

# ML1000 Assignment 3 - Recommender System using Market Basket Analysis Apriori Algorithm and Weighted Alternating Least Squares with Implicit Feedback

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## Abstract

The main goal of recommender systems is to provide suggestions to online users to make better decisions from many alternatives available over the Web. A better recommender system directs towards more personalized recommendations by taking into consideration information about a product, such as specifications, users' purchase history, comparison with other products, and so on, before making recommendations.

We built two main recommender systems using the Instacart Online Grocery Shopping Dataset 2017. The first recommender system uses the APRIORI algorithm to mine for patterns between items which are frequently bought together. The results of the APRIORI method identifies association rules between different products, so that if a customer has a certain item in their basket, other frequently bought items will be suggested.

The second recommender system we built is using Weighted Alternating Least Squares with Implicit Feedback Data (WALSIFD). In the WALSIFD method, if a customer bought an item several times, it is assumed that there is positive feedback in terms of user preference for those items. The objective of this model is to identify products that has a high probability of being clicked on or purchased by a user, based on their previous transactions.

## Business Case

## Ethical Machine Learning Framework

The Instacart Online Grocery Shopping dataset does not contain identifiable information for the users who made the transactions. User data does not contain any customer names, only anonymous user ids are included, which helps to maintain privacy of Instacart customers. Transaction data also does not include any sensitive information such as postal code. The current data set do not contain any information about gender or ethnicity, so this information will not have any influence on the recommendations predicted by the recommender systems. The Instacart R Shiny app is hosted on Shinyapps.io which is secure by design, where the application will run on its own protected environment, and access is SSL encrypted (RStudio, 2020). Only writers of the Instacart recommendation app is able to modify the code for the application, because user authentication is required for login to the shinyapps.io site where the application is hosted.

## Data Understanding

The "Instacart Online Grocery Shopping Dataset 2017" was obtained from <https://www.kaggle.com/c/instacart-market-basket-analysis/data> The dataset is anonymized and contains a total of 3 million grocery

orders from more than 200,000 Instacart users. For each user, 4 to 100 of their orders was included in the data, including the sequence in which customers purchased products for each order. Other information in the dataset include the day of week the transaction occurred, time between orders, product name, product id, grocery aisle information, and whether products were reordered. The dataset was originally collected by Instacart for use as a public dataset for machine learning. The dataset can be used to create and test models to predict which products are likely to be re-ordered by a user, ordered for the first time or added to the cart next in a transaction (Stanley, 2017).

## How did we merge the data files?

There are six data files, excluding the sample\_submission.csv file, from the Instacart Market Basket Analysis data - aisles.csv, departments.csv, order\_products\_\_train.csv, order\_products\_\_prior.csv, orders.csv and products.csv.

## Data file descriptions

aisles.csv - contains aisle id and aisle description columns

departments.csv - contains department id and department description columns

order\_products\_\_\*.csv - These files specify which products were purchased in each order. order\_products\_\_prior.csv contains previous order contents for all customers. 'reordered' indicates that the customer has a previous order that contains the product. order\_products\_\_train.csv contains order information for transactions which will be used for training the model.

orders.csv - This file tells to which set (prior, train, test) an order belongs.

products.csv - contains product\_id, product\_name, aisle\_id, department\_id

## Steps to merge the data files:

1. Merged the aisles data with the products data to obtain Merged dataset 1, so that we know which aisle each product belongs to.
2. Combined the Merged dataset 1 with the department data to obtain Merged dataset 2, so we know which aisle and department each product is from.
3. Added Merged dataset 2, which contains product full information, to order\_products\_\_train and order\_products\_\_prior files, respectively, to obtain Merged dataset 3 (Train) and Merged dataset 4 (Prior), so that we know the product information (e.g. product names, aisles and departments they belong to) of the products in the training and prior orders.

## Data Preparation

Read in the merged training data set:

```
X <- read.csv("C:/Users/qt09n/Desktop/Project/orders_TRAIN_products_MERGED.csv")
```

```
str(X)
```

```
## 'data.frame':    1384617 obs. of  16 variables:
## $ order_id      : num  1 1 1 1 1 1 1 1 36 36 ...
## $ user_id       : num  112108 112108 112108 112108 112108 ...
```

```
## $ eval_set          : chr  "train" "train" "train" "train" ...
## $ order_number      : int   4 4 4 4 4 4 4 4 23 23 ...
## $ order_dow         : int   4 4 4 4 4 4 4 4 6 6 ...
## $ order_hour_of_day : int  10 10 10 10 10 10 10 10 18 18 ...
## $ days_since_prior_order: int  9 9 9 9 9 9 9 9 30 30 ...
## $ product_id        : int  10246 11109 22035 47209 13176 49302 49683 43633 39612 46620 ...
## $ add_to_cart_order  : int   3 2 8 7 6 1 4 5 1 5 ...
## $ reordered         : int   0 1 1 0 0 1 0 1 0 1 ...
## $ product_name      : chr   "Organic Celery Hearts" "Organic 4% Milk Fat Whole Milk Cottage Cheese" ...
## $ aisle             : chr   "fresh vegetables" "other creams cheeses" "packaged cheese" "fresh f..."
## $ department        : chr   "produce" "dairy eggs" "dairy eggs" "produce" ...
## $ aisle_id          : int   83 108 21 24 24 120 83 95 2 86 ...
## $ department_id     : int   4 16 16 4 4 16 4 15 16 16 ...
## $ X_merge           : int   3 3 3 3 3 3 3 3 3 3 ...
```

```
dim(X)
```

```
## [1] 1384617      16
```

Check missing values: `complete.cases` will return a logical vector indicating which rows have no missing values. Then use the vector to get only complete rows with `X[,]`

```
X <- X[complete.cases(X),]
```

```
sum(is.na(X))
```

```
## [1] 0
```

No missing values in dataset.

