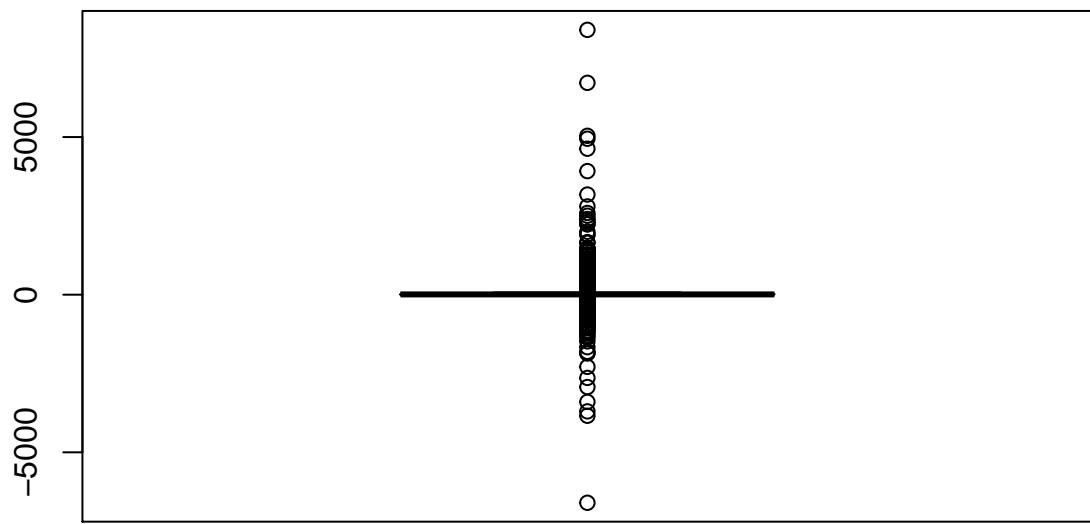


Figure 8: Boxplot of profit. Most of the profits are outside of the box - but most of them clustered close to the box(not with so extreme values

```

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`.

```

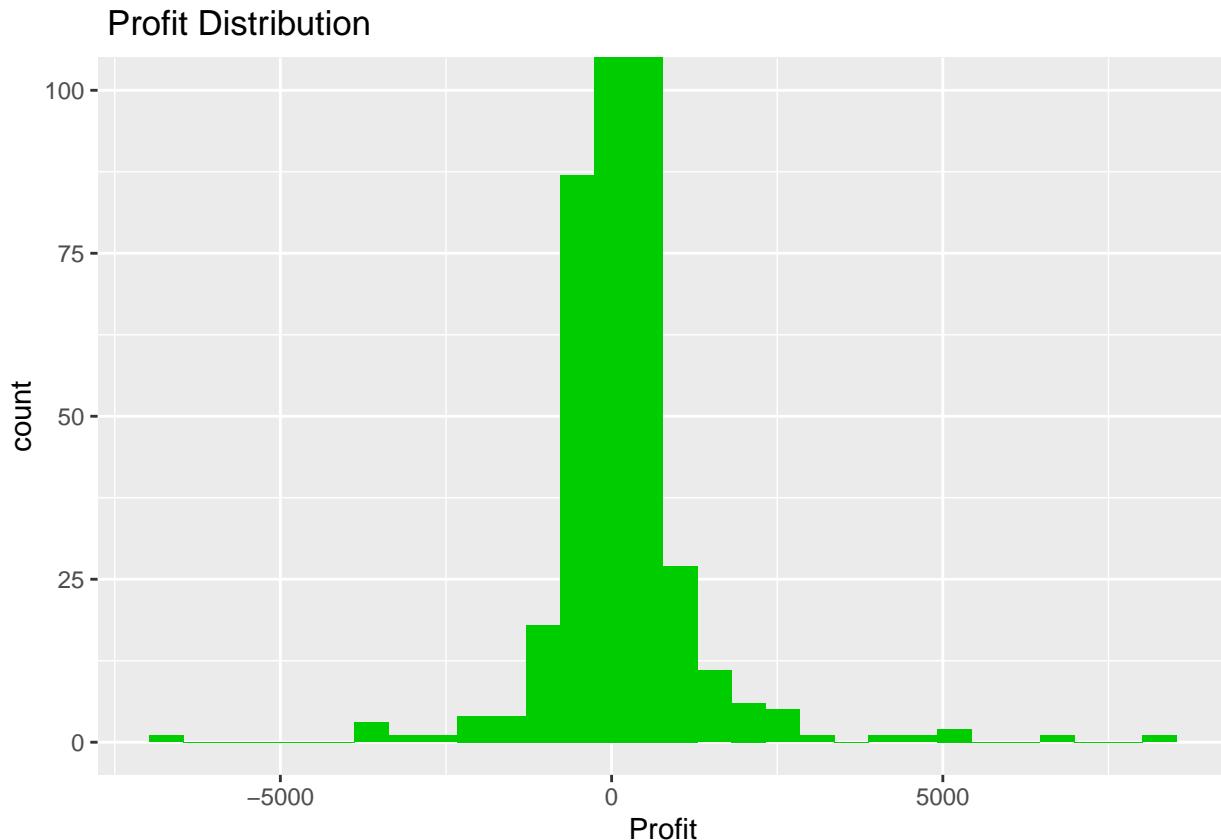


Figure 9: Profit distribution from transactions

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

```
summary(data$Profit)
```

```

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

```

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

```

## [1] "i_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"

```

Plot Sales in relation to Order Date:

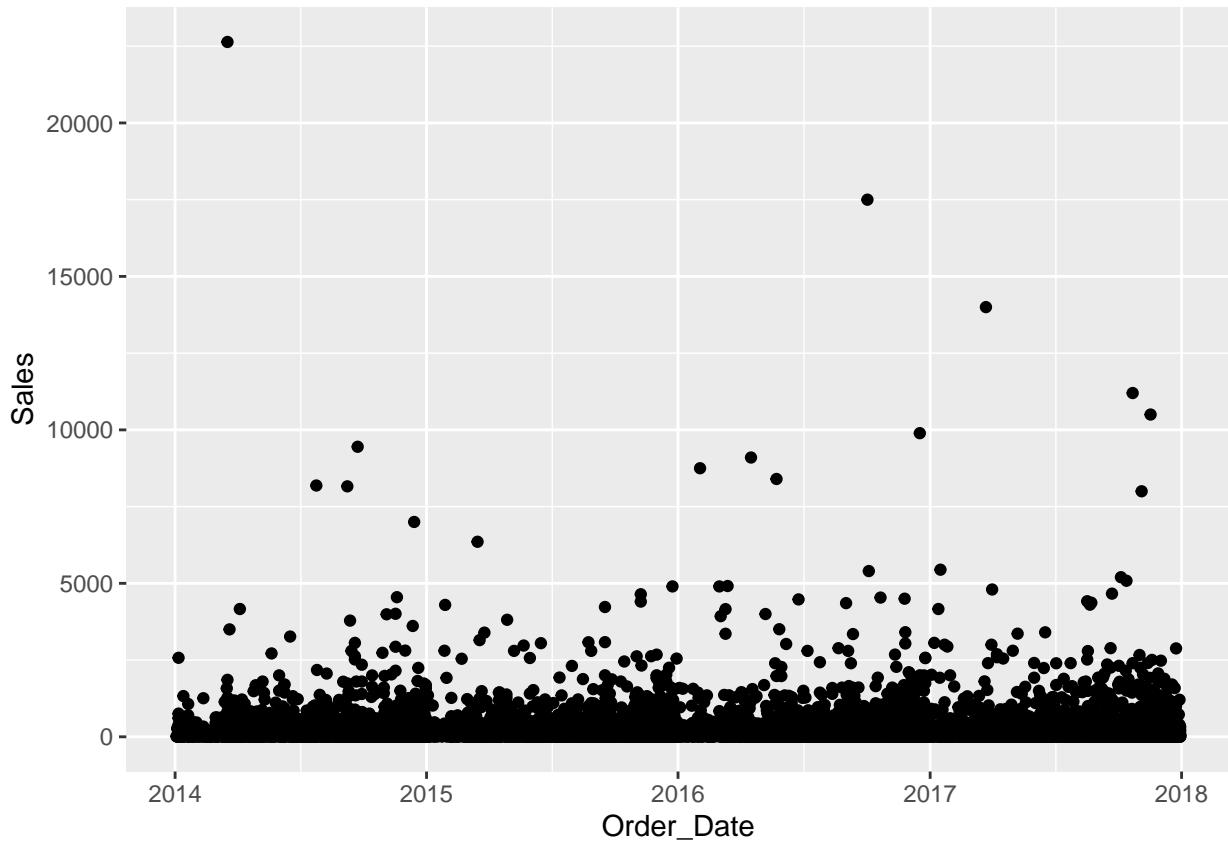


Figure 10: Sales by order date. There are some clear outliers where the sales amount is much greater

Plot Profit in relation to Order Date:

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

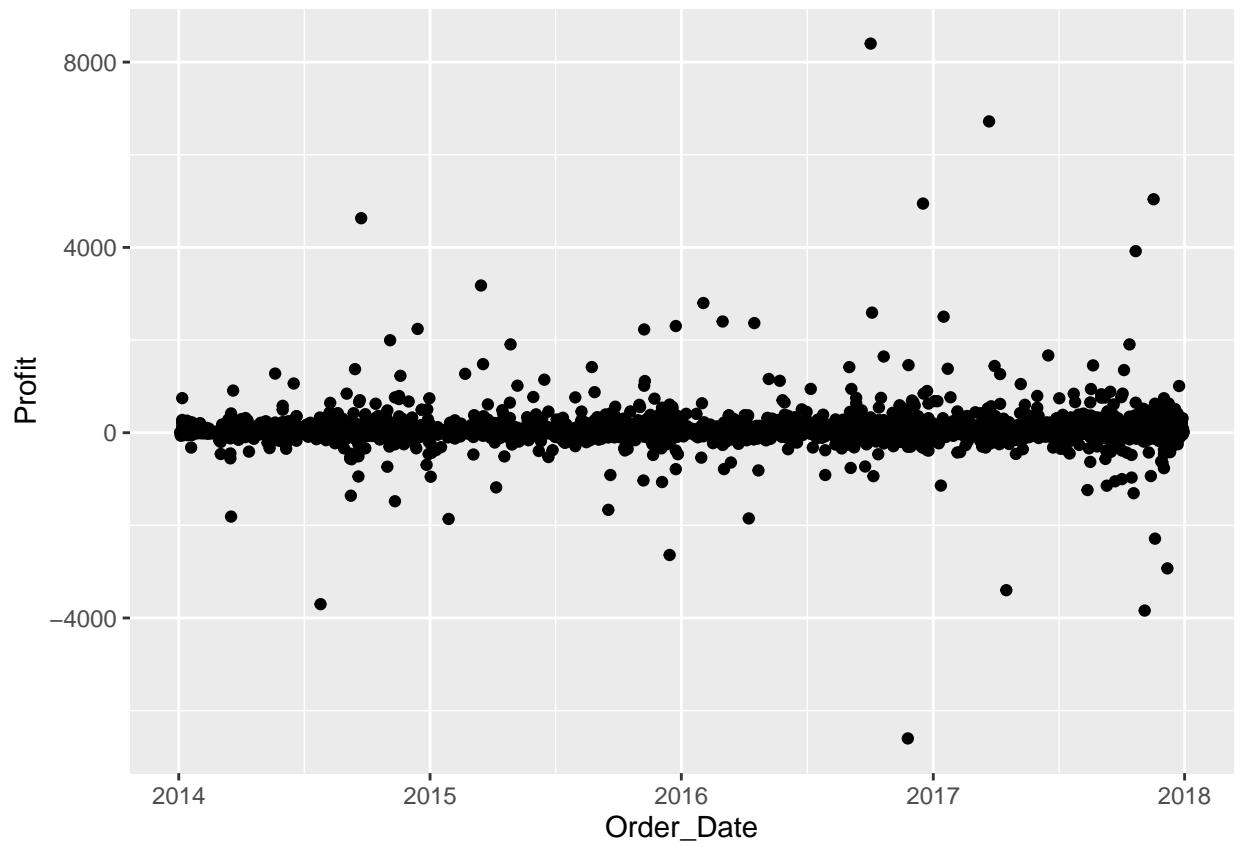
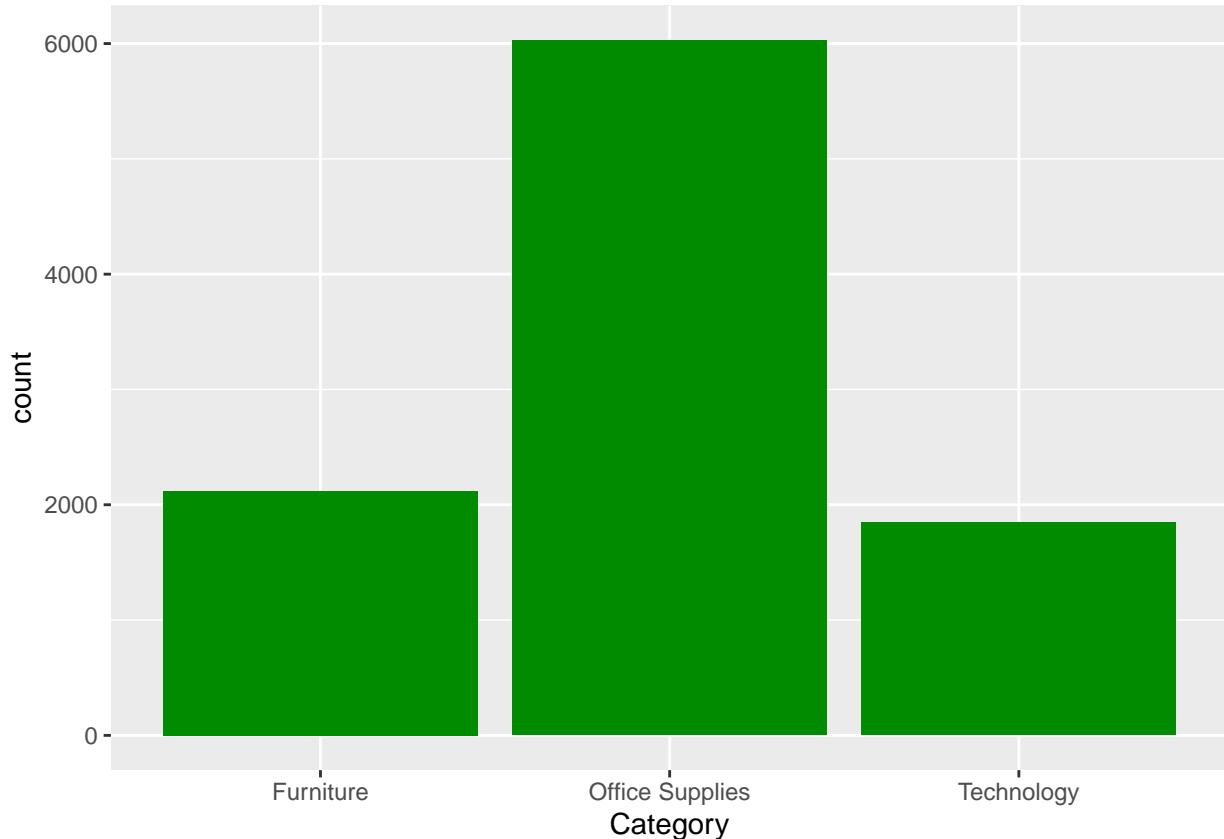


Figure 11: Profit in relation to order date. There are some outliers for certain days where profit is much lower or higher than the usual amount, such as when profit is below \$2000, or above \$2000.

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

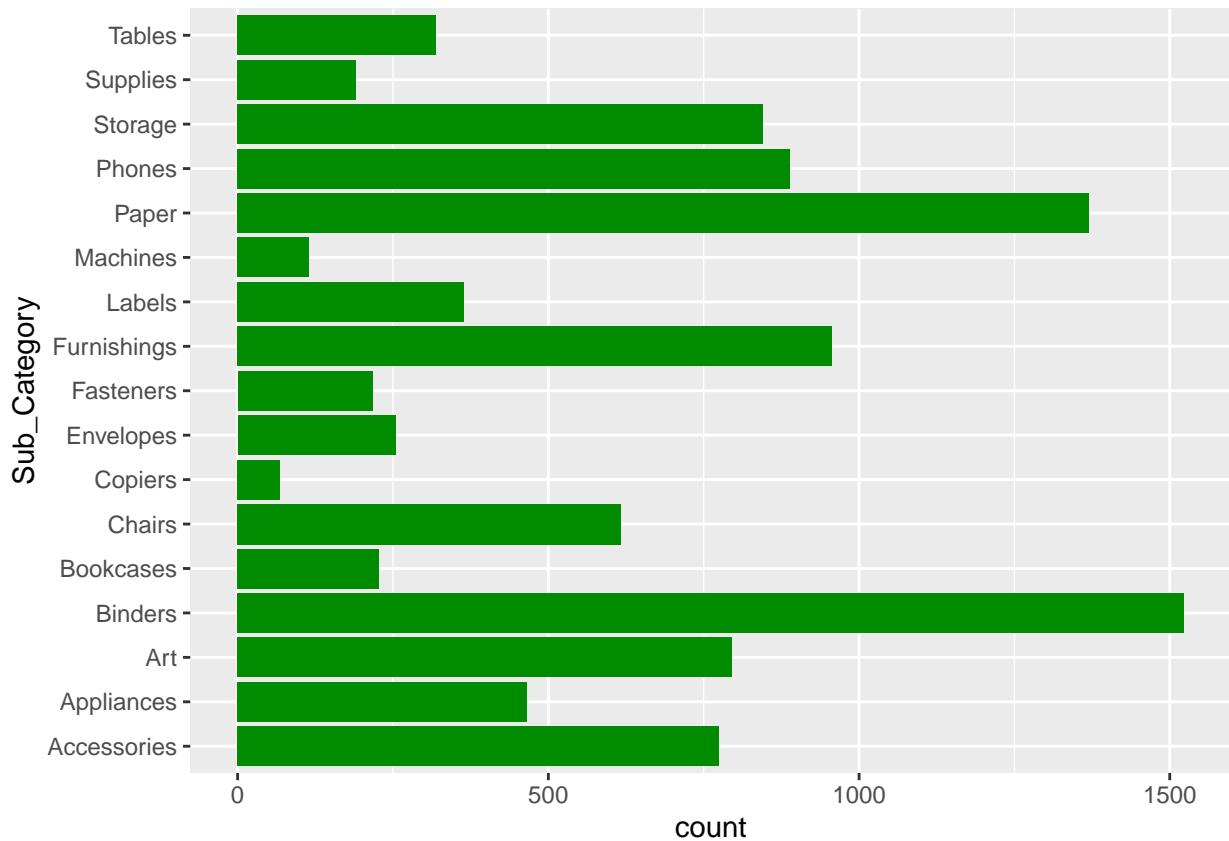
Basically this dataset covers transactions ranging from 2014-01-03 to 2017-12-30.

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



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

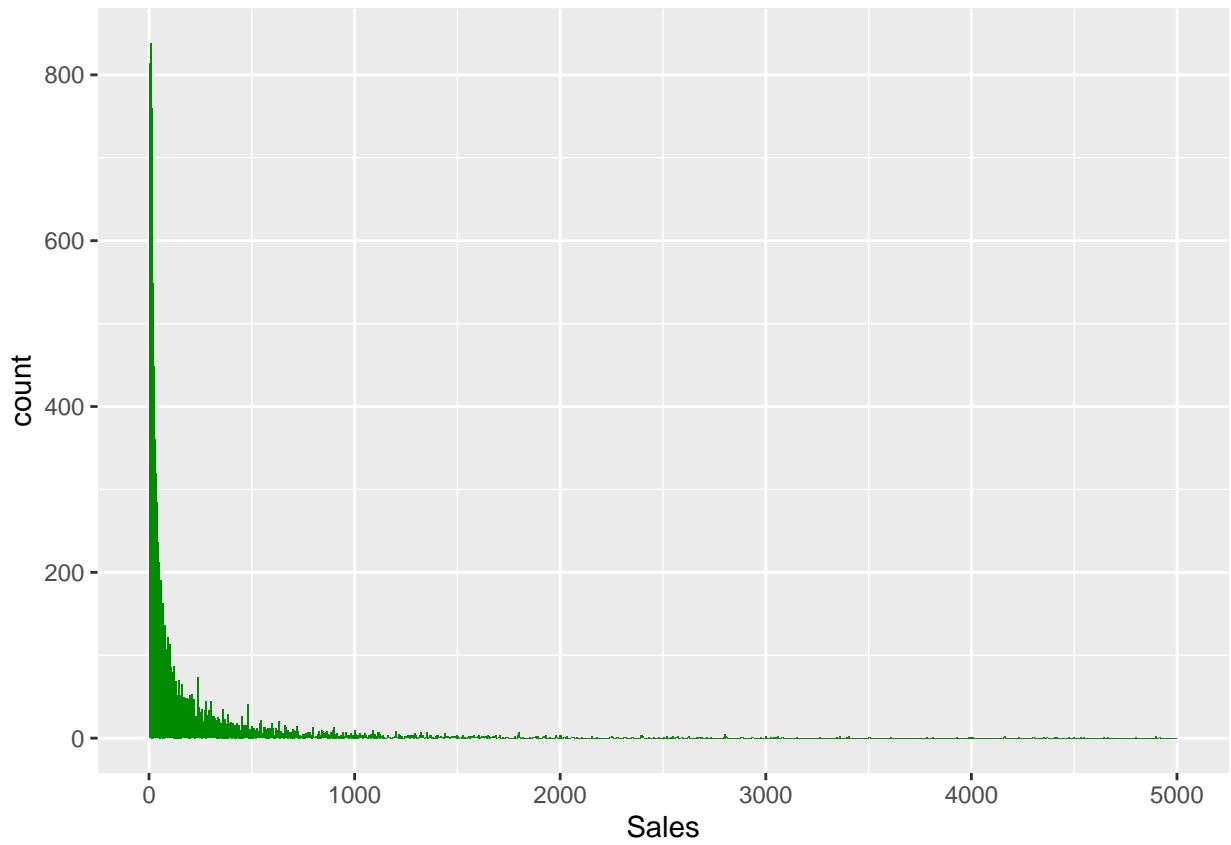
```
ggplot(data = data) +  
  geom_bar(mapping = aes(y = `Sub_Category`), fill="green4")
```



```
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).
```

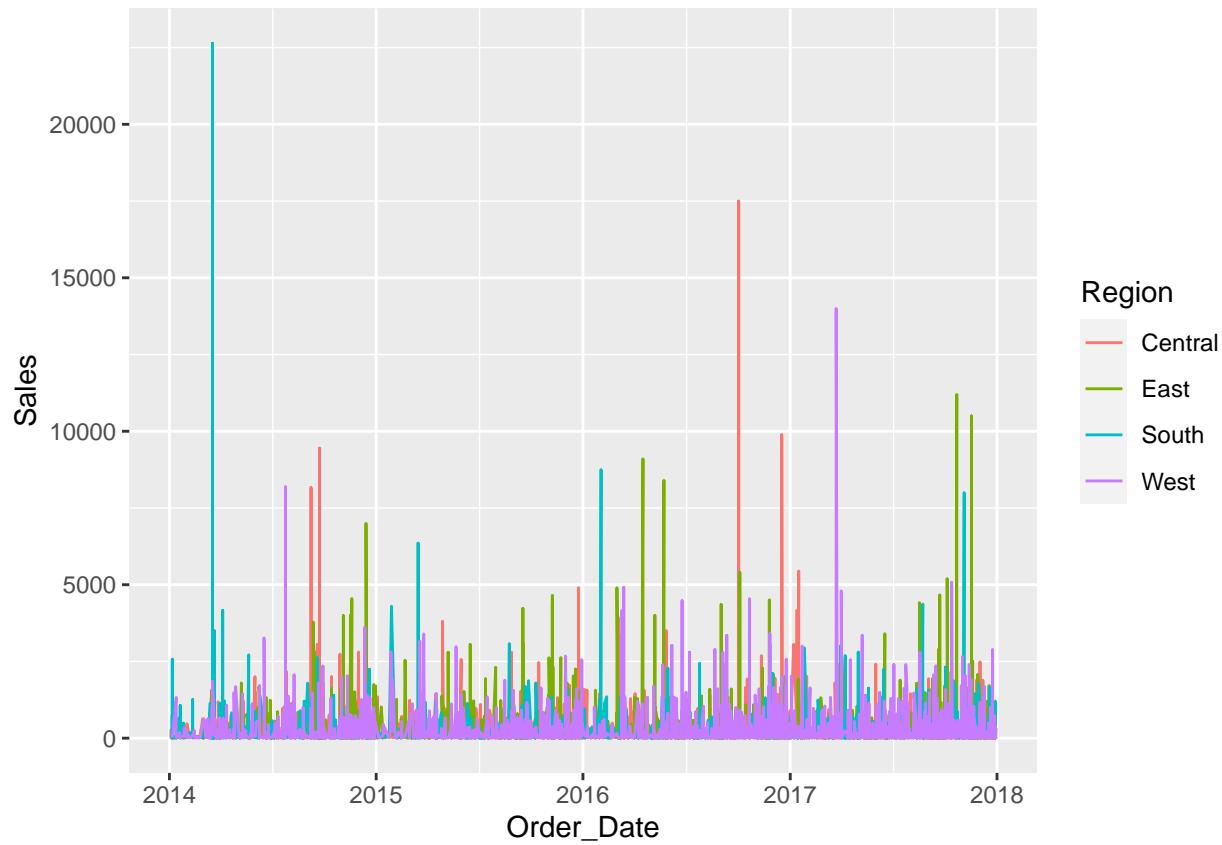
```
## Warning: Removed 2 rows containing missing values (geom_bar).
```



Most sales are very few items (<500).

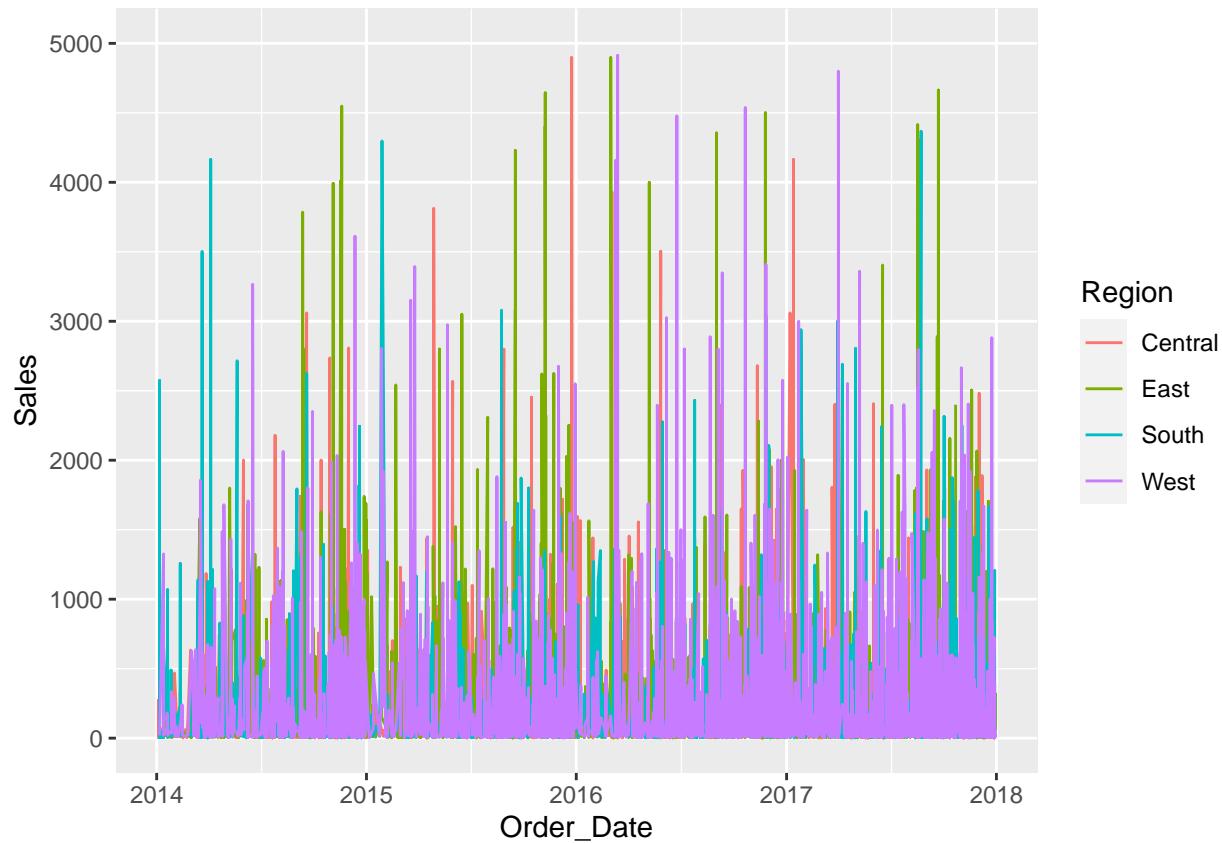
Visualise sales transactions by Region over time (order date).

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



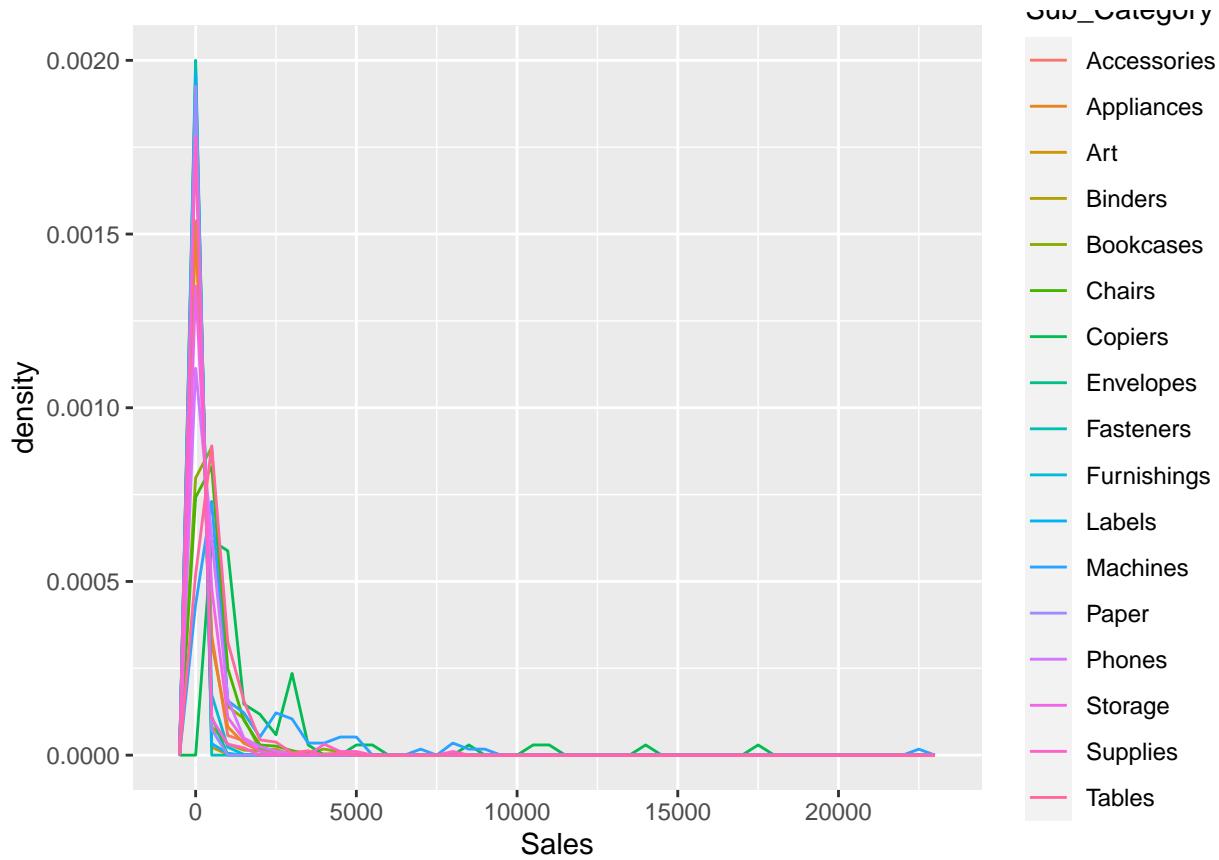
Let's zoom in a little bit - Visualise sales transactions by Region over time (order date).

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



How does profit change with sub-category?

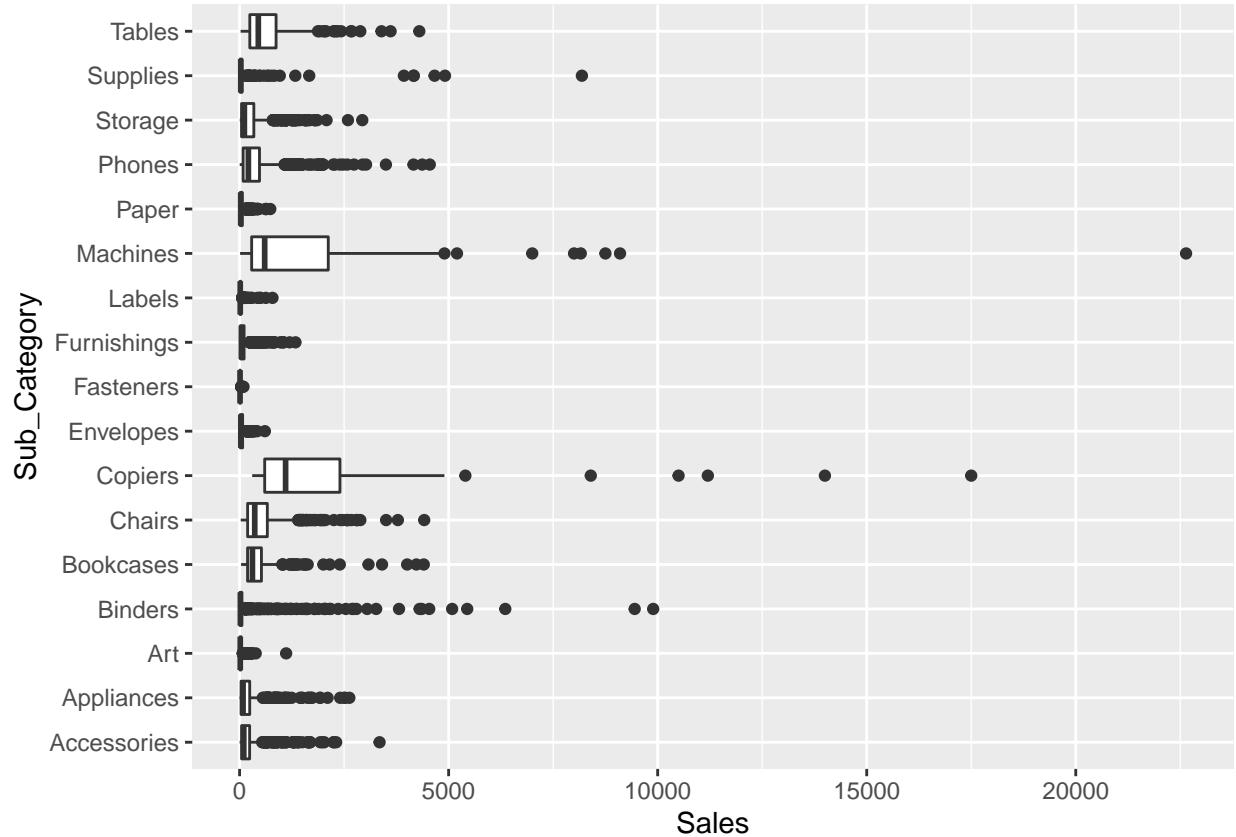
```
#density plot where the count is standardized,area under each frequency is 1
ggplot(data = data, mapping = aes(x = Sales, y = ..density..)) +
  geom_freqpoly(mapping = aes(colour = Sub_Category), binwidth = 500)
```



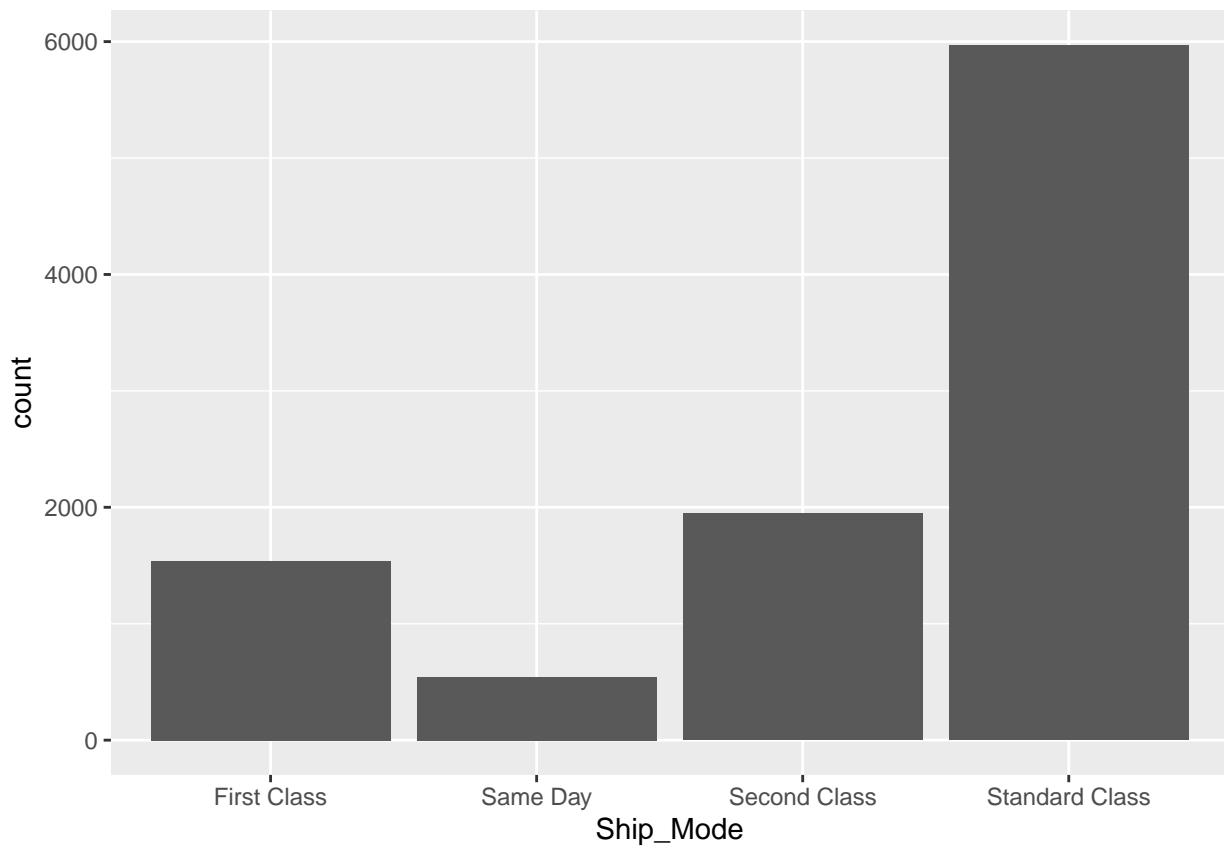
It looks like some categories of items ie. supplies or accessories have negative sales values.

How does sales vary across sub category?

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

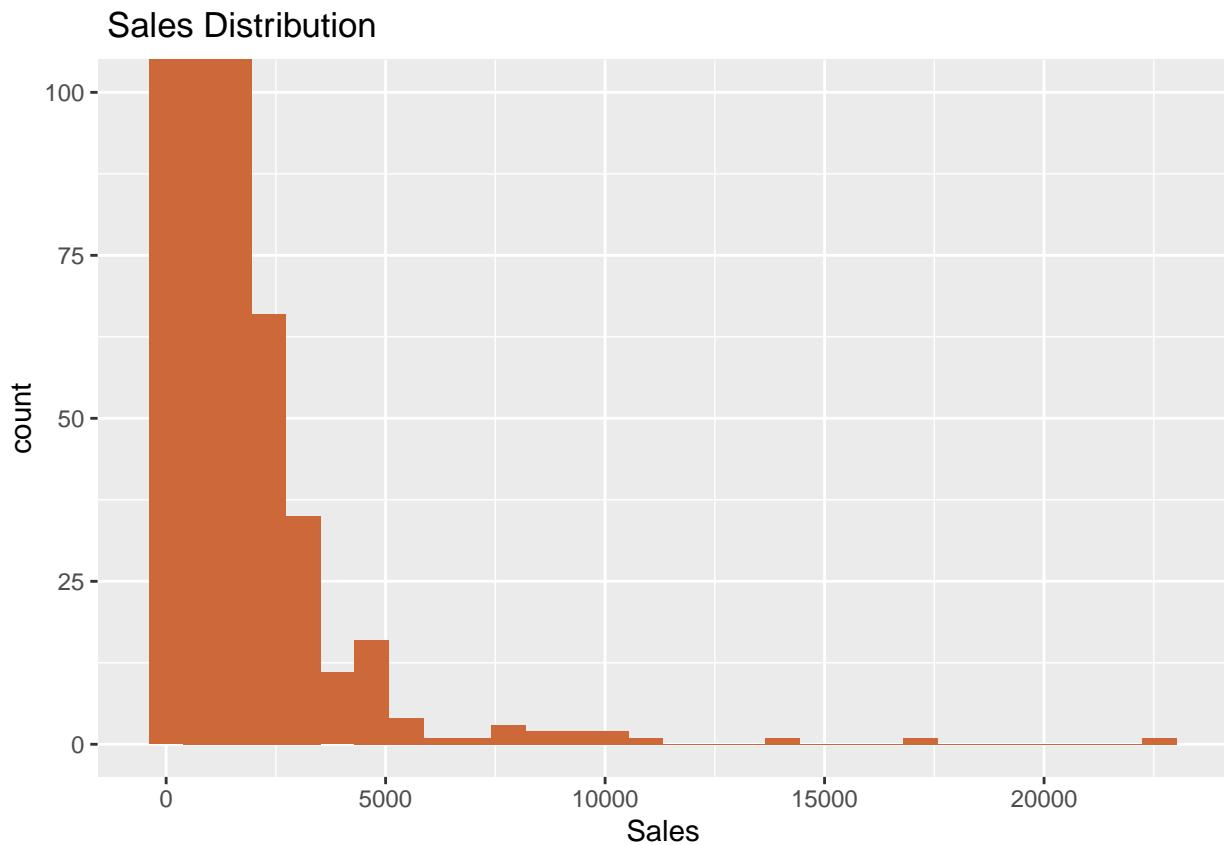


```
ggplot(data = data, mapping = aes(x = Ship_Mode)) +  
  geom_bar()
```



Most transactions are shipped via Standard Class method.

```
ggplot(data)+  
  geom_histogram(mapping=aes(x=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")
```