look at first 10 rows of dataset

```
head(X)
```

```
##   order_id user_id eval_set order_number order_dow order_hour_of_day
## 1         1  112108   train           4         4             10
## 2         1  112108   train           4         4             10
## 3         1  112108   train           4         4             10
## 4         1  112108   train           4         4             10
## 5         1  112108   train           4         4             10
## 6         1  112108   train           4         4             10
##   days_since_prior_order product_id add_to_cart_order reordered
## 1                      9      10246                3         0
## 2                      9      11109                2         1
## 3                      9      22035                8         1
## 4                      9      47209                7         0
## 5                      9      13176                6         0
## 6                      9      49302                1         1
##                                product_name      aisle department
## 1                                Organic Celery Hearts  fresh vegetables  produce
## 2 Organic 4% Milk Fat Whole Milk Cottage Cheese  other creams cheeses  dairy eggs
## 3                                Organic Whole String Cheese  packaged cheese  dairy eggs
```

```
## 4          Organic Hass Avocado      fresh fruits    produce
## 5          Bag of Organic Bananas    fresh fruits    produce
## 6          Bulgarian Yogurt          yogurt dairy eggs
##   aisle_id department_id X_merge
## 1      83           4         3
## 2     108          16         3
## 3      21          16         3
## 4      24           4         3
## 5      24           4         3
## 6     120          16         3
```

To examine some of the statistics of the dataset:

```
summary(X)
```

```
##      order_id      user_id      eval_set      order_number
## Min.   :      1  Min.   :      1  Length:1384617  Min.   :  4.00
## 1st Qu.: 843370  1st Qu.: 51732  Class :character  1st Qu.:  6.00
## Median :1701880  Median :102933  Mode  :character  Median : 11.00
## Mean   :1706298  Mean   :103113          Mean   : 17.09
## 3rd Qu.:2568023  3rd Qu.:154959          3rd Qu.: 21.00
## Max.   :3421070  Max.   :206209          Max.   :100.00
##      order_dow      order_hour_of_day  days_since_prior_order  product_id
## Min.   :0.000  Min.   : 0.00  Min.   : 0.00  Min.   :      1
## 1st Qu.:1.000  1st Qu.:10.00  1st Qu.: 7.00  1st Qu.:13380
## Median :3.000  Median :14.00  Median :15.00  Median :25298
## Mean   :2.701  Mean   :13.58  Mean   :17.07  Mean   :25556
## 3rd Qu.:5.000  3rd Qu.:17.00  3rd Qu.:30.00  3rd Qu.:37940
## Max.   :6.000  Max.   :23.00  Max.   :30.00  Max.   :49688
##      add_to_cart_order  reordered      product_name      aisle
## Min.   : 1.000  Min.   :0.0000  Length:1384617  Length:1384617
## 1st Qu.: 3.000  1st Qu.:0.0000  Class :character  Class :character
## Median : 7.000  Median :1.0000  Mode  :character  Mode  :character
## Mean   : 8.758  Mean   :0.5986          Mean   : 8.758
## 3rd Qu.:12.000  3rd Qu.:1.0000          3rd Qu.:12.000
## Max.   :80.000  Max.   :1.0000          Max.   :80.000
##      department      aisle_id      department_id      X_merge
## Length:1384617  Min.   :  1.0  Min.   :  1.00  Min.   :  3
## Class :character  1st Qu.: 31.0  1st Qu.:  4.00  1st Qu.:  3
## Mode  :character  Median : 83.0  Median :  8.00  Median :  3
##                      Mean   : 71.3  Mean   :  9.84  Mean   :  3
##                      3rd Qu.:107.0  3rd Qu.:16.00  3rd Qu.:  3
##                      Max.   :134.0  Max.   :21.00  Max.   :  3
```

Check total users:

```
user_count <- unique(X$user_id)
length(user_count)
```

```
## [1] 131209
```

Change the character columns to factors and create a new column using mutate:

```
X$product_name <- as.factor(X$product_name)
X$department<- as.factor(X$department)
X$aisle <- as.factor(X$aisle)
```

```
unique(X$aisle)
```

```
##      [1] fresh vegetables      other creams cheeses
##      [3] packaged cheese      fresh fruits
##      [5] yogurt               canned meat seafood
##      [7] specialty cheeses    eggs
##      [9] lunch meat           cream
##     [11] water seltzer sparkling water packaged vegetables fruits
##     [13] oils vinegars        fresh herbs
##     [15] frozen produce       nuts seeds dried fruit
##     [17] canned meals beans   food storage
##     [19] baking ingredients   hot dogs bacon sausage
##     [21] refrigerated         plates bowls cups flatware
##     [23] butter               canned jarred vegetables
##     [25] paper goods          fresh dips tapenades
##     [27] soup broth bouillon  dish detergents
##     [29] tortillas flat bread condiments
##     [31] milk                 soap
##     [33] frozen meat seafood  soy lactosefree
##     [35] canned fruit applesauce refrigerated pudding desserts
##     [37] laundry              frozen appetizers sides
##     [39] crackers             ice cream ice
##     [41] juice nectars        chips pretzels
##     [43] cold flu allergy     muscles joints pain relief
##     [45] pasta sauce          bread
##     [47] grains rice dried goods spreads
##     [49] popcorn jerky        baby accessories
##     [51] other                missing
##     [53] digestion            more household
##     [55] packaged produce    breakfast bars pastries
##     [57] candy chocolate     spices seasonings
##     [59] cleaning products   diapers wipes
##     [61] fresh pasta         frozen breakfast
##     [63] asian foods          preserved dips spreads
##     [65] latino foods         pickled goods olives
##     [67] instant foods       energy granola bars
##     [69] packaged meat       hot cereal pancake mixes
##     [71] soft drinks         cookies cakes
##     [73] frozen pizza        tea
##     [75] prepared meals      energy sports drinks
##     [77] poultry counter     trail mix snack mix
##     [79] doughs gelatins bake mixes prepared soups salads
##     [81] buns rolls          dry pasta
##     [83] deodorants          cereal
##     [85] frozen meals        breakfast bakery
##     [87] white wines         coffee
##     [89] fruit vegetable snacks oral hygiene
##     [91] packaged seafood    bulk grains rice dried goods
##     [93] packaged poultry    body lotions soap
```

```
## [95] tofu meat alternatives      dog food care
## [97] bakery desserts             baby food formula
## [99] honeys syrups nectars       meat counter
## [101] trash bags liners           kitchen supplies
## [103] hair care                   beers coolers
## [105] first aid                   vitamins supplements
## [107] granola                     protein meal replacements
## [109] shave needs                 salad dressing toppings
## [111] indian foods                frozen vegan vegetarian
## [113] spirits                     frozen dessert
## [115] mint gum                    cat food care
## [117] facial care                 specialty wines champagnes
## [119] skin care                   frozen breads doughs
## [121] red wines                   marinades meat preparation
## [123] feminine care               baking supplies decor
## [125] ice cream toppings          seafood counter
## [127] cocoa drink mixes           kosher foods
## [129] air fresheners candles      beauty
## [131] bulk dried fruits vegetables eye ear care
## [133] baby bath body care         frozen juice
## 134 Levels: air fresheners candles asian foods ... yogurt
```