*#Most of the orders were placed without any discounts or with 20% off*

### Sales Profit

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

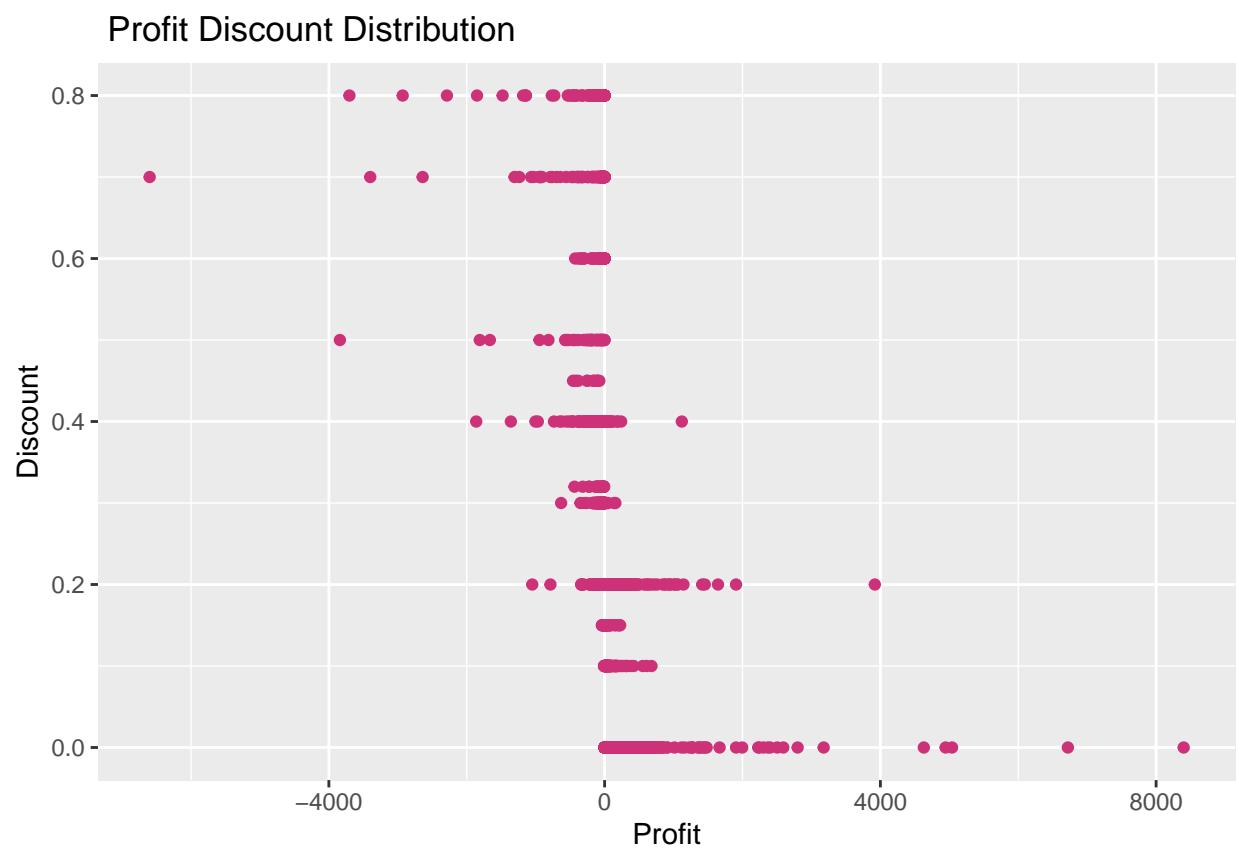
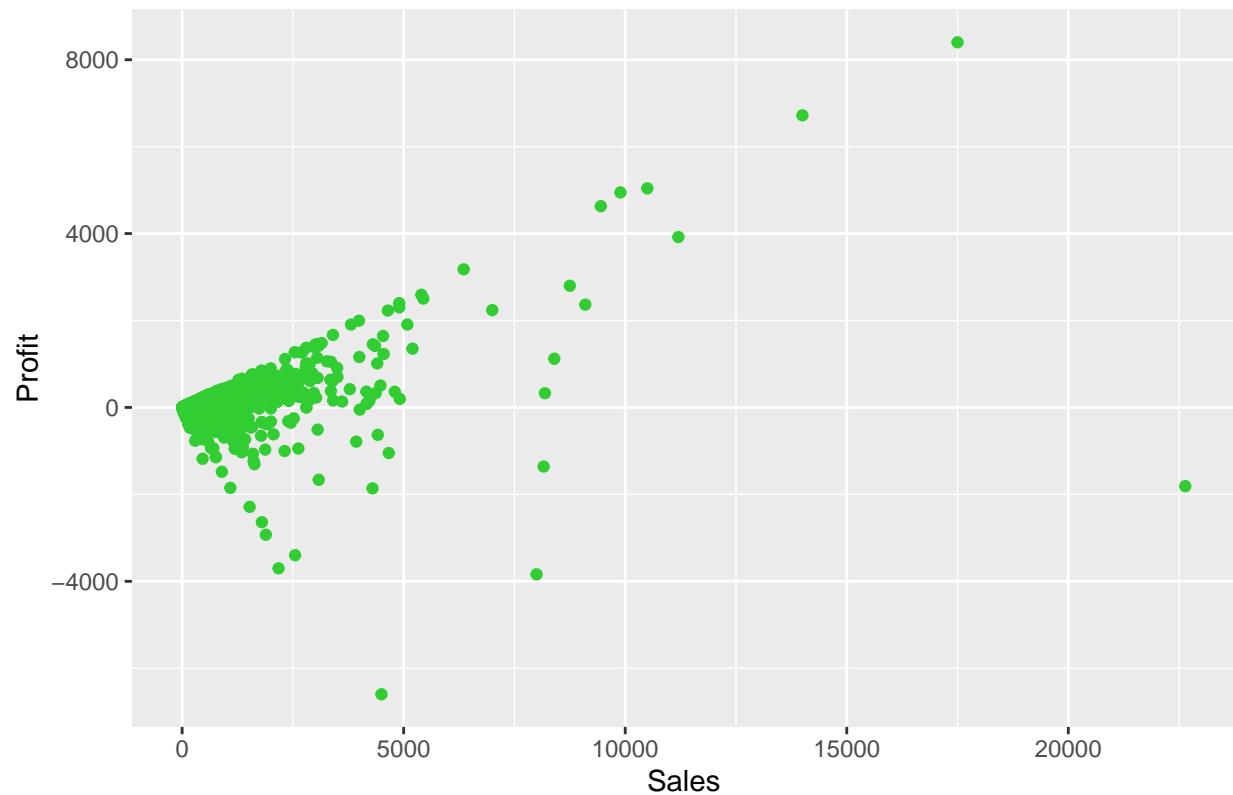


Figure 12: Plot of profit versus discount

## Sales Profit Distribution



```
#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
```

```
#total category and subcategory
```

```

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

## [1] 3

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

## [1] 17

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

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

superstore_sales<-as_tibble(superstore_sales)

```

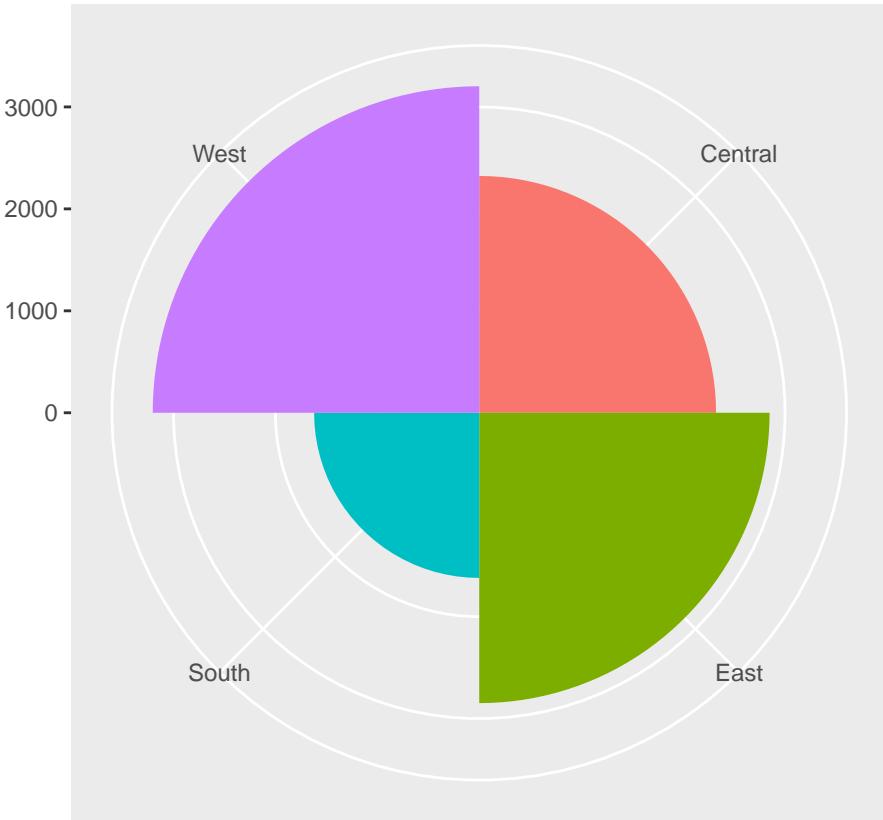
Transactions by region:

```

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)

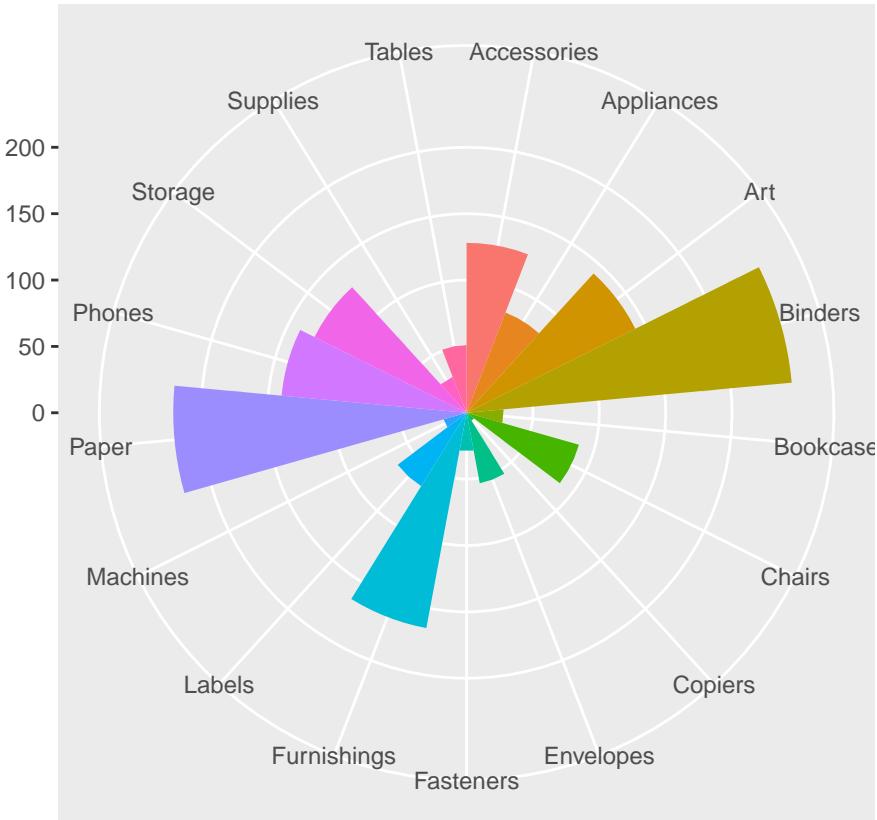
bar + coord_polar()

```



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. For the other regions, the distribution of product sub categories are very similar to the distribution of product subcategories in the south.

- 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")
```

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

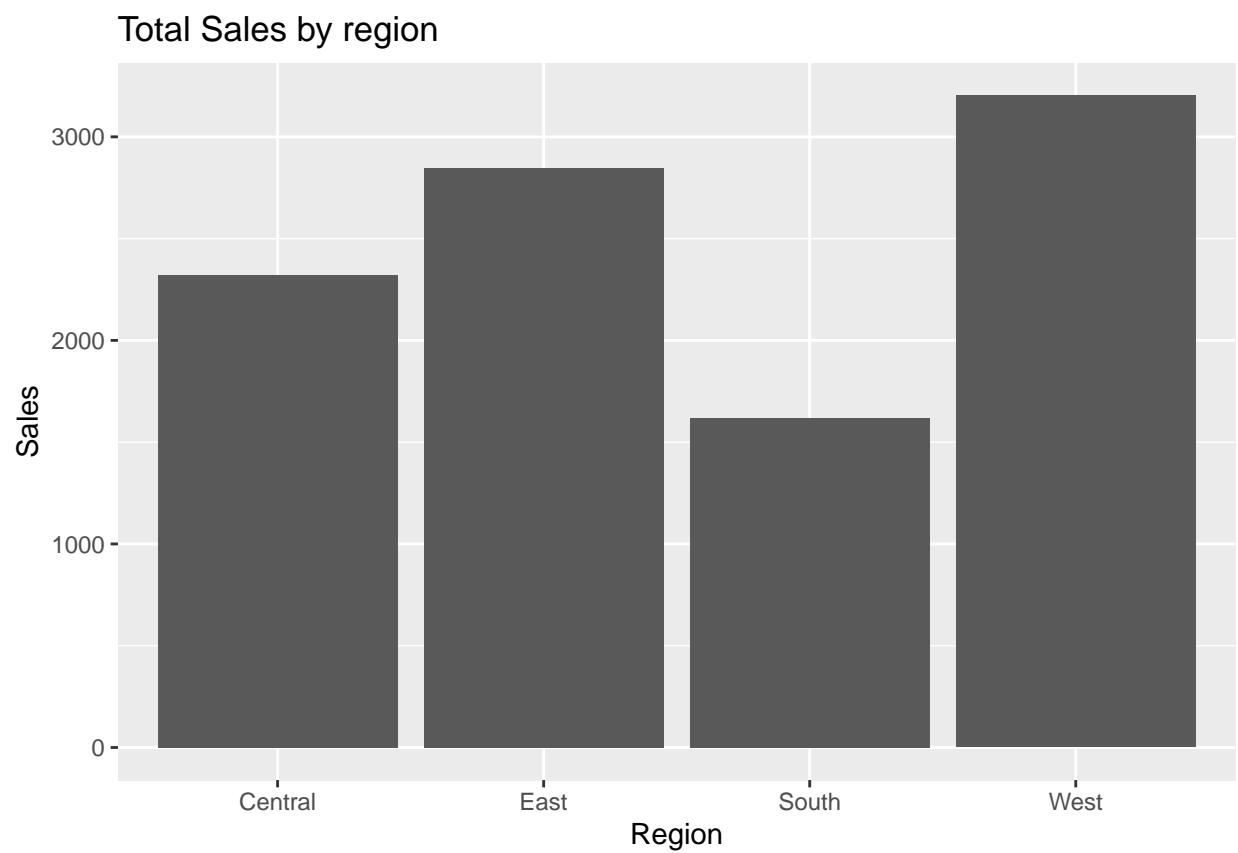
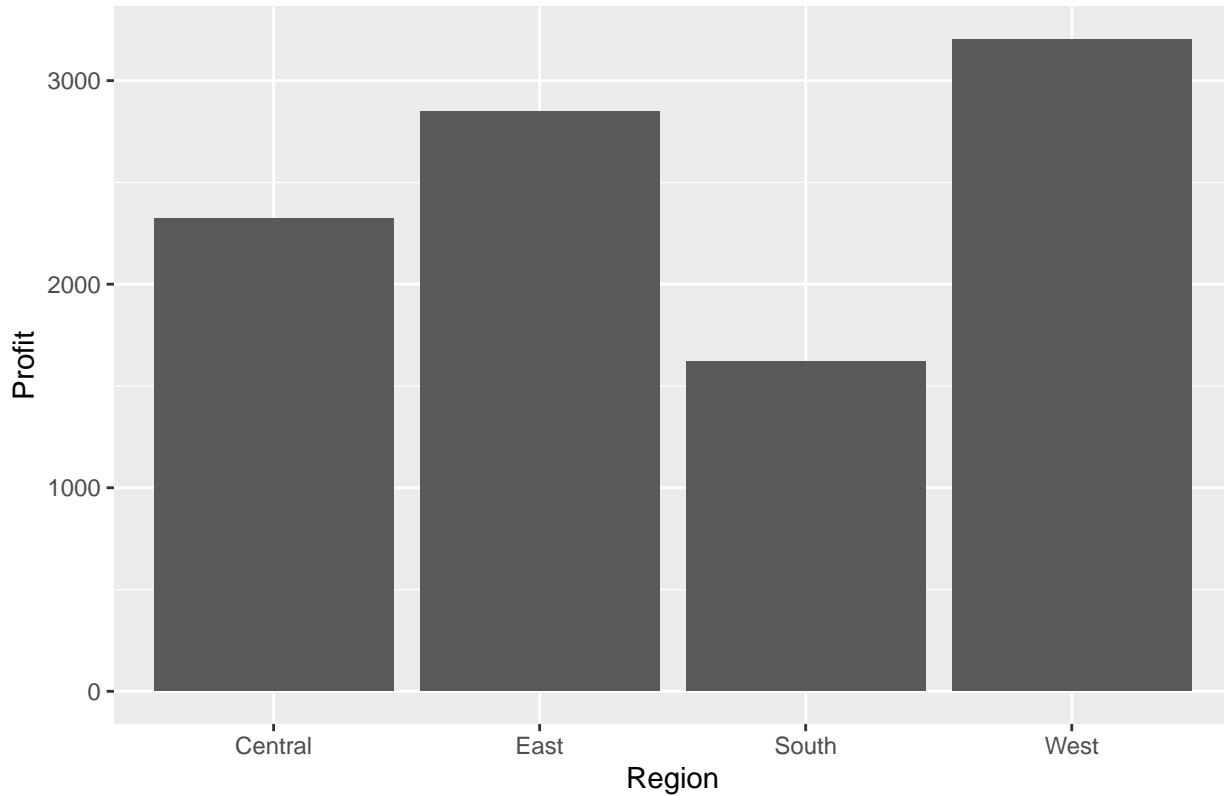


Figure 13: Total sales per region.

## Total Profit by region



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
```

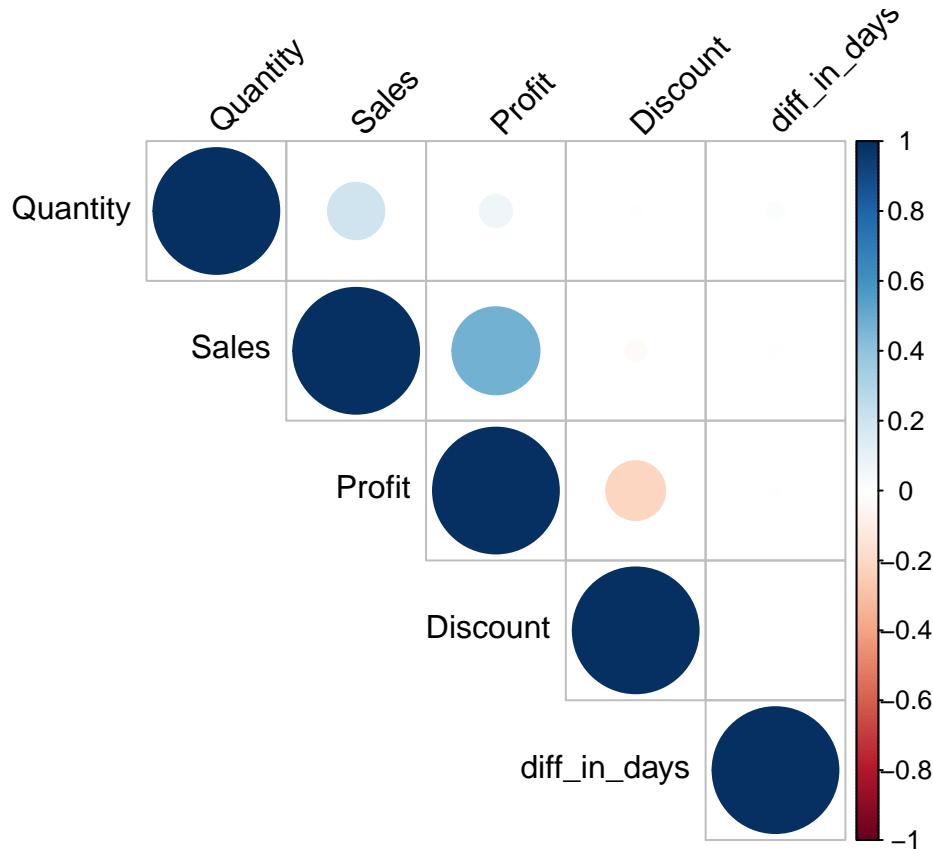
```
##                  Sales   Quantity   Discount   Profit  diff_in_days  
## Sales      1.000000000 0.20079477 -0.0281901242 0.479064350 -0.0073535371  
## Quantity    0.200794771 1.00000000  0.0086229703 0.066253189  0.0182984399
```

```

## Discount      -0.028190124 0.00862297  1.00000000000 -0.219487456  0.0004084856
## Profit       0.479064350 0.06625319 -0.2194874564  1.0000000000 -0.0046493531
## diff_in_days -0.007353537 0.01829844  0.0004084856 -0.004649353  1.00000000000

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","i_Row_ID", "Country", "Customer_Name")]<-NULL
```

```
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
```

## Modelling

### Method 1: Clustering with Kmeans without removing outliers

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 a partitional, exclusive and complete type of clustering approach, meaning the clustering is independent, (not nested within each other), and every observation has to be placed inside a cluster (Nwanganga and Chapple, 2020). 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.

```
summary(results_kmeans)
```

```
##          Length Class  Mode
## cluster      9994  -none- numeric
## centers        12  -none- numeric
## totss          1  -none- numeric
## withinss       3  -none- numeric
## tot.withinss   1  -none- numeric
## betweenss      1  -none- numeric
## size           3  -none- numeric
```

```
## iter      1   -none- numeric  
## ifault    1   -none- numeric
```