*#134 aisles*

```
unique(X$department)
```

```
## [1] produce      dairy eggs    canned goods  deli
## [5] beverages    pantry        frozen        snacks
## [9] household    meat seafood  bakery        personal care
## [13] dry goods pasta babies        other         missing
## [17] breakfast    international alcohol        bulk
## [21] pets
## 21 Levels: alcohol babies bakery beverages breakfast bulk ... snacks
```

```
levels(X$department)
```

```
## [1] "alcohol"      "babies"      "bakery"      "beverages"
## [5] "breakfast"    "bulk"        "canned goods" "dairy eggs"
## [9] "deli"         "dry goods pasta" "frozen"      "household"
## [13] "international" "meat seafood" "missing"     "other"
## [17] "pantry"       "personal care" "pets"        "produce"
## [21] "snacks"
```

*#21 departments*

```
length(unique(X$product_name))
```

```
## [1] 39123
```

```
#39123 products
```

Total products from product id column:

```
product_count <- unique(X$product_id)
length(product_count)
```

```
## [1] 39123
```

```
class(X$order_hour_of_day)
```

```
## [1] "integer"
```

```
#[1] "integer"
```

How many unique orders are in the training dataset?

```
length(unique(X$order_id))
```

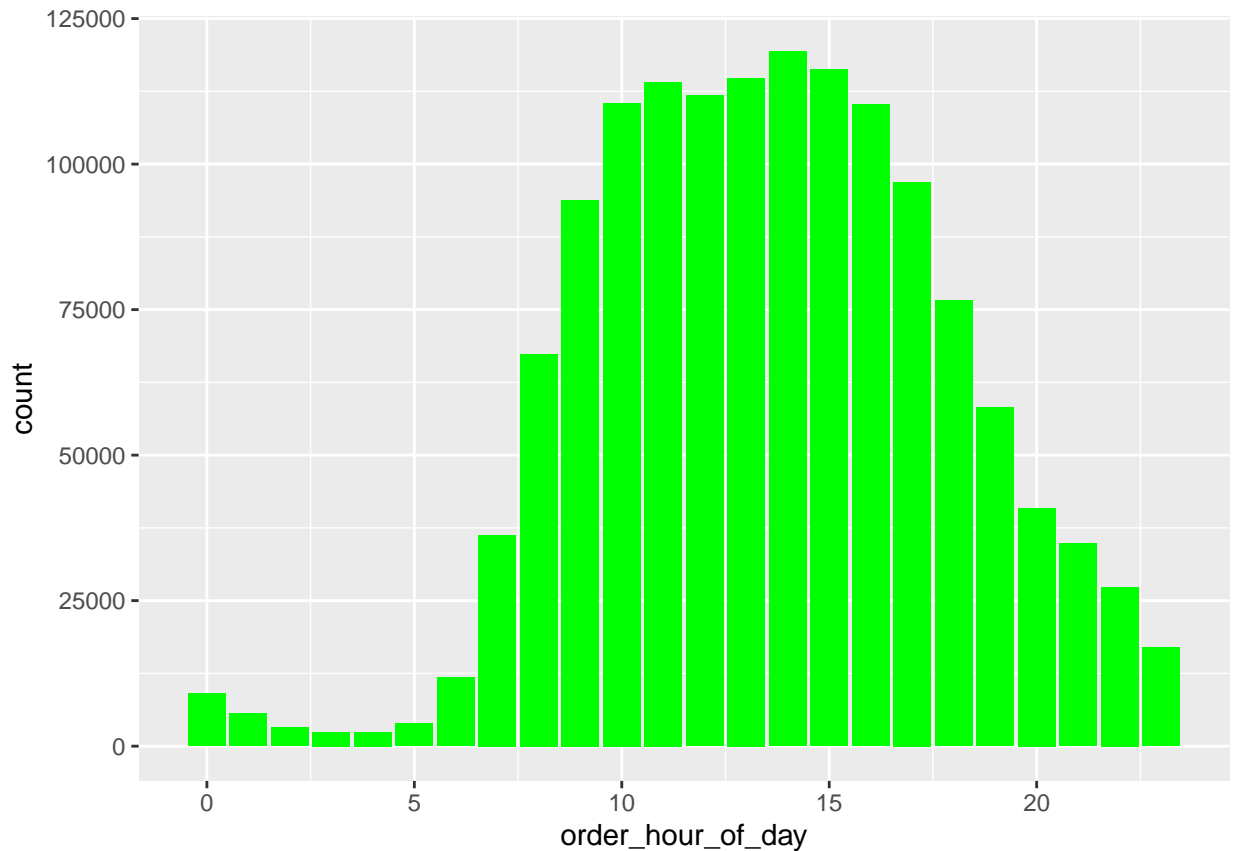
```
## [1] 131209
```

Recode order\_hour\_of\_day to numeric:

```
X$order_hour_of_day <- as.numeric(X$order_hour_of_day)
```

What times are orders placed?

```
X %>% ggplot(aes(x= order_hour_of_day)) +
  geom_bar(stat="count", fill="green")
```



People mostly order from 8:00 - 17:00 (8AM - 5PM).

Number of distinct orders by user:

```
p1<-X %>%
  group_by(user_id) %>%
  dplyr::summarise(count_order=n()) %>%
  ungroup()

ggplot(p1, aes(count_order)) + geom_histogram(binwidth = 10)+labs(title="Number of distinct orders by user",
  x ="Number of Orders", y = "Number of Users")+coord_cartesian(xlim = c(0, 80))
```

Number of distinct products per user:

```
p2 <- X %>%
  group_by(user_id, product_id) %>%
  dplyr::summarise(count3=n()) %>%
  select(user_id, product_id, count3) %>%
  ungroup() %>%
  group_by(user_id) %>%
  dplyr::summarise(count_product=n()) %>%
  ungroup()
```

## 'summarise()' has grouped output by 'user\_id'. You can override using the '.groups' argument.



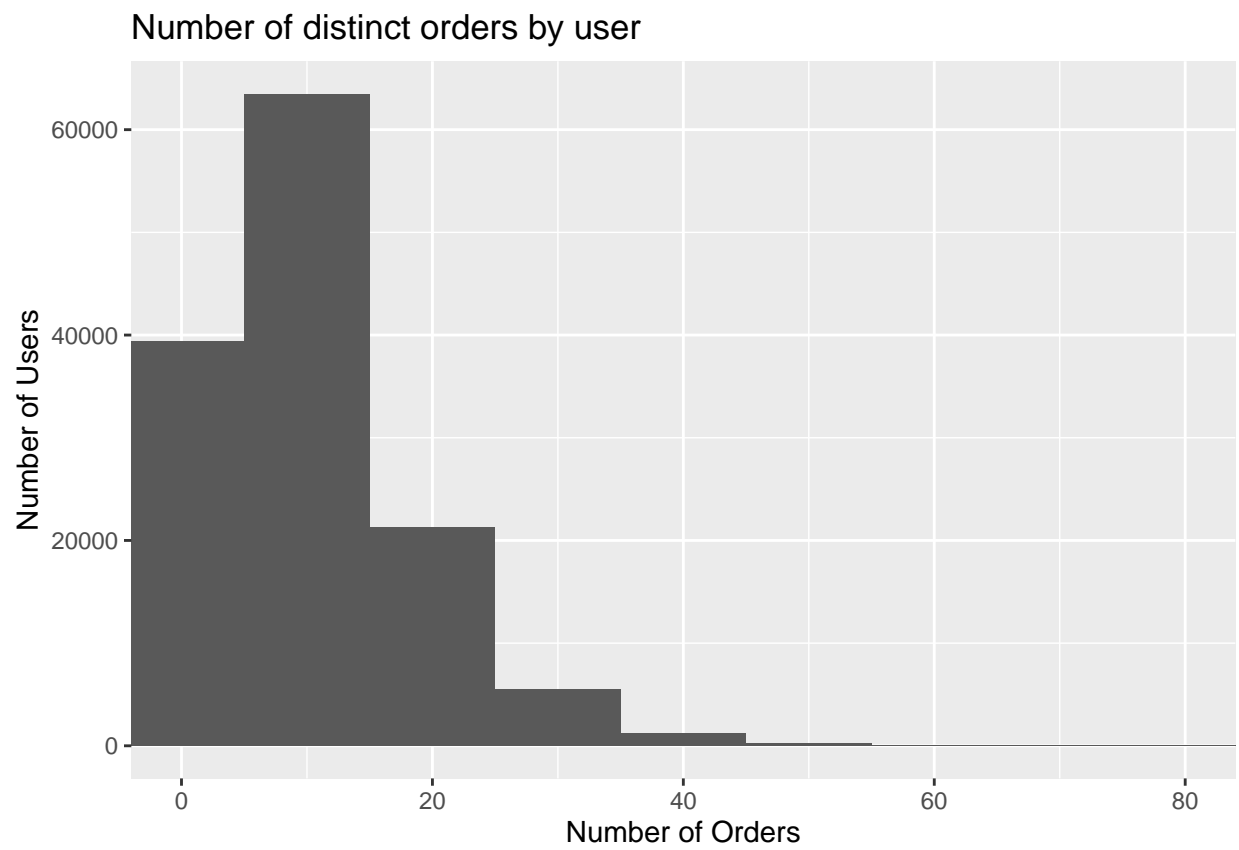


Figure 1: Bar chart of number of distinct orders by user. Most users (around 65000) have 10 distinct orders. The next biggest group of users (40000) have between 0 -10 distinct orders placed.

```
ggplot(p2, aes(count_product)) + geom_histogram(binwidth = 10)+labs(title="Number of distinct products by user",
  x = "Number of Products", y = "Number of Users")+coord_cartesian(xlim = c(0, 250))
```