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

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" "betweenss" "size" "iter"  
[9] "ifault"
```

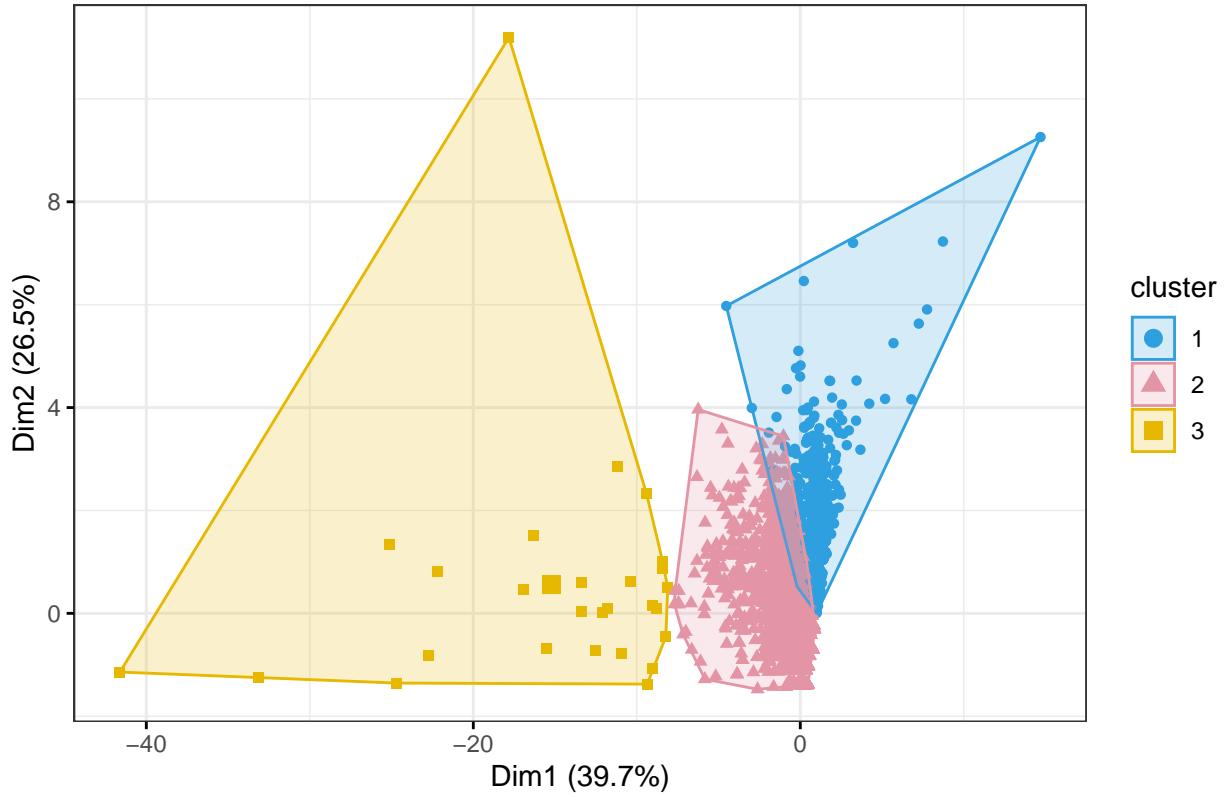
The results of this clustering indicate that the within cluster sum of squares by cluster is 37.0 % which means that the observations within a given group are not very similar to each other.

## 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",  
             ggtheme = theme_bw()  
)
```

Cluster plot



Reduce dimensions using Principal Component Analysis.

```

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.

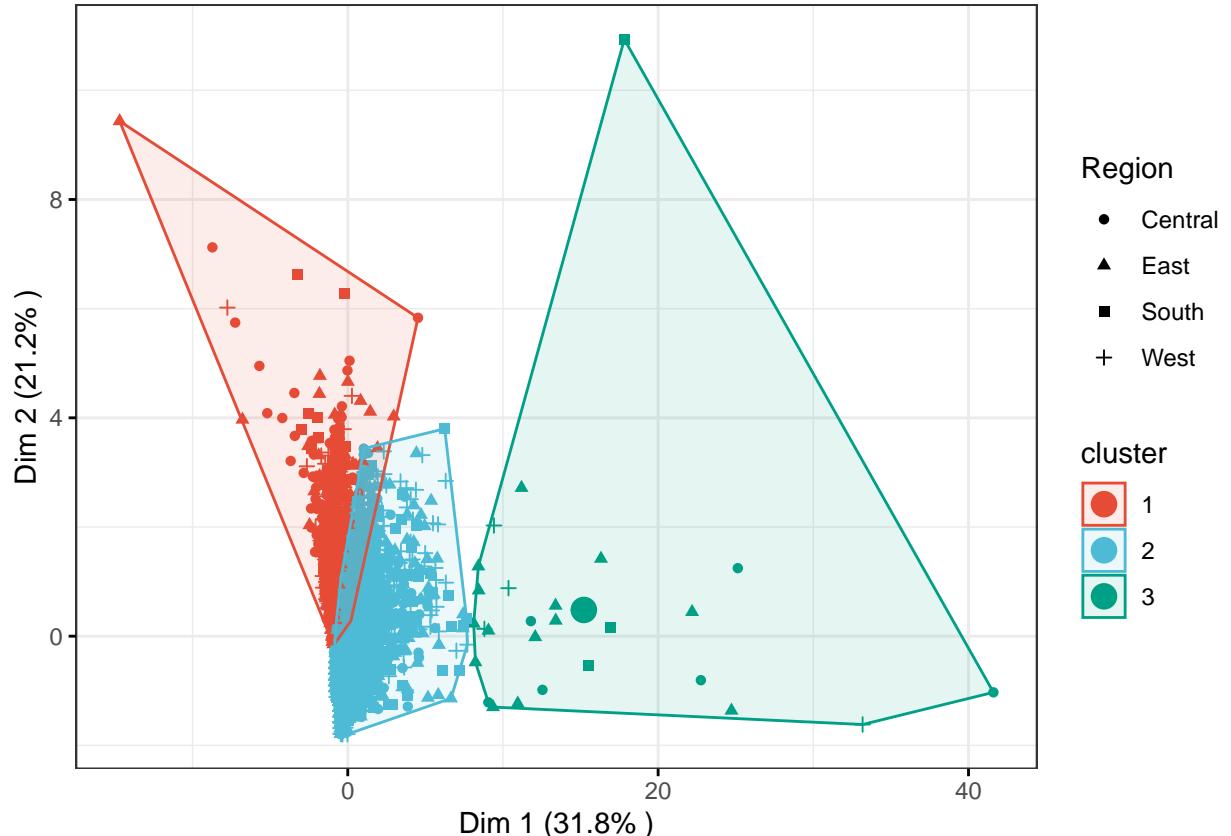
```
eigenvalue <- round(get_eigenvalue(results_pca), 1)
variance.percent <- eigenvalue$variance.percent
head(eigenvalue)
```

|          | 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).

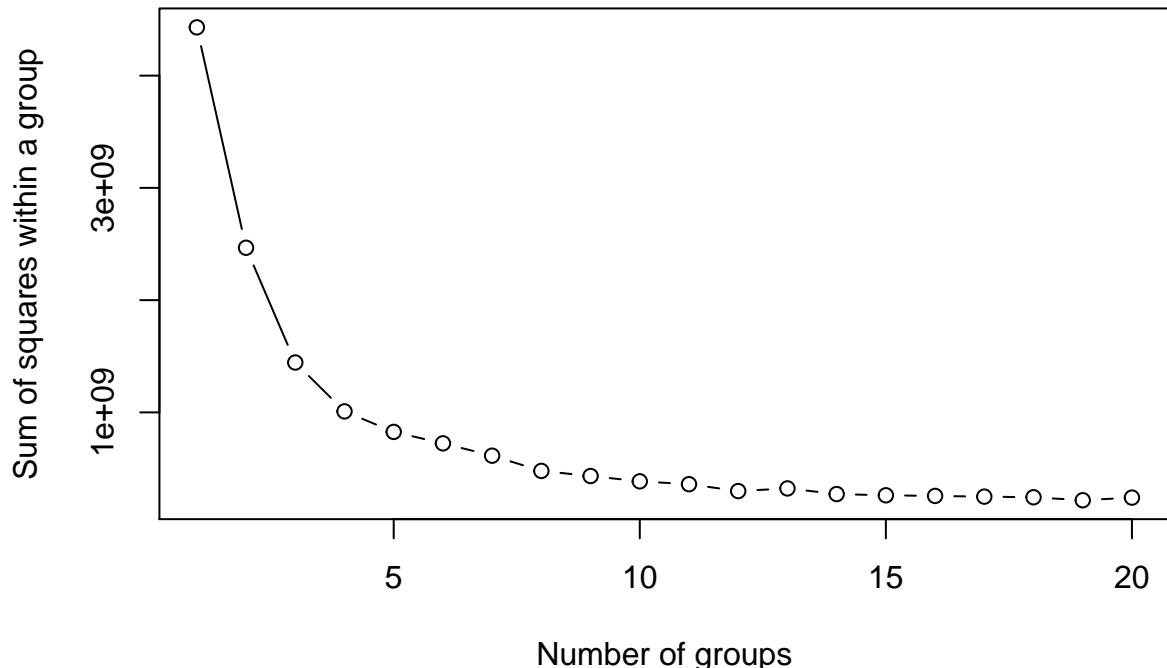
## Evaluation of Kmeans Clustering

(<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.

(Foncseca, 2019)

```
#To plot a within sum of squares plot for a range of different number of initial K-means centroids:  
#This function is modified from: (https://towardsdatascience.com/clustering-analysis-in-r-using-k-means-73eca4fb7967)  
  
#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)
```



From the Within sum of squares plot, the optimal number of clusters is around 4. when the number of groups (k) initially increases 1 to 4, the error measures (sum of squares within a group) starts to decrease. After around k=4 or k=5, the sum or squares within a group error value starts to mostly 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

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

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" "betweenss" "size" "iter"
[9] "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.

```
# Dimension reduction using PCA
results_pca_4 <- prcomp(data1[, (15:18)], scale = TRUE)

# Coordinates of individuals
ind.coord <- as.data.frame(get_pca_ind(results_pca_4)$coord)

# Add clusters obtained using the K-means algorithm
ind.coord$cluster <- factor(clustering_results_4$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     4   South
## 2 -1.1546701 -0.7511273  0.25351937  0.22331213     4   South
## 3  0.3107253 -1.1081474 -0.01276717  0.15000936     4   West
## 4  0.6283963  1.9637213  0.37261495  1.54367992     2   South
## 5  0.5768386 -0.4056909  0.55980463 -0.06649362     4   South
## 6 -0.3936310  0.3152509 -1.56442060 -0.20148637     3   West
```

```
# Percentage of variance explained by dimensions
eigenvalue <- round(get_eigenvalue(results_pca_4), 1)
variance.percent <- eigenvalue$variance.percent
head(eigenvalue)
```

```
##           eigenvalue variance.percent cumulative.variance.percent
## Dim.1           1.6              39.7                  39.7
```

```

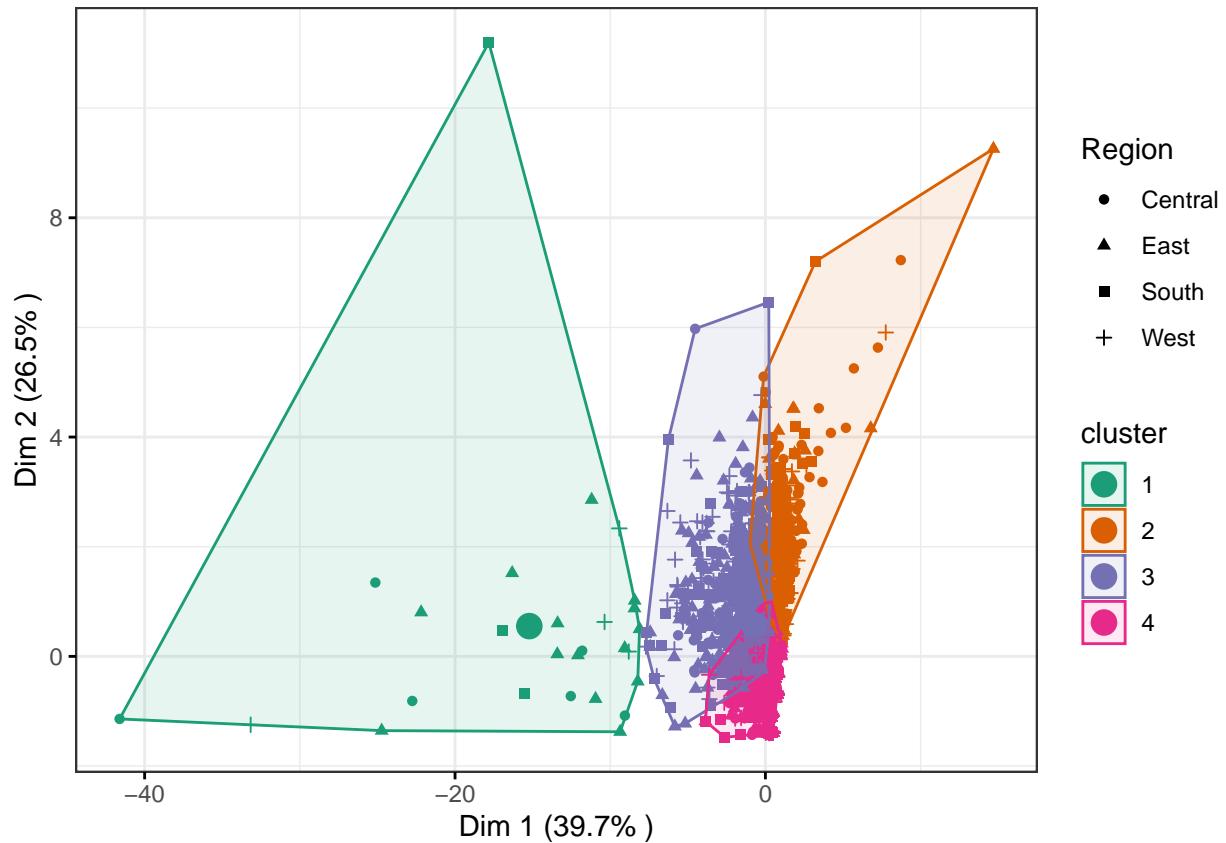
## Dim.2      1.1      26.5      66.2
## Dim.3      0.9      22.0      88.3
## Dim.4      0.5      11.7     100.0

```

```

gsscatter(
  ind.coord, x = "Dim.1", y = "Dim.2",
  color = "cluster", palette = brewer.pal(n = 8, name = "Dark2"), ellipse = TRUE, ellipse.type = "convex",
  shape = "Region", size = 1.5, legend = "right", ggtheme = theme_bw(), #change point size
  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

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  $D_i$ .

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  $C_i$ .

Next find the silhouette width which is the difference between  $C_i$  and  $D_i$ , divided by the maximum difference between  $C_i$  and  $D_i$ .  $S_i = (C_i - D_i)/\max(D_i, C_i)$

$S_i > 0$  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.

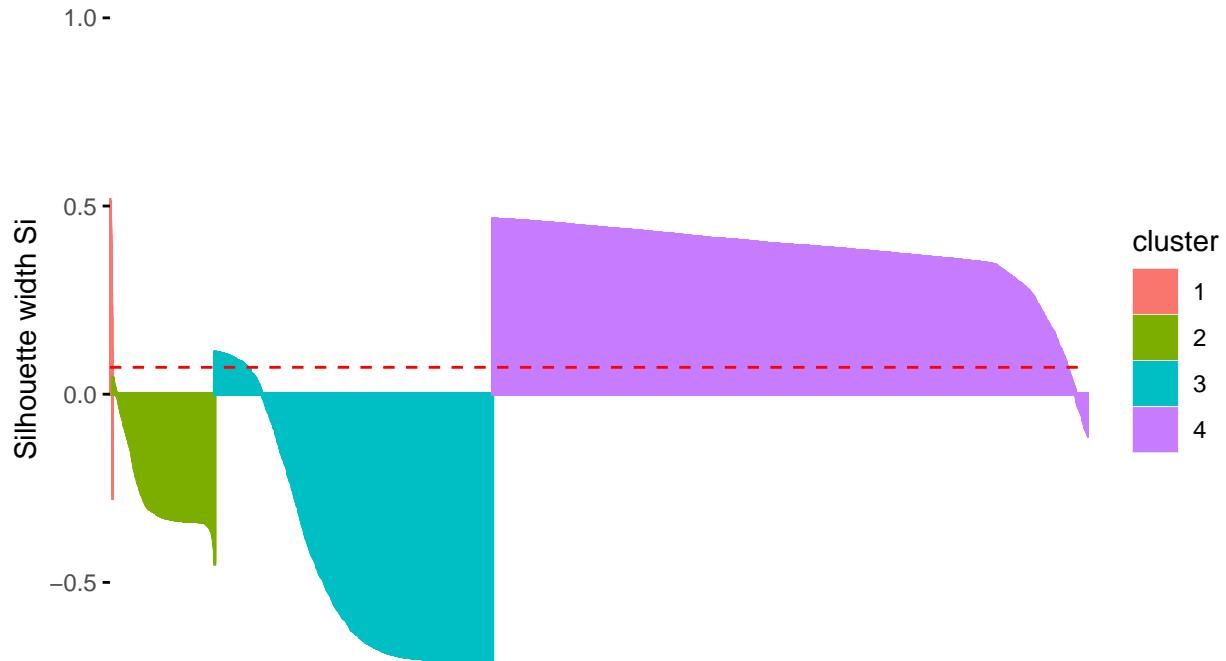
$Si = 0$  means the observation is between 2 clusters.

```
library(cluster)
library(factoextra)

sil <- silhouette(clustering_results_4$cluster, dist(data1[, (15:18)]))
fviz_silhouette(sil)

##   cluster size ave.sil.width
## 1       1    27      0.28
## 2       2 1044     -0.27
## 3       3 2838     -0.45
## 4       4 6085      0.37
```

Clusters silhouette plot  
Average silhouette width: 0.07



Compute PCA and extract individual components and extract individual components.

### Anomaly Detection using Local Outlier Factor Algorithm -Nearest neighbour method

LOF uses density based methods to calculate degree of outlying. LOF is a unsupervised anomaly detection technique, every point in the dataset is assigned LOF score based on the threshold value it classify the data points as outlier or non-outlier.

Points which are much lower in density compared to its neighbours are considered outliers.

A LOF score of approximately 1 indicates that density around the point is comparable to its neighbors. Scores significantly larger than 1 indicate outliers (Hahsler).

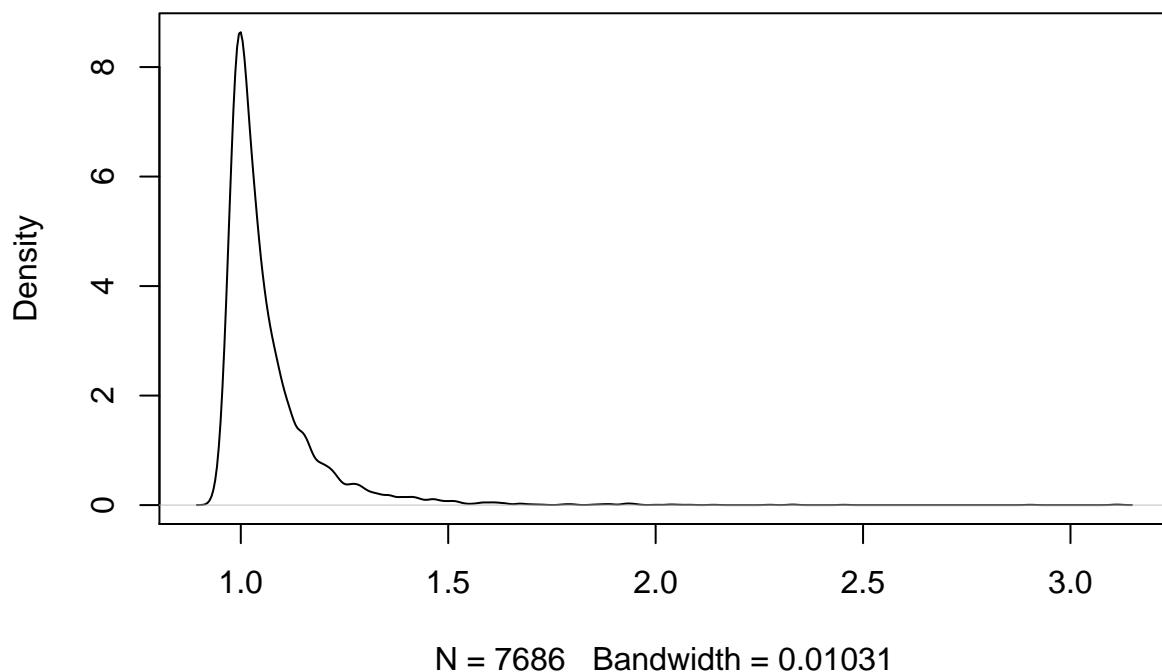
If there are more than k duplicate points in the data, then lof can become NaN caused by an infinite local density. In this case we set lof to 1

```
#remove duplicates rows
superstore_unq<-data1[!duplicated(data1[c("Sales","Profit","Quantity","Discount"))],]

#select numerical variables
superstore_lof<-superstore_unq[,c("Sales","Profit","Quantity","Discount")]

# for k=10, ,lof produces a vector of local outlier factor for each data point
lof_scores <- lofactor(superstore_lof, k=10)
plot(density(lof_scores))
```