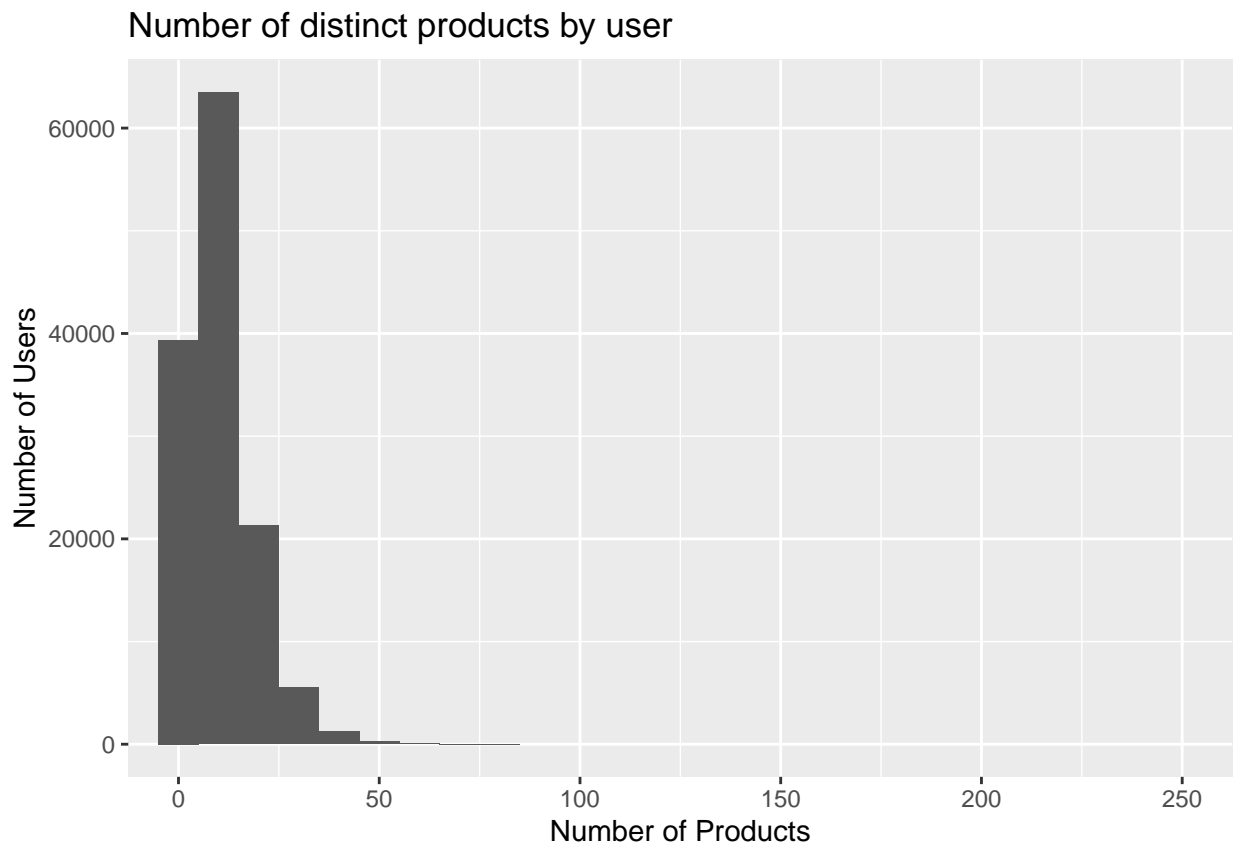


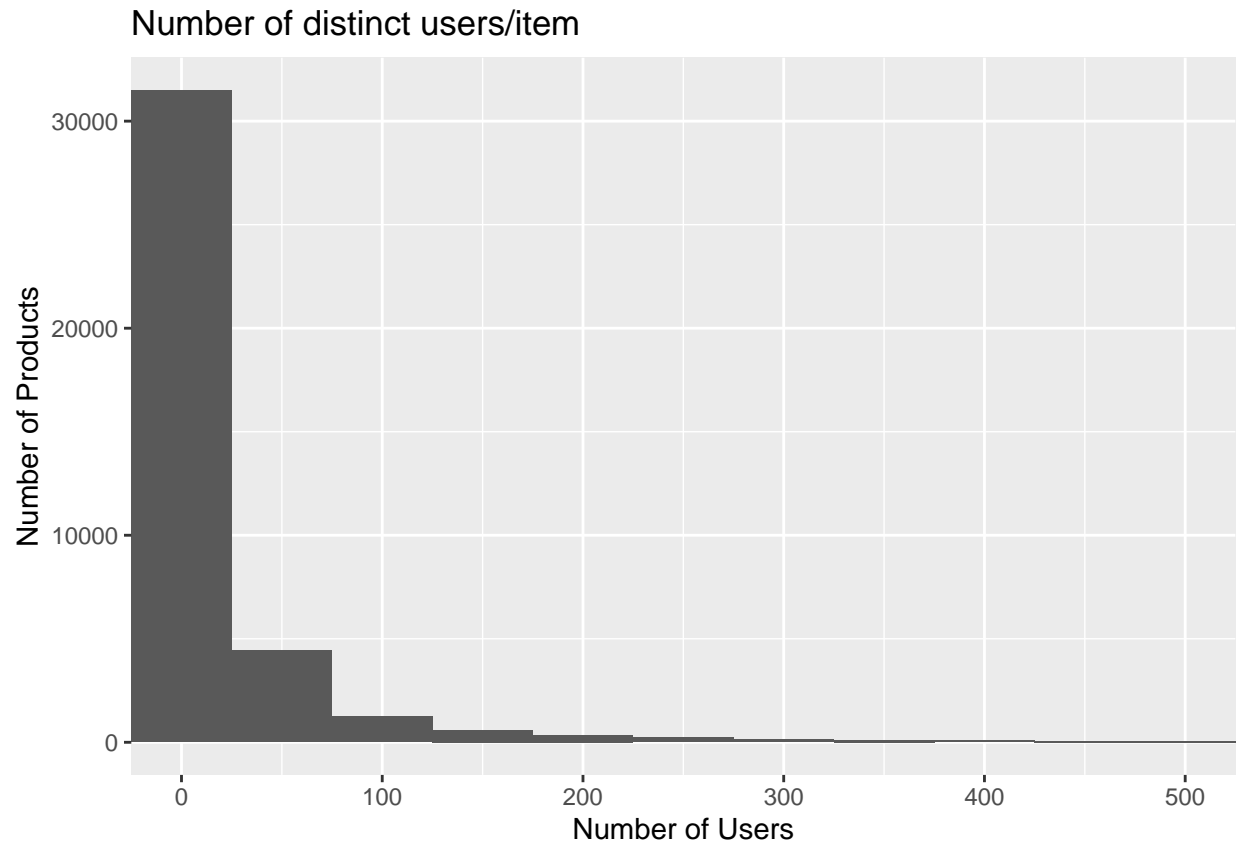
Figure 2: Bar chart of number of distinct products by user for training orders

Number of distinct users/item

```
p3 <- X %>%
  group_by(product_id,user_id) %>%
  dplyr::summarise(count4=n()) %>%
  select(user_id,product_id,count4) %>%
  ungroup() %>%
  group_by(product_id) %>%
  dplyr::summarise(count_user=n()) %>%
  ungroup()
```