**density.default(x = lof\_scores)**

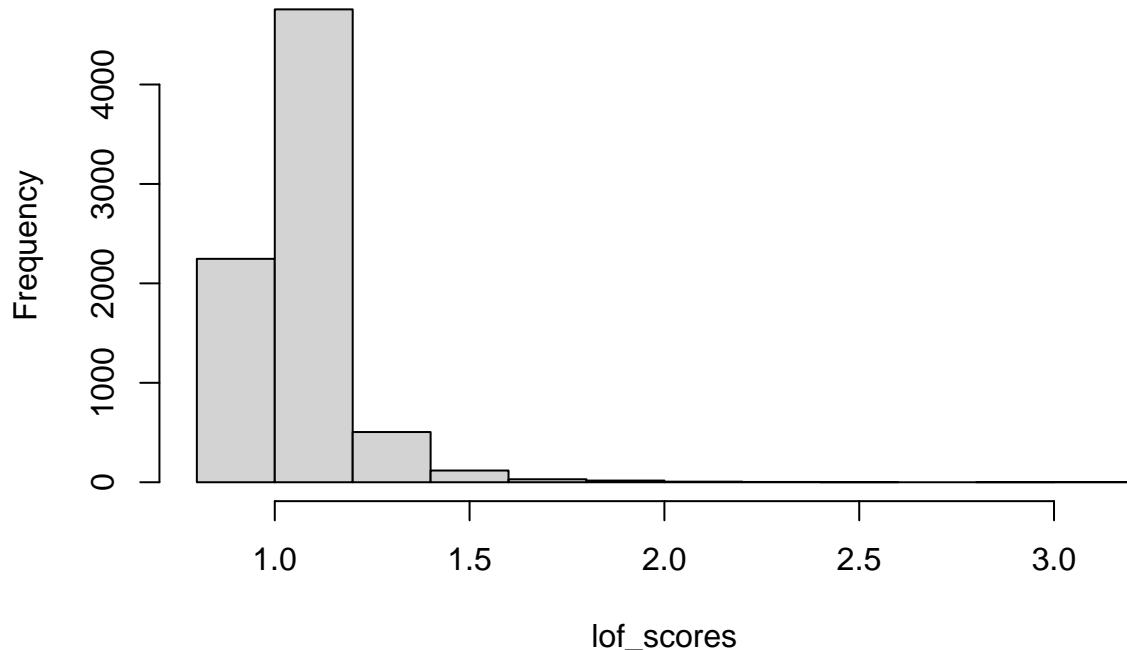


```
# distribution of outlier factors
summary(lof_scores)
```

```
##      Min. 1st Qu. Median      Mean 3rd Qu.      Max.
##  0.9250  0.9952  1.0267  1.0635  1.0870  3.1173
```

```
hist(lof_scores, breaks=10)
```

### Histogram of lof\_scores



#### Manual Evaluation of Local Outlier Factor

```
#top 5 outliers transactions , the greater the lof_scores the farther the point is from the cluster. Choose
lof_outliers <- order(lof_scores>2, decreasing=T)[1:13]
superstore_unq[lof_outliers,]
```

```
##          Order_ID Order_Date Ship_Date     Ship_Mode Customer_ID
## 28    US-2015-150630 2015-09-17 2015-09-21 Standard Class   TB-21520
## 166   CA-2014-139892 2014-09-08 2014-09-12 Standard Class   BM-11140
## 684   US-2017-168116 2017-11-04 2017-11-04      Same Day   GT-14635
## 2506  CA-2014-143917 2014-07-25 2014-07-27 Second Class   KL-16645
## 2698  CA-2014-145317 2014-03-18 2014-03-23 Standard Class   SM-20320
## 3012  CA-2017-134845 2017-04-17 2017-04-23 Standard Class   SR-20425
## 4992  US-2017-122714 2017-12-07 2017-12-13 Standard Class   HG-14965
## 5868  CA-2016-158211 2016-01-04 2016-01-08 Standard Class   BP-11185
## 6257  CA-2015-133977 2015-09-06 2015-09-08 Second Class   AT-10435
## 6827  CA-2016-118689 2016-10-02 2016-10-09 Standard Class   TC-20980
## 7773  CA-2016-108196 2016-11-25 2016-12-02 Standard Class   CS-12505
## 9410  US-2017-110149 2017-12-10 2017-12-13 First Class   WB-21850
## 9775  CA-2014-169019 2014-07-26 2014-07-30 Standard Class   LF-17185
##            Segment           City       State Postal_Code Region
## 28      Consumer Philadelphia Pennsylvania      19140   East
## 166     Consumer    San Antonio        Texas     78207 Central
## 684    Corporate   Burlington North Carolina  27217   South
```

|         |   |                 |              |              |         |
|---------|---|-----------------|--------------|--------------|---------|
| ## 2506 | Consumer  | San Francisco   | California   | 94122        | West    |
| ## 2698 | Home Office   | Jacksonville    | Florida      | 32216        | South   |
| ## 3012 | Home Office   | Louisville      | Colorado     | 80027        | West    |
| ## 4992 | Corporate   | Chicago         | Illinois     | 60653        | Central |
| ## 5868 | Corporate   | Philadelphia    | Pennsylvania | 19143        | East    |
| ## 6257 | Home Office   | Tamarac         | Florida      | 33319        | South   |
| ## 6827 | Corporate   | Lafayette       | Indiana      | 47905        | Central |
| ## 7773 | Consumer  | Lancaster       | Ohio         | 43130        | East    |
| ## 9410 | Consumer  | Philadelphia    | Pennsylvania | 19143        | East    |
| ## 9775 | Consumer  | San Antonio     | Texas        | 78207        | Central |
| ##      | Product_ID  | Category        | Sub_Category |              |         |
| ## 28   | FUR-BO-10004834   | Furniture       | Bookcases    |              |         |
| ## 166  | TEC-MA-10000822   | Technology      | Machines     |              |         |
| ## 684  | TEC-MA-10004125   | Technology      | Machines     |              |         |
| ## 2506 | OFF-SU-10000151   | Office Supplies | Supplies     |              |         |
| ## 2698 | TEC-MA-10002412   | Technology      | Machines     |              |         |
| ## 3012 | TEC-MA-10000822   | Technology      | Machines     |              |         |
| ## 4992 | OFF-BI-10001120   | Office Supplies | Binders      |              |         |
| ## 5868 | OFF-AR-10004078   | Office Supplies | Art          |              |         |
| ## 6257 | OFF-BI-10003166   | Office Supplies | Binders      |              |         |
| ## 6827 | TEC-CO-10004722   | Technology      | Copiers      |              |         |
| ## 7773 | TEC-MA-10000418   | Technology      | Machines     |              |         |
| ## 9410 | OFF-BI-10000014   | Office Supplies | Binders      |              |         |
| ## 9775 | OFF-BI-10004995   | Office Supplies | Binders      |              |         |
| ##      |   | Product_Name    | Sales        |              |         |
| ## 28   | Riverside Palais Royal Lawyers Bookcase, Royale Cherry Finish |                 | 3083.430     |              |         |
| ## 166  | Lexmark MX611dhe Monochrome Laser Printer                     |                 | 8159.952     |              |         |
| ## 684  | Cubify CubeX 3D Printer Triple Head Print                     |                 | 7999.980     |              |         |
| ## 2506 | High Speed Automatic Electric Letter Opener                   |                 | 8187.650     |              |         |
| ## 2698 | Cisco TelePresence System EX90 Videoconferencing Unit         |                 | 22638.480    |              |         |
| ## 3012 | Lexmark MX611dhe Monochrome Laser Printer                     |                 | 2549.985     |              |         |
| ## 4992 | Ibico EPK-21 Electric Binding System                          |                 | 1889.990     |              |         |
| ## 5868 | Newell 312  |                 | 4.672        |              |         |
| ## 6257 | GBC Plasticlear Binding Covers                                |                 | 3.444        |              |         |
| ## 6827 | Canon imageCLASS 2200 Advanced Copier                         |                 | 17499.950    |              |         |
| ## 7773 | Cubify CubeX 3D Printer Double Head Print                     |                 | 4499.985     |              |         |
| ## 9410 | Heavy-Duty E-Z-D Binders                                      |                 | 3.273        |              |         |
| ## 9775 | GBC DocuBind P400 Electric Binding System                     |                 | 2177.584     |              |         |
| ##      | Quantity  | Discount        | Profit       | diff_in_days |         |
| ## 28   | 7   | 0.5             | -1665.0522   | 4            |         |
| ## 166  | 8   | 0.4             | -1359.9920   | 4            |         |
| ## 684  | 4   | 0.5             | -3839.9904   | 0            |         |
| ## 2506 | 5   | 0.0             | 327.5060     | 2            |         |
| ## 2698 | 6   | 0.5             | -1811.0784   | 5            |         |
| ## 3012 | 5   | 0.7             | -3399.9800   | 6            |         |
| ## 4992 | 5   | 0.8             | -2929.4845   | 6            |         |
| ## 5868 | 1   | 0.2             | 0.5840       | 4            |         |
| ## 6257 | 1   | 0.7             | -2.5256      | 2            |         |
| ## 6827 | 5   | 0.0             | 8399.9760    | 7            |         |
| ## 7773 | 5   | 0.7             | -6599.9780   | 7            |         |
| ## 9410 | 1   | 0.7             | -2.5093      | 3            |         |
| ## 9775 | 8   | 0.8             | -3701.8928   | 4            |         |

Here we are filtering for outliers which have LOF scores greater than 2.

```

#outliers for z-score >2(how far an observation is from the mean)

outlier_orderid<-superstore_unq[which(lof_scores >2),1]
vec<-as.vector(outlier_orderid)

#new column for outlier status
superstore_unq<-mutate(superstore_unq,outlier_status=ifelse(Order_ID %in% (vec) , "Yes","No"))

x<-subset(superstore_unq,superstore_unq$outlier_status=="Yes")
head(x, 10)           #look at top 10 rows of x

```

```

##          Order_ID Order_Date     Ship_Date      Ship_Mode Customer_ID Segment
## 28    US-2015-150630 2015-09-17 2015-09-21 Standard Class    TB-21520 Consumer
## 29    US-2015-150630 2015-09-17 2015-09-21 Standard Class    TB-21520 Consumer
## 30    US-2015-150630 2015-09-17 2015-09-21 Standard Class    TB-21520 Consumer
## 31    US-2015-150630 2015-09-17 2015-09-21 Standard Class    TB-21520 Consumer
## 32    US-2015-150630 2015-09-17 2015-09-21 Standard Class    TB-21520 Consumer
## 33    US-2015-150630 2015-09-17 2015-09-21 Standard Class    TB-21520 Consumer
## 34    US-2015-150630 2015-09-17 2015-09-21 Standard Class    TB-21520 Consumer
## 165   CA-2014-139892 2014-09-08 2014-09-12 Standard Class    BM-11140 Consumer
## 166   CA-2014-139892 2014-09-08 2014-09-12 Standard Class    BM-11140 Consumer
## 167   CA-2014-139892 2014-09-08 2014-09-12 Standard Class    BM-11140 Consumer
##          City            State Postal_Code Region       Product_ID
## 28    Philadelphia Pennsylvania        19140   East FUR-B0-10004834
## 29    Philadelphia Pennsylvania        19140   East OFF-BI-10000474
## 30    Philadelphia Pennsylvania        19140   East FUR-FU-10004848
## 31    Philadelphia Pennsylvania        19140   East OFF-EN-10001509
## 32    Philadelphia Pennsylvania        19140   East OFF-AR-10004042
## 33    Philadelphia Pennsylvania        19140   East OFF-BI-10001525
## 34    Philadelphia Pennsylvania        19140   East OFF-AR-10001683
## 165   San Antonio      Texas        78207 Central OFF-AR-10004441
## 166   San Antonio      Texas        78207 Central TEC-MA-10000822
## 167   San Antonio      Texas        78207 Central OFF-ST-10000991
##          Category Sub_Category
## 28      Furniture Bookcases
## 29  Office Supplies Binders
## 30      Furniture Furnishings
## 31  Office Supplies Envelopes
## 32  Office Supplies      Art
## 33  Office Supplies Binders
## 34  Office Supplies      Art
## 165 Office Supplies      Art
## 166   Technology    Machines
## 167 Office Supplies Storage
##          Product_Name
## 28      Riverside Palais Royal Lawyers Bookcase, Royale Cherry Finish
## 29      Avery Recycled Flexi-View Covers for Binding Systems
## 30      Howard Miller 13-3/4" Diameter Brushed Chrome Round Wall Clock
## 31      Poly String Tie Envelopes
## 32      BOSTON Model 1800 Electric Pencil Sharpeners, Putty/Woodgrain
## 33 Acco Pressboard Covers with Storage Hooks, 14 7/8" x 11", Executive Red
## 34      Lumber Crayons

```

```

## 165                               BIC Brite Liner Highlighters
## 166                               Lexmark MX611dhe Monochrome Laser Printer
## 167                               Space Solutions HD Industrial Steel Shelving.
##   Sales Quantity Discount Profit diff_in_days outlier_status
## 28  3083.430      7     0.5 -1665.0522        4       Yes
## 29   9.618       2     0.7   -7.0532        4       Yes
## 30  124.200      3     0.2   15.5250        4       Yes
## 31   3.264       2     0.2   1.1016        4       Yes
## 32   86.304      6     0.2   9.7092        4       Yes
## 33   6.858       6     0.7  -5.7150        4       Yes
## 34  15.760       2     0.2   3.5460        4       Yes
## 165   9.936       3     0.2   2.7324        4       Yes
## 166 8159.952      8     0.4 -1359.9920        4       Yes
## 167  275.928      3     0.2  -58.6347        4       Yes

```

## Plot LOF outliers

```

pch <- rep(".", 7000)
pch[lof_outliers] <- "+"
col <- rep("black",7000)
col[lof_outliers] <- "red"
pairs(superstore_lof, pch=pch, col=col)

```

## Re-running K-means after removing outliers identified with the Local Outlier Factor

From here we can keep just the normal transactions of the superstore dataset (which are not outliers):

```
normal_transactions <- subset(superstore_unq,superstore_unq$outlier_status=="No")
```

**Data Preparation** Extract just the numeric columns from the normal transactions:

```

normal_transactions_numeric <- normal_transactions %>%
    select(Sales, Quantity, Discount, Profit)

```

First scale the data since the variables are measured in different scales:

```

normal_transactions_scaled <- scale(normal_transactions_numeric)

rownames(normal_transactions_scaled) <- normal_transactions_numeric$name      #re-assign the rownames

```

Use PCA to scale the dimensions of the data:

```

res.pca <- PCA(normal_transactions_scaled, graph = FALSE)

#Visualize eigenvalues/variances
fviz_screeplot(res.pca, addlabels = TRUE, ylim = c(0, 50))

```

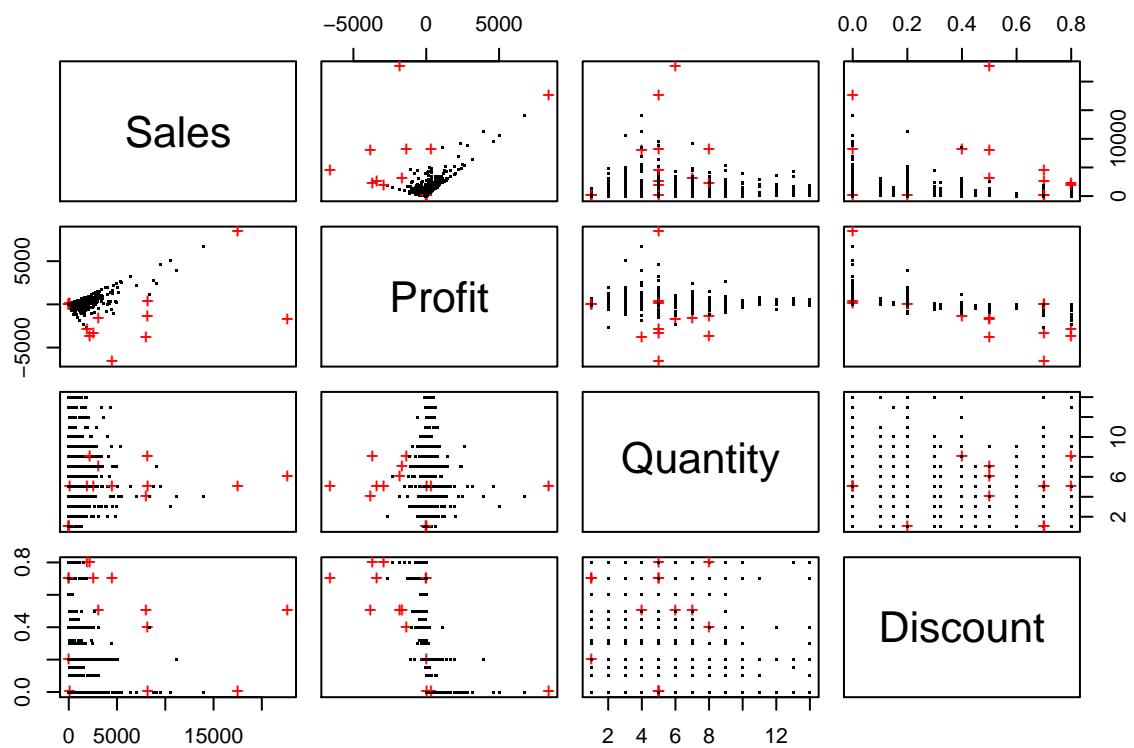
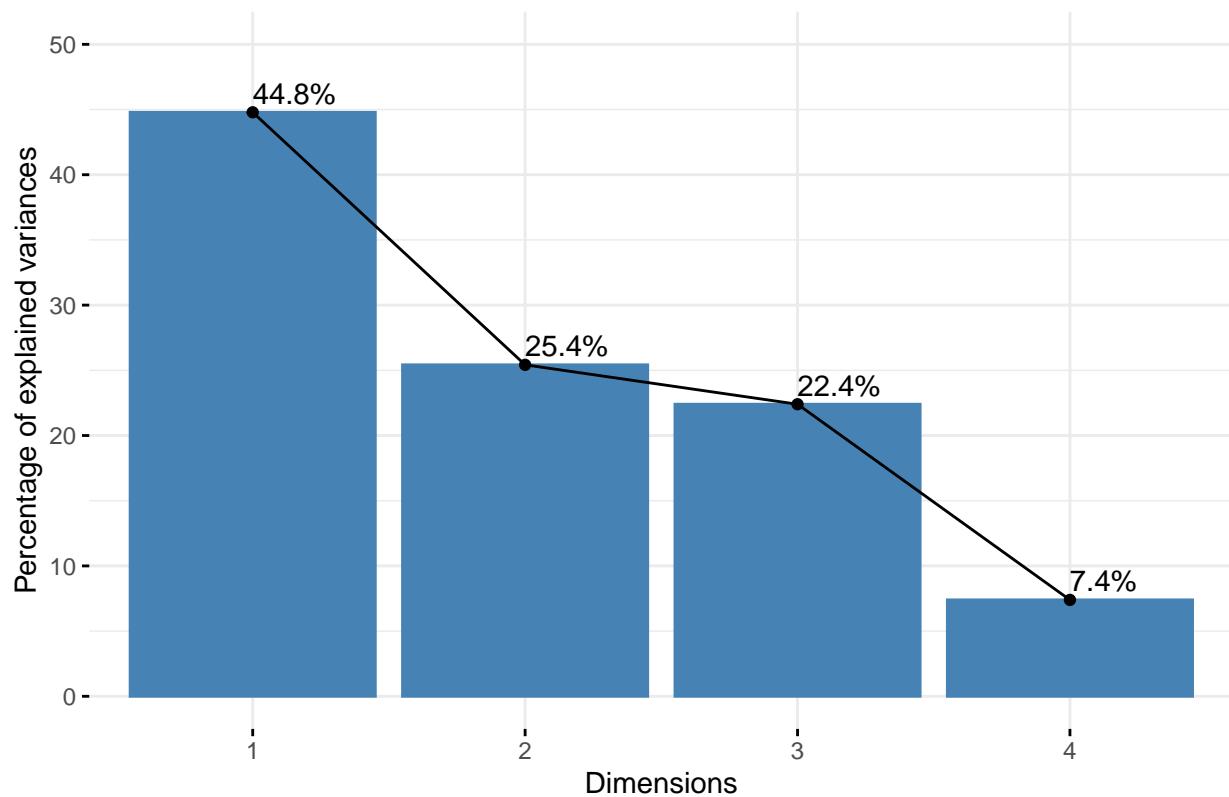


Figure 14: Plot of outliers found using Local Outlier Factor algorithm. Outliers are represented as red + signs.

Scree plot



Scree plot shows dimension 1 captures 44.8% of the variance while dimension 2 captures 25.4% of the variance.