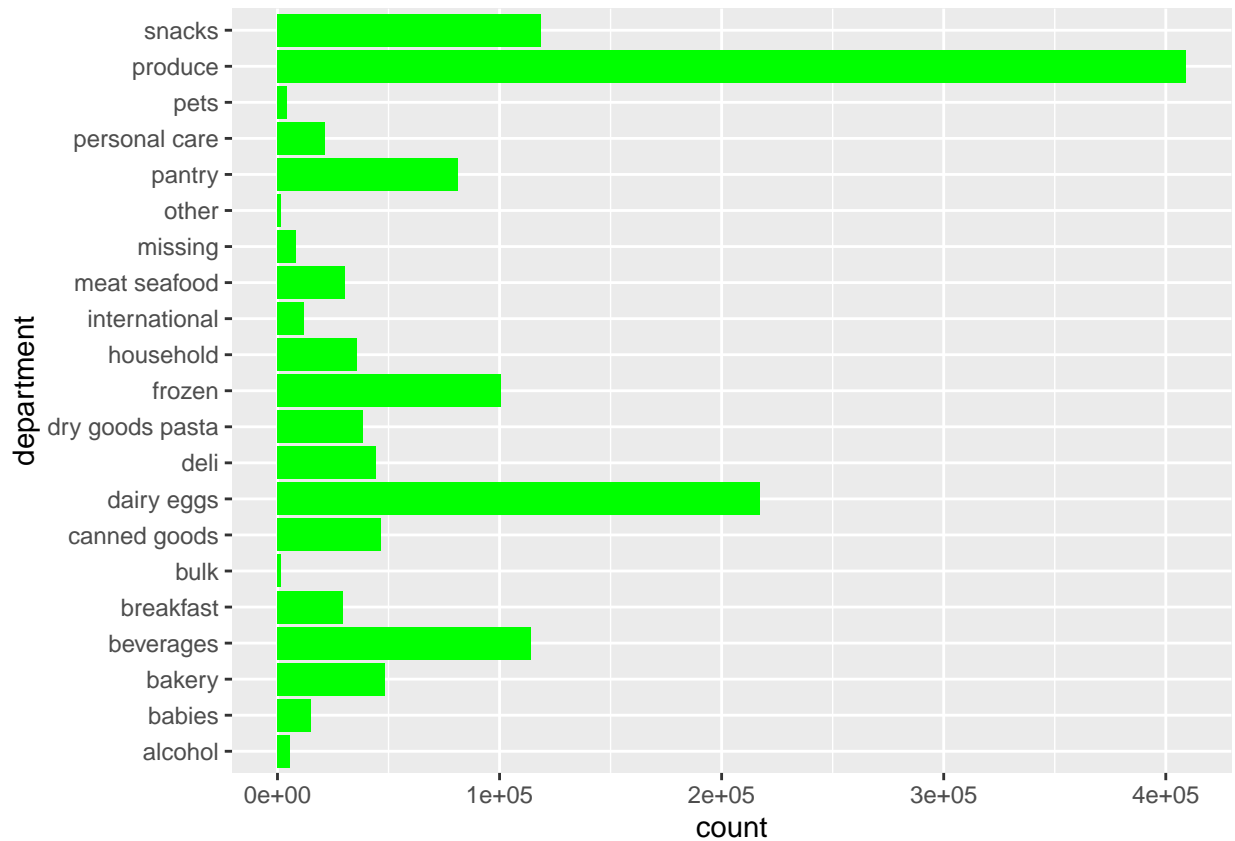
## 'summarise()' has grouped output by 'product\_id'. You can override using the '.groups' argument.

```
ggplot(p3, aes(count_user)) + geom_histogram(binwidth = 50)+labs(title="Number of distinct users/item",
  x = "Number of Users", y = "Number of Products")+coord_cartesian(xlim = c(0, 500))
```



Most frequently bought products

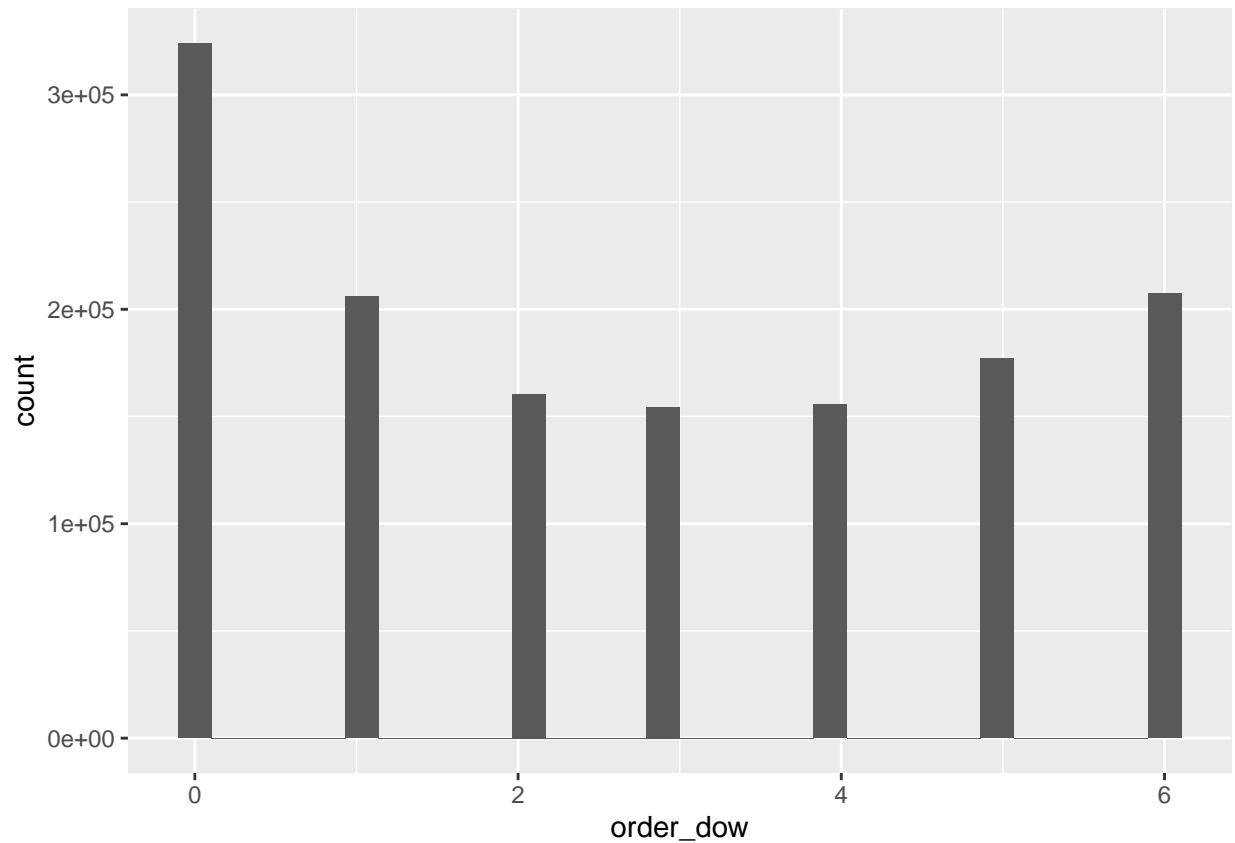
```
X %>% ggplot(aes(x= department)) +  
  geom_histogram(stat="count", fill="green")+  
  coord_flip()
```