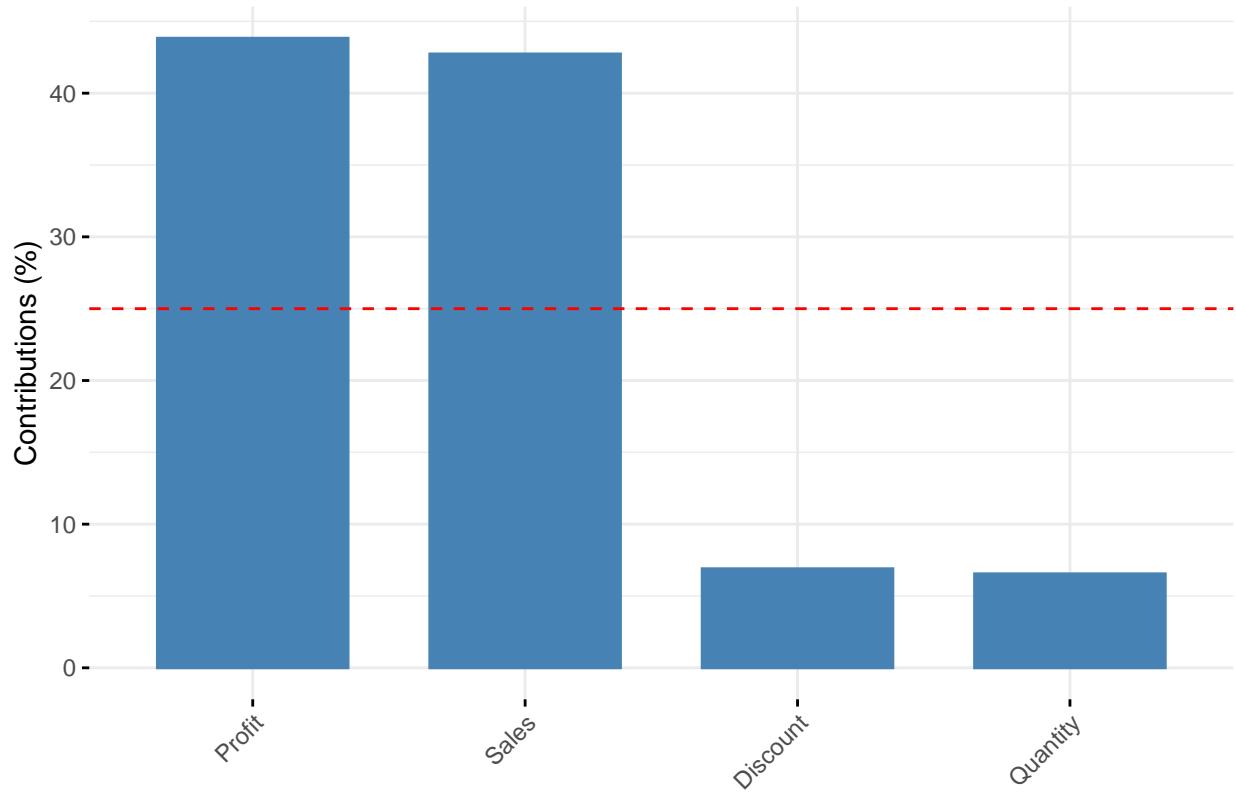
Extract the results for variables

```
var <- get_pca_var(res.pca)
```

Contributions of variables to PC1

```
fviz_contrib(res.pca, choice = "var", axis = 1, top = 10)
```

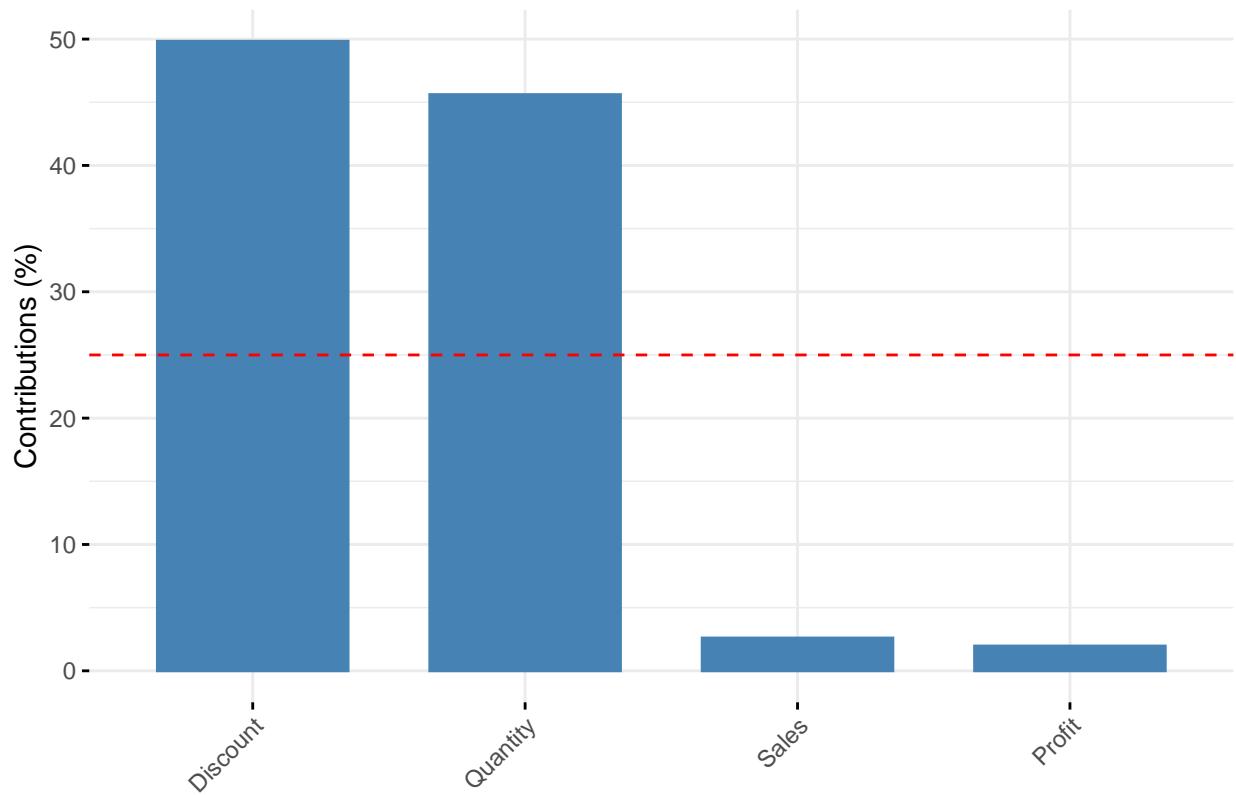
### Contribution of variables to Dim-1



### Contributions of variables to PC2

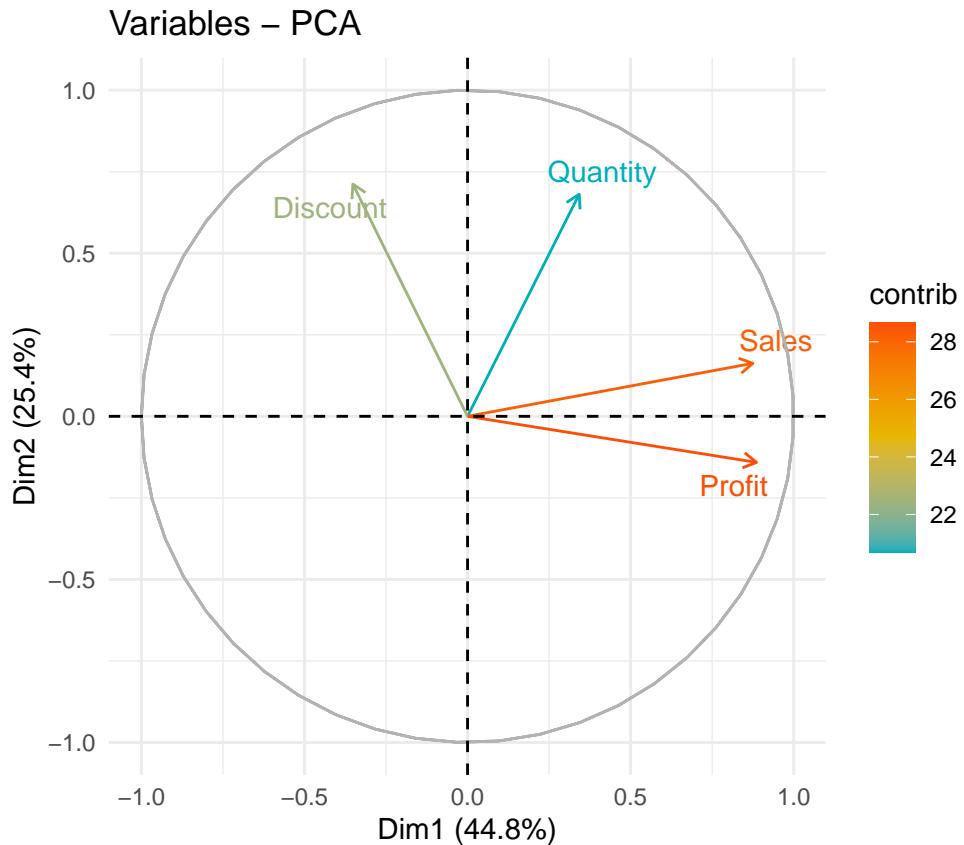
```
fviz_contrib(res.pca, choice = "var", axes = 2, top = 10)
```

## Contribution of variables to Dim–2



```
#Control variable colours using their contributions to the principal axis
```

```
fviz_pca_var(res.pca, col.var = "contrib",
             gradient.cols =c("#00AFBB", "#E7B800", "#FC4E07"),
             repel = TRUE #prevent text overlapping
           ) + theme_minimal() + ggtitle("Variables - PCA")
```



From the above visualization, sales and profit tend to increase together. Quantity also increases as sales and profits increase. Discount is inversely related to sales, profit and quantity.

## Determining the Optimal Number of Clusters for Kmeans Clustering

### Elbow Method

Using the Elbow method to determine the optimal number of clusters involves plotting the within cluster sum of squares. The optimal number of clusters is the one located at the “bend” on the graph, where WSS is lowered. Within-cluster sum of squares (WCSS) is the degree to which items within a cluster are similar or dissimilar (Nwanganga and Chapple, 2020).

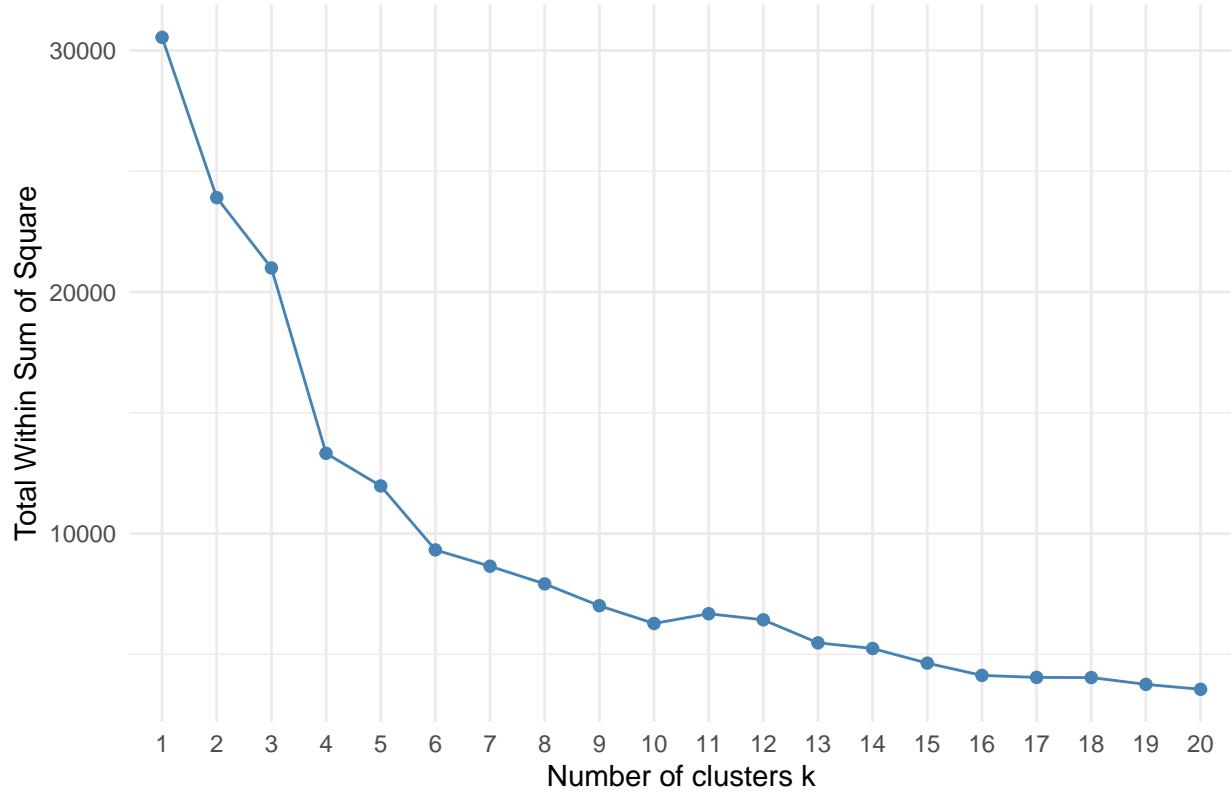
The closer the items within a cluster are to the centroid, the lower the value of WCSS.

```
set.seed(123)

#to compute the total within-cluster sum of squares:
fviz_nbclust(normal_transactions_scaled, kmeans, method = "wss", k.max = 20) +
  theme_minimal() + ggtitle("The Elbow Method")

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

## The Elbow Method



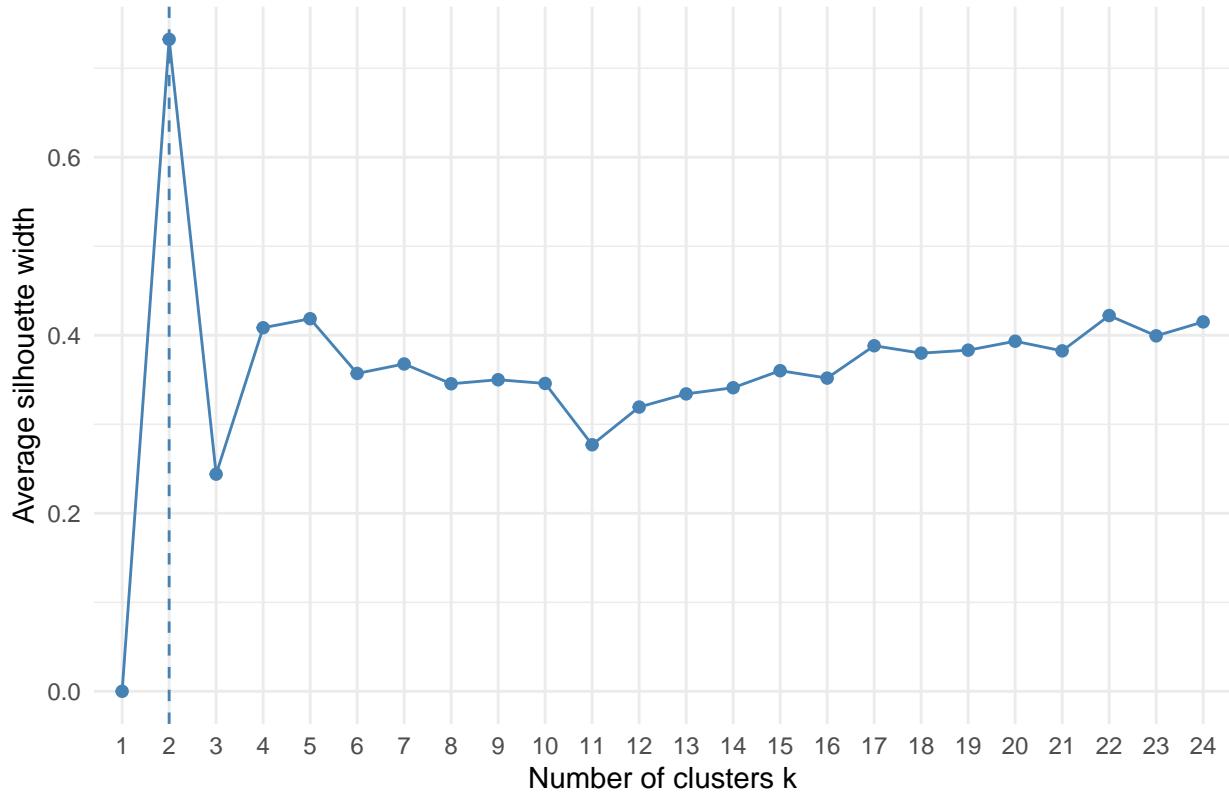
The optimal number of clusters looks to be  $k = 4$  (the elbow point).  $K=4$  is where the curve bends, indicating the point at which increasing the number of clusters ( $k$ ) does not significantly decrease the total within cluster sum of square value.

## Silhouette Method

Another method is to look at the silhouette method. The silhouette of an observation is a value that represents how closely the item is matched with other items with the same cluster and how loosely matched it is with observations in a different cluster.

```
fviz_nbclust(normal_transactions_scaled, kmeans, method = "silhouette", k.max = 24) + theme_minimal() +
```

## The Silhouette Plot



The silhouette method suggests the optimal number of clusters is 2, since  $k=2$  corresponds to the highest average silhouette width value.

## Gap Statistic Method

A third statistical approach called the gap statistic method, compares the difference between clusters created from observed data and clusters created from a randomly generated dataset called the reference dataset. The gap statistic for a given  $k$  value is the difference in the total WCSS for the observed data and that of the reference dataset. The optimal number of clusters is denoted by the  $k$  value that yields the largest gap statistic.

```
## Clustering Gap statistic ["clusGap"] from call:
## clusGap(x = normal_transactions_scaled, FUNcluster = kmeans,      K.max = 10, B = 50, nstart = 25)
## B=50 simulated reference sets, k = 1..10; spaceH0="scaledPCA"
## --> Number of clusters (method 'firstmax'): 1
##          logW     E.logW      gap      SE.sim
## [1,] 8.306406 10.448005 2.141599 0.003477234
## [2,] 8.241126 10.062968 1.821842 0.003109020
## [3,] 8.061164  9.925043 1.863879 0.002762539
## [4,] 7.886457  9.859774 1.973317 0.002815694
## [5,] 7.800480  9.807267 2.006787 0.002722500
## [6,] 7.687966  9.754879 2.066913 0.002540280
## [7,] 7.652700  9.707431 2.054731 0.002442805
## [8,] 7.609052  9.668883 2.059831 0.002425359
## [9,] 7.555042  9.633817 2.078775 0.002477761
## [10,] 7.469413  9.599961 2.130548 0.002478904
```

Visualize the results of the gap statistic method.

```
fviz_gap_stat(gap_stat)
```

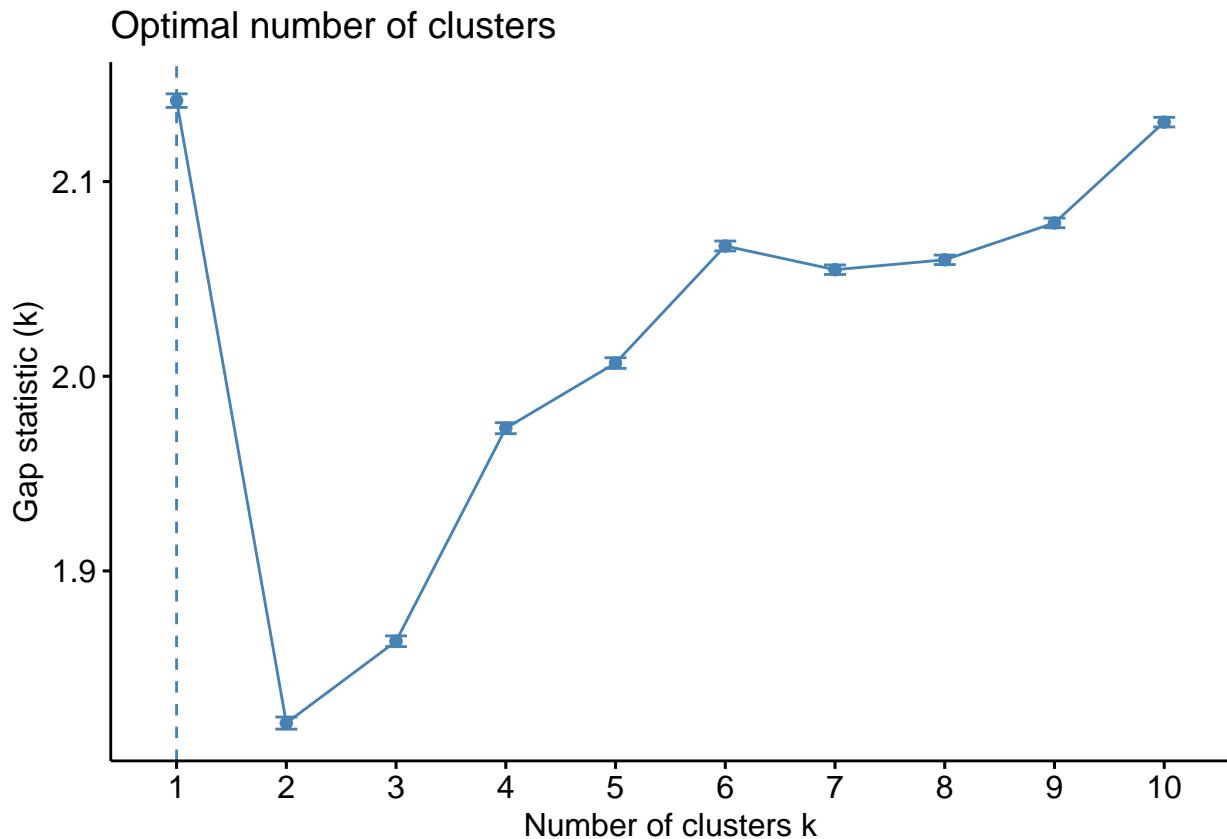
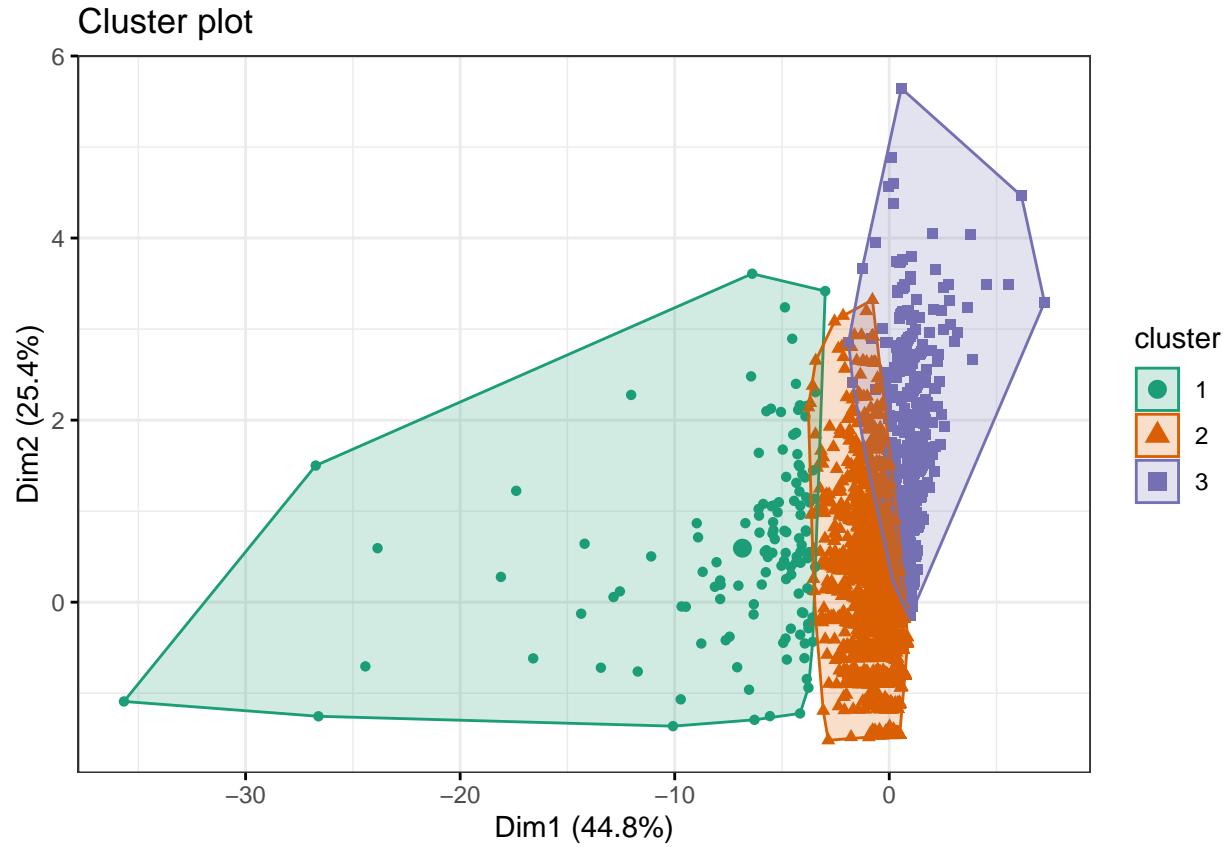


Figure 15: Finding the optimal number of clusters for k-medoids using the gap statistic method

According to the gap statistic method, the optimal number of clusters is 1 which does not make sense as all observations will be in a single cluster. The next optimal k-value is 6.

From the results of the silhouette method, elbow method and gap statistic method, the optimal value of k=4 is the most common result (from both the silhouette method and the elbow method). So we tried both k=3 and k=4 for kmeans clustering.

```
library(RColorBrewer)
fviz_cluster(results_kmeans, data = normal_transactions_scaled,
             palette = brewer.pal(n = 8, name = "Dark2"),
             geom = "point",
             ellipse.type = "convex",
             ggtheme = theme_bw()
           )
```



To see the kmeans results:

```
#results_kmeans
#the clustering vector information has been omitted for brevity.
```

K-means clustering with 3 clusters of sizes 131, 6484, 1022

Cluster means: Sales Quantity Discount Profit 1 5.29934595 1.04564847 -0.4747453 4.5131872279 2 -0.08504992 -0.01836038 -0.3350941 0.0001464245 3 -0.13967774 -0.01754527 2.1868313 -0.5794294944

[1] 4677.307 10427.565 2891.185 (between\_SS / total\_SS = 41.1 %)

Available components:

[1] "cluster" "centers" "totss" "withinss" "tot.withinss" "betweenss" "size" "iter"  
[9] "ifault"

The within cluster sum of squares by cluster is 41.1% for k = 3.

try clustering with kmeans using k = 4

K-means clustering with 4 clusters of sizes 1741, 4917, 941, 38

Cluster means: Sales Quantity Discount Profit 1 0.4660012 1.36028979 -0.3218513 0.2382839 2 -0.1953987 -0.47692843 -0.3185796 -0.0499454 3 -0.1892876 -0.04414503 2.2823862 -0.5695165 4 8.6207116 0.48244836 -0.5506917 9.6485345

Within cluster sum of squares by cluster: [1] 5391.896 3363.327 2252.744 2215.088 (between\_SS / total\_SS = 56.7 %)

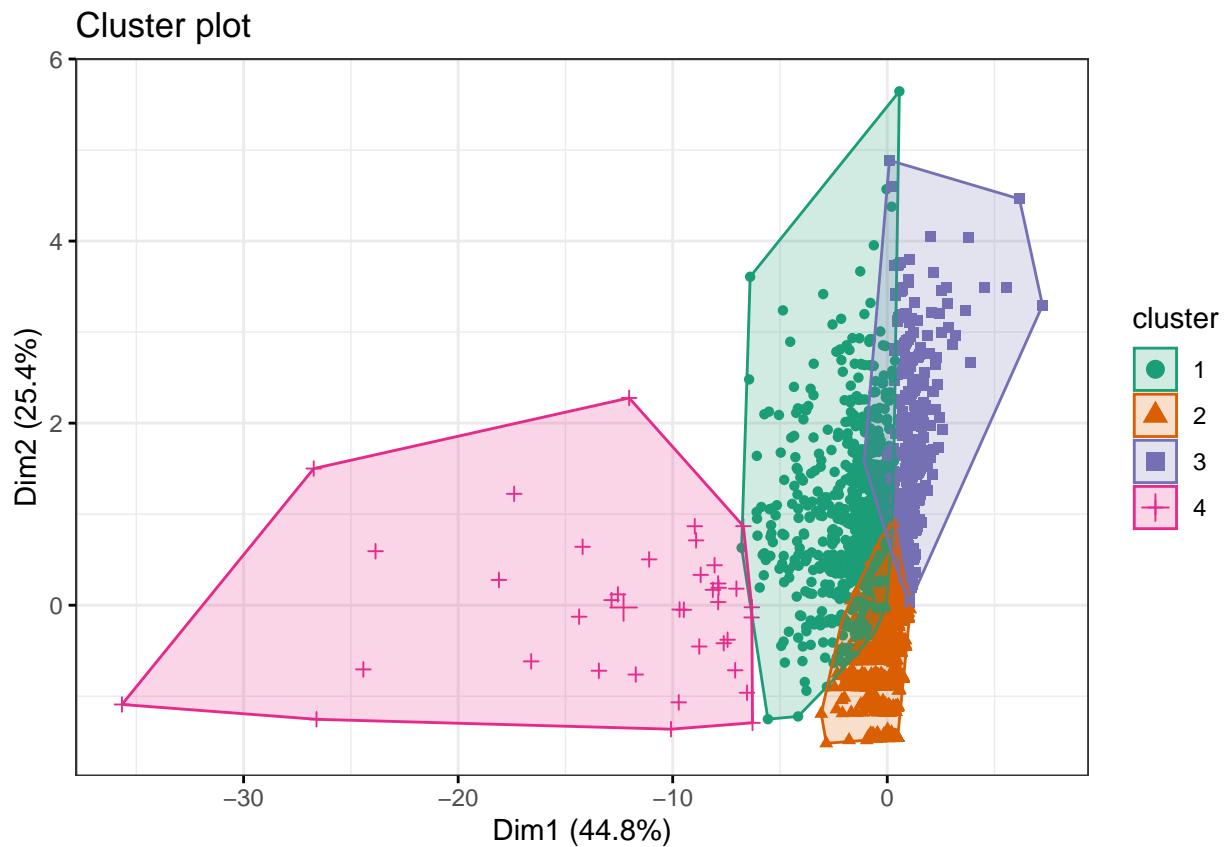
Available components:

```
[1] "cluster" "centers" "totss" "withinss" "tot.withinss" "betweenss" "size" "iter"
[9] "ifault"
```

The within sum of squares by cluster is 56.7%.

Plotting the 4 kmeans clustering results

```
library(RColorBrewer)
fviz_cluster(results_kmeans_4, data = normal_transactions_scaled,
             palette = brewer.pal(n = 8, name = "Dark2"),
             geom = "point",
             ellipse.type = "convex",
             ggtheme = theme_bw()
)
```



## Method 2: Clustering with 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. The reason for this is because K-medoids uses some of the observations as the cluster centres (medoids). 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 (Filaire, 2018).

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.

## 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, Disc...  

#convert all character data type to factor:  

data2[sapply(data2, is.character)] <- lapply(data2[sapply(data2, is.character)],  

  as.factor)
```

Compute the 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  

#Print most dissimilar transactions  

data2[which(gower_mat == max(gower_mat[gower_mat != max(gower_mat)])), arr.ind = TRUE)[1, , ]  

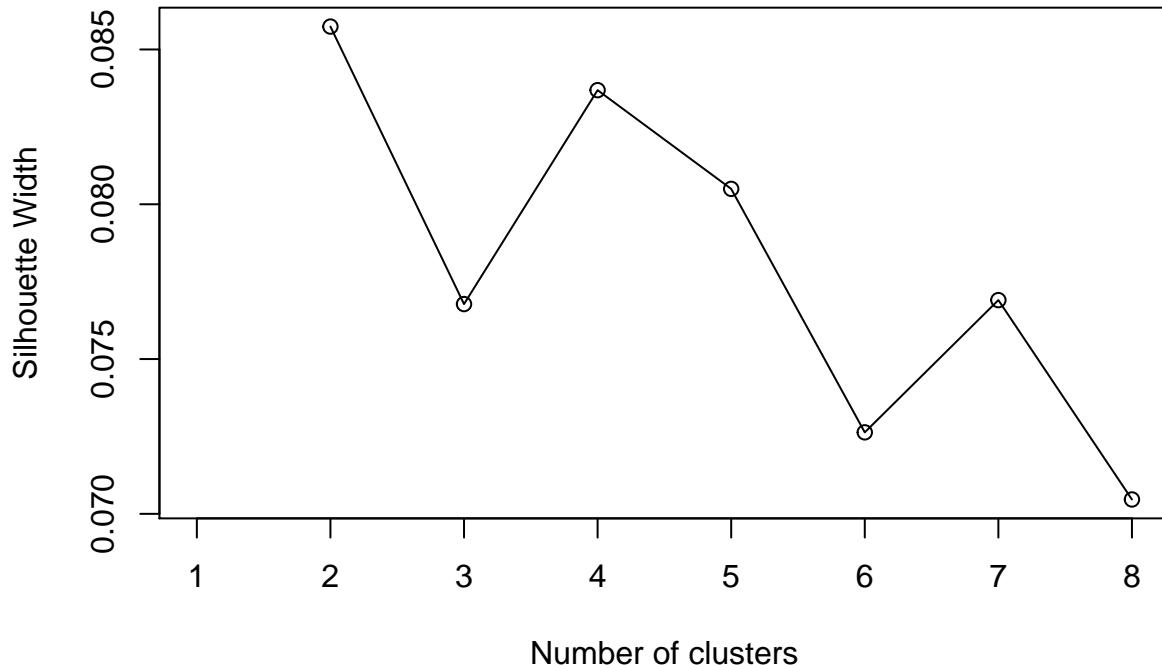
##          Ship_Mode Segment      City State Sub_Category diff_in_days
## 6827 Standard Class Corporate Lafayette Indiana    Copiers        7
## 6798 Same Day Consumer Houston Texas      Binders        0
##          Sales Quantity Discount Profit
## 6827 17499.950       5       0.0 8399.9760
## 6798     3.798       1       0.8   -6.0768
```

## Determine the optimal number of clusters using the Silhouette Width Method

Try to figure out the number of clusters to use by using the silhouette coefficient. Typically the number of clusters used is between 2 and 8.

```
sil_width <- c(NA)
for (i in 2:8){
  pam_fit <- pam(gower_dist, diss = TRUE, k = i )
  sil_width[i] <- pam_fit$silinfo$avg.width
}

plot(1:8, sil_width,
      xlab = "Number of clusters",
      ylab = "Silhouette Width")
lines(1:8, sil_width)
```



2 clusters has the highest silhouette width, while 4 has the second highest. Higher silhouette width is generally better. 2 Clusters may be too simple, so We will pick k = 4.

To look at a summary of each of the clusters:

```
k <- 4
pam_fit_4 <- pam(gower_dist, diss = TRUE, k)
pam_results_4 <- data2 %>%
  mutate(cluster = pam_fit_4$clustering) %>%
  group_by(cluster) %>%
```

```

do(the_summary = summary(..))
pam_results_4$the_summary

```

```

## [[1]]
##           Ship_Mode          Segment            City          State
## First Class : 528   Consumer :1586 San Francisco: 279 California:638
## Same Day    : 284   Corporate : 386   Seattle      : 113   Texas     :195
## Second Class:1262 Home Office: 200 Los Angeles   : 100 Washington:142
## Standard Class: 98
##                               Houston      :  85   Ohio       :127
##                               Chicago      :  66   Illinois   : 95
##                               Columbus    :  53   New York   : 90
##                               (Other)     :1476 (Other)    :885
##           Sub_Category diff_in_days          Sales        Quantity
## Furnishings:407   Min.    :0.000   Min.    : 0.99   Min.    : 1.000
## Paper       :260   1st Qu.:2.000   1st Qu.: 18.58  1st Qu.: 2.000
## Accessories:196   Median   :2.000   Median   : 54.79  Median   : 3.000
## Storage      :193   Mean     :2.358   Mean     : 216.38 Mean     : 3.699
## Art          :188   3rd Qu.:3.000   3rd Qu.: 197.91 3rd Qu.: 5.000
## Phones       :168   Max.    :7.000   Max.    :13999.96 Max.    :14.000
## (Other)      :760
##           Discount         Profit          cluster
## Min.    :0.0000  Min.    :-1862.312  Min.    :1
## 1st Qu.:0.0000  1st Qu.:  2.936  1st Qu.:1
## Median   :0.0000  Median   :  9.752  Median   :1
## Mean     :0.1113  Mean     : 32.005 Mean     :1
## 3rd Qu.:0.2000  3rd Qu.: 31.693  3rd Qu.:1
## Max.    :0.8000  Max.    : 6719.981 Max.    :1
##
##
## [[2]]
##           Ship_Mode          Segment            City
## First Class : 309   Consumer :2746 Los Angeles   : 615
## Same Day    : 69    Corporate : 475  San Francisco: 165
## Second Class:159   Home Office: 237 Houston      : 152
## Standard Class:2921
##                               Chicago      : 136
##                               Seattle      : 135
##                               San Diego    : 100
##                               (Other)     :2155
##           State          Sub_Category diff_in_days        Sales
## California:1142 Binders      :1063   Min.    :0.000   Min.    : 0.444
## Texas      : 408  Phones       : 312   1st Qu.:4.000   1st Qu.: 14.943
## Illinois   : 221  Art          : 263   Median   :5.000   Median   : 49.564
## Washington: 164 Storage      : 263   Mean     :4.711   Mean     : 225.913
## Ohio       : 161 Accessories  : 231   3rd Qu.:6.000   3rd Qu.: 217.584
## Florida    : 135 Chairs       : 213   Max.    :7.000   Max.    :10499.970
## (Other)    :1227 (Other)     :1113
##           Quantity         Discount         Profit          cluster
## Min.    : 1.000  Min.    :0.0000  Min.    :-6599.978  Min.    :2
## 1st Qu.: 2.000  1st Qu.:0.0000  1st Qu.: -0.936  1st Qu.:2
## Median   : 3.000  Median   :0.2000  Median   :  6.774  Median   :2
## Mean     : 3.846  Mean     :0.2148  Mean     : 19.673 Mean     :2
## 3rd Qu.: 5.000  3rd Qu.:0.2000  3rd Qu.: 25.192  3rd Qu.:2
## Max.    :14.000  Max.    :0.8000  Max.    : 5039.986 Max.    :2

```

```

## 
## 
## [[3]]
##           Ship_Mode          Segment            City          State
## First Class : 281   Consumer : 295 Philadelphia:506 Pennsylvania:537
## Same Day     :  83   Corporate : 190    Seattle     : 79      Texas     :147
## Second Class : 204 Home Office:1188 Houston    : 66      Illinois  : 90
## Standard Class:1105                               Chicago    : 55      Washington : 89
##                                         Columbus   : 34      Ohio      : 85
##                                         Springfield : 31      California : 72
##                                         (Other)    :902     (Other)   :653
##           Sub_Category diff_in_days       Sales        Quantity
## Paper       :322   Min.   :0.000   Min.   : 0.852   Min.   : 1.000
## Binders     :187   1st Qu.:3.000  1st Qu.: 15.552  1st Qu.: 2.000
## Phones      :163   Median  :4.000   Median  : 47.984  Median  : 3.000
## Storage     :141   Mean    :4.014   Mean    : 216.941  Mean    : 3.727
## Accessories:137  3rd Qu.:5.000  3rd Qu.: 203.976 3rd Qu.: 5.000
## Furnishings:133 Max.    :7.000   Max.    :22638.480 Max.    :14.000
## (Other)     :590
##           Discount        Profit        cluster
## Min.   :0.0000  Min.   :-3399.980  Min.   :3
## 1st Qu.:0.0000 1st Qu.: -2.131   1st Qu.:3
## Median  :0.2000  Median  :  5.443   Median  :3
## Mean    :0.2065  Mean    : 10.078   Mean    :3
## 3rd Qu.:0.2000 3rd Qu.: 20.539   3rd Qu.:3
## Max.   :0.8000  Max.   : 2591.957  Max.   :3
## 
## 
## [[4]]
##           Ship_Mode          Segment            City
## First Class : 420   Consumer : 564 New York City: 789
## Same Day     : 107   Corporate :1969 Seattle     : 101
## Second Class : 320 Home Office: 158 Houston    :  74
## Standard Class:1844                               Columbus   : 70
##                                         Springfield : 59
##                                         Chicago    : 57
##                                         (Other)    :1541
##           State          Sub_Category diff_in_days       Sales
## New York  : 925   Paper       :600   Min.   :0.000   Min.   :  1.24
## Texas     : 235   Storage     :249   1st Qu.:4.000   1st Qu.: 20.34
## California: 149   Phones     :246   Median  :4.000   Median  : 62.28
## Washington: 111   Art        :215   Mean    :4.248   Mean    : 253.84
## Ohio      :  96   Accessories:211  3rd Qu.:5.000   3rd Qu.: 219.10
## Florida   :  94   Furnishings:205 Max.    :7.000   Max.    :17499.95
## (Other)   :1081   (Other)    :965
##           Quantity        Discount        Profit        cluster
## Min.   : 1.000  Min.   :0.00000  Min.   :-3839.990  Min.   :4
## 1st Qu.: 2.000 1st Qu.:0.00000  1st Qu.: 3.972   1st Qu.:4
## Median  : 3.000  Median :0.00000  Median  :12.118   Median :4
## Mean    : 3.828  Mean   :0.08585  Mean   : 49.049  Mean   :4
## 3rd Qu.: 5.000 3rd Qu.:0.20000  3rd Qu.: 39.660   3rd Qu.:4
## Max.   :14.000  Max.   :0.80000  Max.   : 8399.976  Max.   :4
## 
```

The first cluster has the majority values: ship mode is Second Class , segment is Consumer , City is San Francisco/other, State is California/other, sub category is furnishings. The mean difference in days between order date and ship date is 2.358 days, the mean value for Sales is \$216.38, the mean quantity is 3.699, the discount mean is \$0.1113, profit mean is \$32.

cluster 1 is made of second class shippng, Consumer segment x San Franciso x California x furnishings.

For cluster 2, the ship mode is mostly standard class, segment is mostly consumer, city is mostly Los Angeles/other, State is mostly California/Other, subcategory is mostly Binders/other. The mean difference in days between order date and ship date is 4.7 days, the mean sales \$225.91, mean quantity is 3.48, discount is 0.2148, and profit mean is \$19.67.

Cluster 2 is made of standard class shipping x consumer segment x Los Angeles x California x Binders.

For cluster 3, the main ship mode is First class, the segment is mostly Home Office, the most common city is Philadelphia/Other, the most common State is Pennsylvania/Other, and the most common subcategory is paper/other. For numeric variables, the mean difference in days between order date and ship date is 4.04 days, the mean sales \$216.94, mean quantity is 3.72, mean discount is 0.2065, and mean profit is \$10.08.

Cluster 3 is First class shipping x Home Office segment x Philadelphia x Pennsylvania x Paper. Cluster 3 has the lowest mean profit of the 4 clusters.

For cluster 4, the main ship mode is First class, the most common segment is Corporate, New York City/Other is the most common city, New York State/Other is the most common state, and the most common subcategory is paper. For the numeric features, the mean difference in days between order date and ship date is 4.25 days, the mean sales is \$253.84, and mean quantity is 3.83, mean discount is 0.086, mean profit is \$49.05.

Cluster 4 is made of First Class shipping x Corporate segment x New York City x New York State x Paper. Cluster 4 has the highest mean sales amount and mean profit, with lowest mean discount.

We can now visualise the clusters in lower dimensional space with tSNE (t-Distributed Stochastic Neighbor Embedding) which can be used for dimensionality reduction.

```
#summary(pam_fit_4)
```

Medoids: ID

```
[1,] 560 560 [2,] 9 9 [3,] 951 951 [4,] 6943 6943
```

Objective function: build swap 0.3215923 0.3208374

Numerical information per cluster: size max\_diss av\_diss diameter separation  
[1,] 2172 0.5369861 0.3495248  
0.7527143 0.0004132536 [2,] 3458 0.6045552 0.3040315 0.8092413 0.0142857143 [3,] 1673 0.5553794 0.3280627  
0.7789958 0.0142857143 [4,] 2691 0.5881813 0.3147869 0.8127438 0.0004132536

Isolated clusters: L-clusters: character(0) L\*-clusters: character(0)

Average silhouette width per cluster: [1] 0.07665593 0.11233789 0.05559724 0.07000398 Average silhouette width of total data set: [1] 0.08368581

Available components: [1] "medoids" "id.med" "clustering" "objective" "isolation" "clusinfo" "silinfo" "diss" "call"

These were the observations used as the medoids for the pam fit with k=4:

```
data2[pam_fit_4$medoids, ]
```

|        | Ship_Mode      | Segment  | City          | State      | Sub_Category |
|--------|----------------|----------|---------------|------------|--------------|
| ## 560 | Second Class   | Consumer | San Francisco | California | Furnishings  |
| ## 9   | Standard Class | Consumer | Los Angeles   | California | Binders      |

```

## 951 Standard Class Home Office Philadelphia Pennsylvania      Paper
## 6943 Standard Class Corporate New York City     New York      Paper
##   diff_in_days Sales Quantity Discount Profit
## 560          2 42.600      3    0.0 16.6140
## 9            5 18.504      3    0.2  5.7825
## 951          4 15.552      3    0.2  5.4432
## 6943         4 68.520      3    0.0 31.5192

```

Plotting the k-medoids with k=4. This method applies t-distributed stochastic neighborhood embedding (t-SNE) which enables visualization of several variables in a lower dimensional space.