Most orders come from the produce aisle, with snacks and dairy, eggs among the top 3 department aisles. 'order\_dow' is the day of week. Which days are orders more commonly placed on?

```
X %>% ggplot(aes(x=order_dow))+
  geom_histogram()
```

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

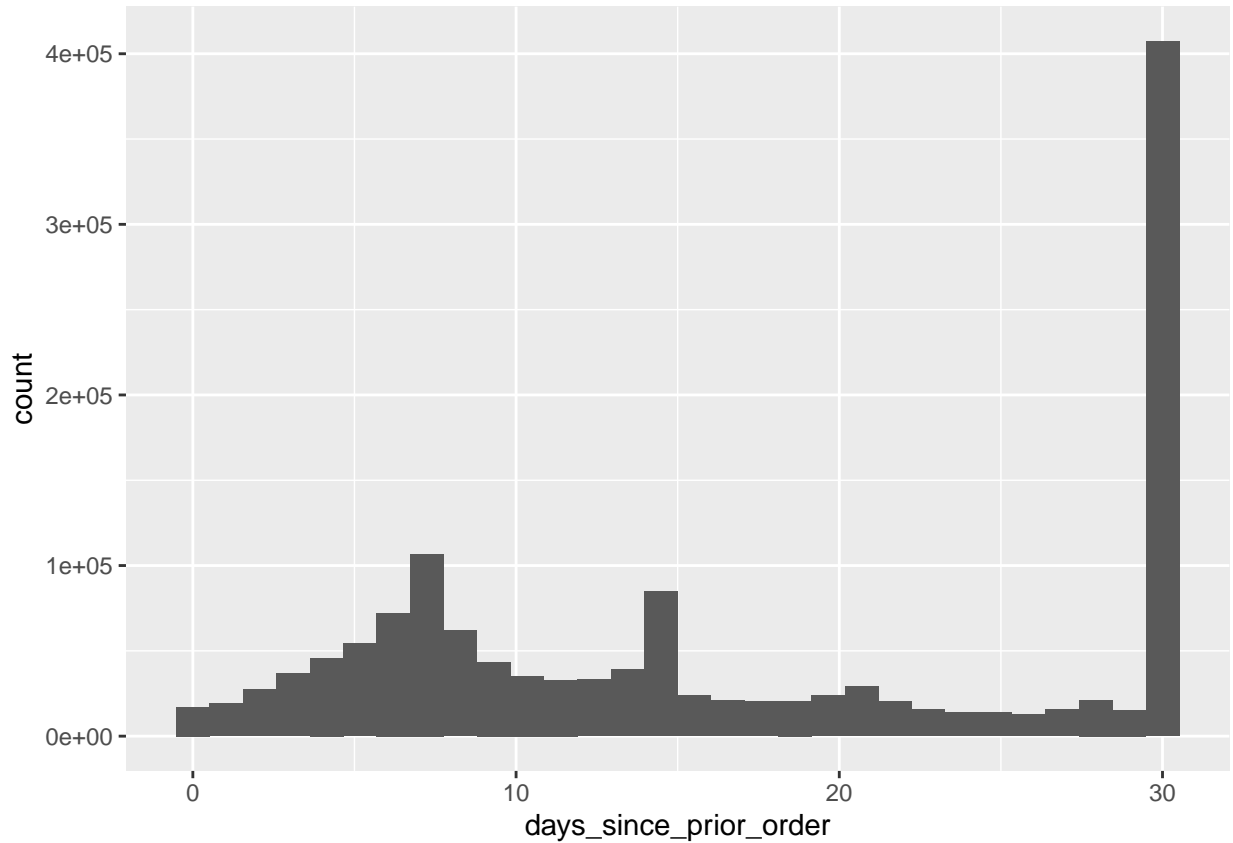


It is assumed for order\_dow that 0=Sunday, 1=Monday, 2=Wednesday... and so on until 6=Saturday. Sunday, Monday and Saturday appear to be the most common days where people place their orders.