```

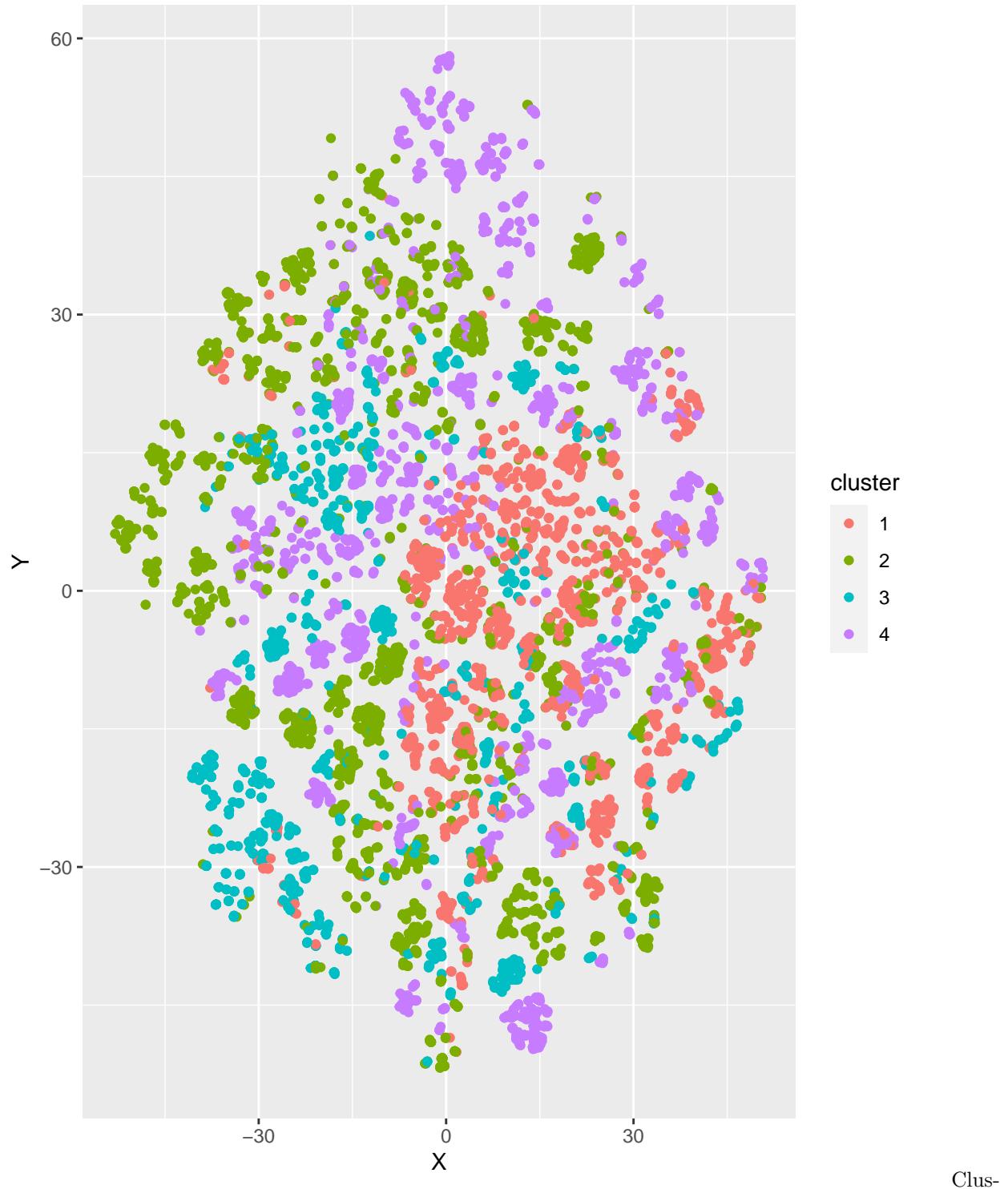
tsne_obj <- Rtsne(gower_dist, is_distance = TRUE)

tsne_data <- tsne_obj$Y %>%
  data.frame() %>%
  setNames(c("X", "Y")) %>%
  mutate(cluster = factor(pam_fit_4$clustering))

ggplot(aes(x = X, y = Y), data = tsne_data) +
  geom_point(aes(color = cluster)) +
  labs(title = 't-SNE 2D Projections of k-medoid clusters') +
  theme(plot.title = element_text(hjust = 0.5))

```

## t-SNE 2D Projections of k-medoid clusters



ters still look like they have some overlap, but cluster 1 is pretty well defined.

```
input_data <- data2
```

We also tried using  $k = 3$  for k-medoids clustering.

Let's try using k=3:

```
gower_dist_3 = daisy(input_data, metric = "gower", type = list(logratio = 3))
gower_mat = as.matrix(gower_dist_3)
pam_fit_3 = pam(gower_mat, k=3, diss=TRUE)

#summary(pam_fit_3)
```

some information from the summary of pam fit for k=3:

Medoids: ID

```
[1,] "399" "399" [2,] "9" "9"
[3,] "7119" "7119"
```

Numerical information per cluster: size max\_diss av\_diss diameter separation  
[1,] 2361 0.6204122 0.3754422  
0.7803200 0.01490751 [2,] 4281 0.6045552 0.3173436 0.8092413 0.01524512 [3,] 3352 0.5882532 0.3311972  
0.8127438 0.01490751

Isolated clusters: L-clusters: character(0) L\*-clusters: character(0)

Average silhouette width per cluster: [1] 0.06840880 0.09434220 0.06023282 Average silhouette width of total data set: [1] 0.07677532

Available components: [1] "medoids" "id.med" "clustering" "objective" "isolation" "clusinfo" "silinfo" "diss" "call"

The average silhouette width of the total data set is 0.0767753.

```
pam_results_3 <- data2 %>%
  mutate(cluster = pam_fit_3$clustering) %>%
  group_by(cluster) %>%
  do(the_summary = summary(.))

pam_results_3$the_summary
```

```
## [[1]]
##           Ship_Mode          Segment            City
## First Class : 650    Consumer   :1593    Houston     : 286
## Same Day    : 276    Corporate  : 342    Philadelphia : 137
## Second Class:1277   Home Office: 426    Seattle      : 135
## Standard Class: 158                               Chicago     :  90
##                                         Dallas      :  64
##                                         San Francisco:  63
##                                         (Other)    :1586
##           State        Sub_Category diff_in_days       Sales
## Texas      : 528    Storage     :340    Min.   :0.000   Min.   :  0.444
## Ohio       : 171    Furnishings:251    1st Qu.:2.000   1st Qu.: 19.152
## Washington : 162    Paper       :251    Median :2.000   Median : 67.000
## California : 152    Phones      :238    Mean   :2.524   Mean   :239.150
## Pennsylvania: 150   Accessories:222    3rd Qu.:3.000   3rd Qu.:239.980
## Illinois   : 140    Art         :203    Max.   :7.000   Max.   :13999.960
## (Other)    :1058   (Other)     :856
##           Quantity      Discount       Profit       cluster
## Min.   : 1.000   Min.   :0.0000   Min.   :-2639.991   Min.   :1
## 1st Qu.: 2.000   1st Qu.:0.0000   1st Qu.:  0.691   1st Qu.:1
## Median : 3.000   Median :0.2000   Median :  6.871   Median :1
## Mean   : 3.713   Mean   :0.1758   Mean   : 20.726   Mean   :1
```

```

## 3rd Qu.: 5.000   3rd Qu.:0.2000   3rd Qu.:    28.310   3rd Qu.:1
## Max.     :14.000   Max.     :0.8000   Max.     : 6719.981   Max.     :1
##
## 
## [[2]]
##             Ship_Mode          Segment            City
## First Class    : 391   Consumer    :3015   Los Angeles  : 710
## Same Day       : 138   Corporate   : 549   San Francisco: 335
## Second Class   : 292   Home Office: 717   Philadelphia : 257
## Standard Class:3460
##                               Chicago      : 154
##                               Seattle      : 154
##                               San Diego    : 133
##                               (Other)     :2538
##             State          Sub_Category  diff_in_days   Sales
## California    :1583   Binders     :1217   Min.    :0.000   Min.    :    0.836
## Texas         : 283   Phones      : 376   1st Qu.:4.000   1st Qu.: 14.910
## Pennsylvania  : 282   Furnishings: 354   Median  :5.000   Median  : 47.976
## Illinois      : 253   Art         : 317   Mean    :4.497   Mean    : 224.406
## Ohio          : 185   Accessories: 299   3rd Qu.:5.000   3rd Qu.: 206.962
## Washington    : 184   Paper        : 285   Max.    :7.000   Max.    :22638.480
## (Other)       :1511   (Other)     :1433
##             Quantity      Discount      Profit           cluster
## Min.    : 1.000   Min.    :0.00000   Min.    :-6599.978   Min.    :2
## 1st Qu.: 2.000   1st Qu.:0.00000   1st Qu.: 0.000   1st Qu.:2
## Median  : 3.000   Median  :0.20000   Median  : 6.888   Median  :2
## Mean    : 3.815   Mean    :0.2051   Mean    : 19.091   Mean    :2
## 3rd Qu.: 5.000   3rd Qu.:0.2000   3rd Qu.: 24.858   3rd Qu.:2
## Max.    :14.000   Max.    :0.8000   Max.    : 5039.986   Max.    :2
##
## 
## [[3]]
##             Ship_Mode          Segment            City
## First Class    : 497   Consumer    : 583   New York City: 796
## Same Day       : 129   Corporate   :2129   Philadelphia : 143
## Second Class   : 376   Home Office: 640   Seattle      : 139
## Standard Class:2350
##                               San Francisco: 112
##                               Columbus     : 87
##                               Chicago      : 70
##                               (Other)     :2005
##             State          Sub_Category  diff_in_days   Sales
## New York       : 935   Paper        : 834   Min.    :0.00   Min.    :    1.24
## California     : 266   Furnishings: 352   1st Qu.:4.00   1st Qu.: 18.96
## Texas          : 174   Art         : 276   Median  :4.00   Median  : 53.28
## Washington     : 160   Phones      : 275   Mean    :4.28   Mean    : 230.28
## Pennsylvania   : 155   Accessories: 254   3rd Qu.:5.00   3rd Qu.: 197.18
## Ohio           : 113   Storage     : 237   Max.    :7.00   Max.    :17499.95
## (Other)        :1549   (Other)     :1124
##             Quantity      Discount      Profit           cluster
## Min.    : 1.000   Min.    :0.00000   Min.    :-3839.99   Min.    :3
## 1st Qu.: 2.000   1st Qu.:0.00000   1st Qu.: 4.02   1st Qu.:3
## Median  : 3.000   Median  :0.00000   Median  : 11.65   Median  :3
## Mean    : 3.811   Mean    :0.07989   Mean    : 46.46   Mean    :3
## 3rd Qu.: 5.000   3rd Qu.:0.20000   3rd Qu.: 37.14   3rd Qu.:3
## Max.    :14.000   Max.    :0.80000   Max.    : 8399.98   Max.    :3

```

```
##
```

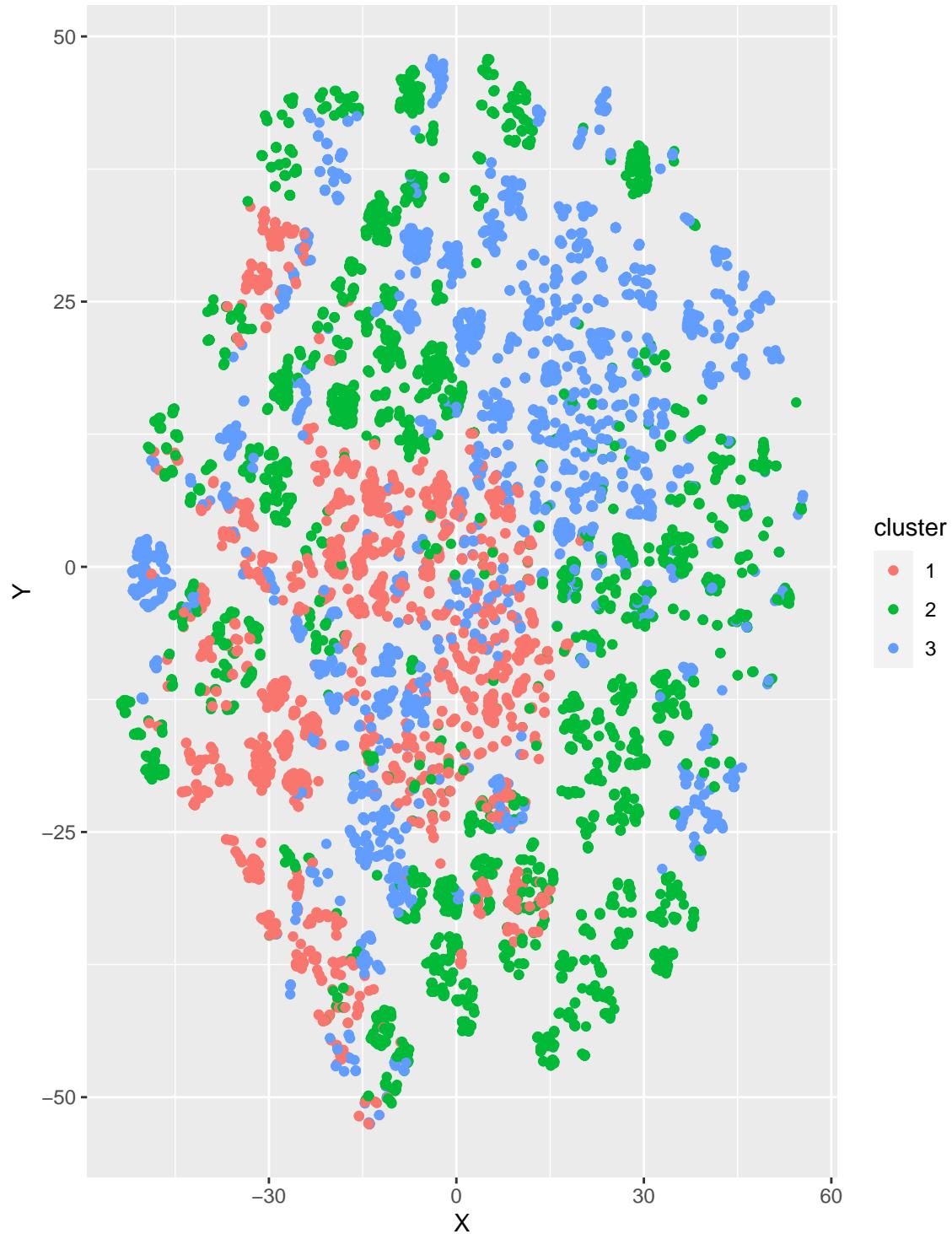
## Visualise the clusters using T-SNE

```
tsne_obj <- Rtsne(gower_dist_3, is_distance = TRUE)

tsne_data <- tsne_obj$Y %>%
  data.frame() %>%
  setNames(c("X", "Y")) %>%
  mutate(cluster = factor(pam_fit_3$clustering))

ggplot(aes(x = X, y = Y), data = tsne_data) +
  geom_point(aes(color = cluster)) +
  labs(title = 't-SNE 2D Projections of k-medoid clusters') +
  theme(plot.title = element_text(hjust = 0.5))
```

### t-SNE 2D Projections of k-medoid clusters



We also tried  $k=5$  for k-medoids clustering. For  $k=5$ , The average silhouette width per cluster were: [1] 0.05349182 0.10906323 0.04114758 0.08911682 0.07800729. The average silhouette width of the total data set for  $k=5$  is 0.08049662, which is less than the silhouette width for  $k=4$  (0.08368581). The optimal number of clusters is  $k=4$ , since it maximises the average silhouette width. Higher silhouette width values indicate better quality clustering (Datanova, 2018). We also plotted the clustering result using the gower distance

metric and t-SNE for dimensionality reduction. However, the plot shows there is still a great deal of overlap between the clusters.

### Method 3 - Clustering on Principal Components using Factor analysis of mixed data (FAMD)

Factor analysis of mixed data is a principal component method useful for analyzing datasets which contain numeric and categorical data.

Quantitative variables and qualitative variables are normalized to obtain a balance of the different sets of variables (Kassambra, 2017).

To run the Factor Analysis of Mixed Data method:

```
set.seed(123)

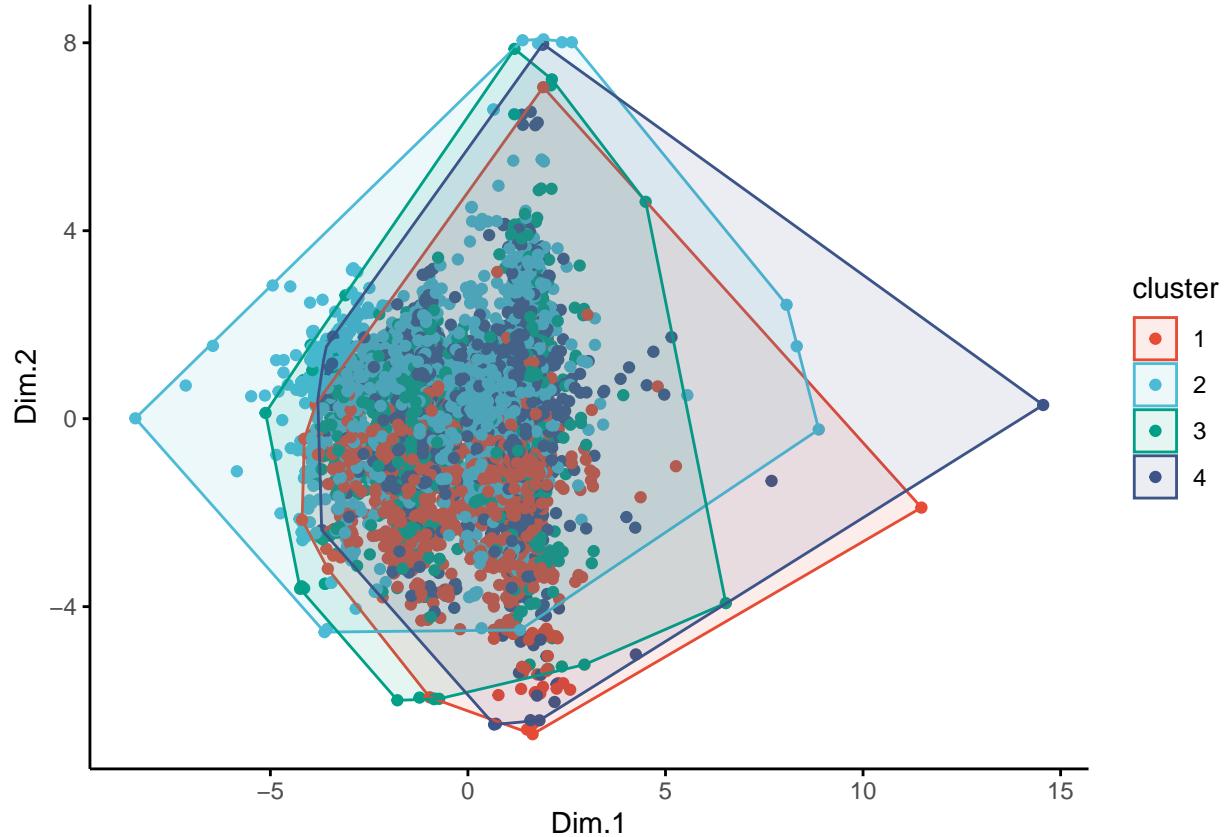
famd_fca=FAMD(input_data, ncp = 5, sup.var = NULL, ind.sup = NULL, graph = FALSE) #ncp is the number o

ind=get_famd_ind(famd_fca)$coord    #retrieve the results for the individual observations
ind=as.data.frame(ind)
ind$cluster=as.factor(pam_fit_4$clustering)
```

Plotting the clusters found using Factor Analysis of Mixed Data (FAMD).

```
ggscatter(
  ind, x = "Dim.1", y = "Dim.2",
  color = "cluster", palette = "npg", ellipse = TRUE, ellipse.type = "convex",      #adding the concent
  size = 1.5,   legend = "right", ggtheme = theme_classic()

)
```



## Evaluating the consistency within Clusters of Data Silhouette coefficient can be used to compare the average distance to observations within the same cluster, to the average distance to observations in other clusters.

High silhouette coefficient means that the observation is well clustered, while a low silhouette coefficient may indicate outliers.

## Deployment

The clustering model and anomaly detection app are deployed in shiny app. The interactive applications accepts inputs from the user and display accordingly. The url for application is below  
Clustering Anomaly Detection

## Responsible ML Framework

Superstore dataset has transaction data for online orders from Superstore customers. The dataset has Personally Identifiable information like Customer Name and Postal code. The use of personal information for other purposes, subsequent to the original transaction between an individual and an organization need consent from the customer. Individuals are increasingly feeling that they are losing control over their own personal information that may reside on thousands of servers largely beyond the control of existing privacy laws. This scenario can lead to privacy invasion on a scale never before possible if not handled ethically. In this project, personally identifiable attributes are removed from the data as part of data cleansing and not considered in any stages of the study. The techniques used in the project is not biased for any particular region, city or customer segment.

## Conclusion

In K means clustering, the goal is to have high similarity within each cluster, and low similarity between clusters. High similarity within a group means low variance within the cluster (within\_SS), while low similarity between the groups is the same as high variance between the clusters (between\_SS). Total\_SS is all the variance in the data. The goal is to maximize the between\_ss/total\_ss value.

For K-means clustering, for k=4 (4 clusters), when we perform clustering on the data without removing the outliers first, the Within cluster sum of squares by cluster: is 3315.203, 4284.643, 7571.058, 3614.724, and the between\_SS / total\_SS = 53.0 %. In comparison, when outlier transactions are first removed using the Local Outlier Factor method, for k=4, the Kmeans Within cluster sum of squares by cluster values are: 5391.896, 3363.327, 2252.744, 2215.088 and between\_SS / total\_SS = 56.7 %. This shows that by removing the outlier transactions first before performing K-means clustering, there is better clustering with a greater between\_SS / total\_SS percentage.

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