How many days pass between an order and the next order?

```
X %>% ggplot(aes(x=days_since_prior_order))+  
  geom_histogram()
```

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



People most commonly order again after 30 days (1 month), or 7 days (1 week).

```
ggplot(X) +  
geom_bar(mapping= aes(x=reordered))
```

Find the percentage of transactions from the top 10 products sold.

```
percentage <- X %>%  
  group_by(product_name) %>%  
  dplyr::summarize(count =n()) %>%  
  mutate(pct=(count/sum(count))*100) %>%  
  arrange(desc(pct)) %>%  
  ungroup() %>%  
  top_n(10, wt=pct)  
  
kable(percentage, caption = "Percentage of Transactions for Top 10 Products, from Instacart Training Orders data")
```

Table 1: Percentage of Transactions for Top 10 Products, from Instacart Training Orders data

product_name	count	pct
Banana	18726	1.3524318
Bag of Organic Bananas	15480	1.1179987
Organic Strawberries	10894	0.7867880
Organic Baby Spinach	9784	0.7066214

product_name	count	pct
Large Lemon	8135	0.5875271
Organic Avocado	7409	0.5350938
Organic Hass Avocado	7293	0.5267161
Strawberries	6494	0.4690106
Limes	6033	0.4357162
Organic Raspberries	5546	0.4005440

Top 10 products sold and the percentage of transactions they are involved in. Bananas make up 1.35% of the transactions, while organic bananas make up 1.1% of the transactions and organic strawberries make up 0.79% of the transactions.

How many items are in each transaction?

```
X %>%
  group_by(order_id) %>%
  dplyr::summarise(number_items=last(add_to_cart_order)) %>%
  ggplot(aes(x=number_items)) +
  geom_histogram(stat="count", fill="blue") +
  geom_rug()+
  coord_cartesian(xlim=c(0,80))
```

Items most often reordered:

```
reordered <- X %>%
  group_by(product_name) %>%
  dplyr::summarize(proportion_reordered = mean(reordered), n=n()) %>%
  filter(n>40) %>%
  top_n(10, wt=proportion_reordered) %>%
  arrange(desc(proportion_reordered))
```

*#kable takes reordered dataframe as input and outputs it as a markdown table*

`kable(reordered, caption = "Reorederd products from the Instacart orders training data set showing the p`

Table 2: Reorederd products from the Instacart orders training data set showing the proportion of reordered transactions that contain the product

product_name	proportion_reordered	n
2% Lactose Free Milk	0.9347826	92
Organic Low Fat Milk	0.9130435	368
100% Florida Orange Juice	0.8983051	59
Organic Spelt Tortillas	0.8888889	81
Original Sparkling Seltzer Water Cans	0.8888889	45
Banana	0.8841717	18726
Petit Suisse Fruit	0.8833333	120
Organic Lowfat 1% Milk	0.8819876	483
Organic Lactose Free 1% Lowfat Milk	0.8810409	269
1% Lowfat Milk	0.8785249	461

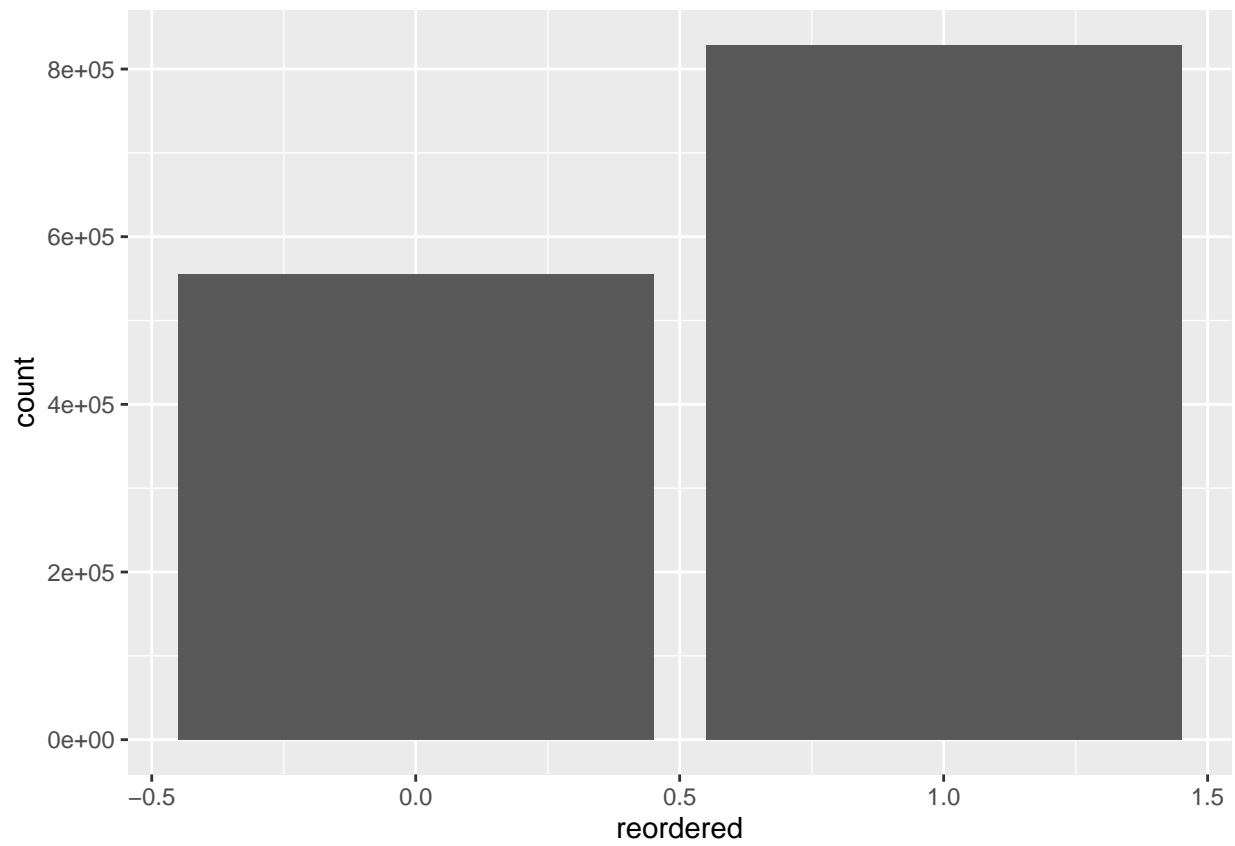


Figure 3: Bar chart of transactions from the Instacart training dataset showing whether the product ordered is the first time a user ordered that product (0) or the product is an item that the user is reordering (1).



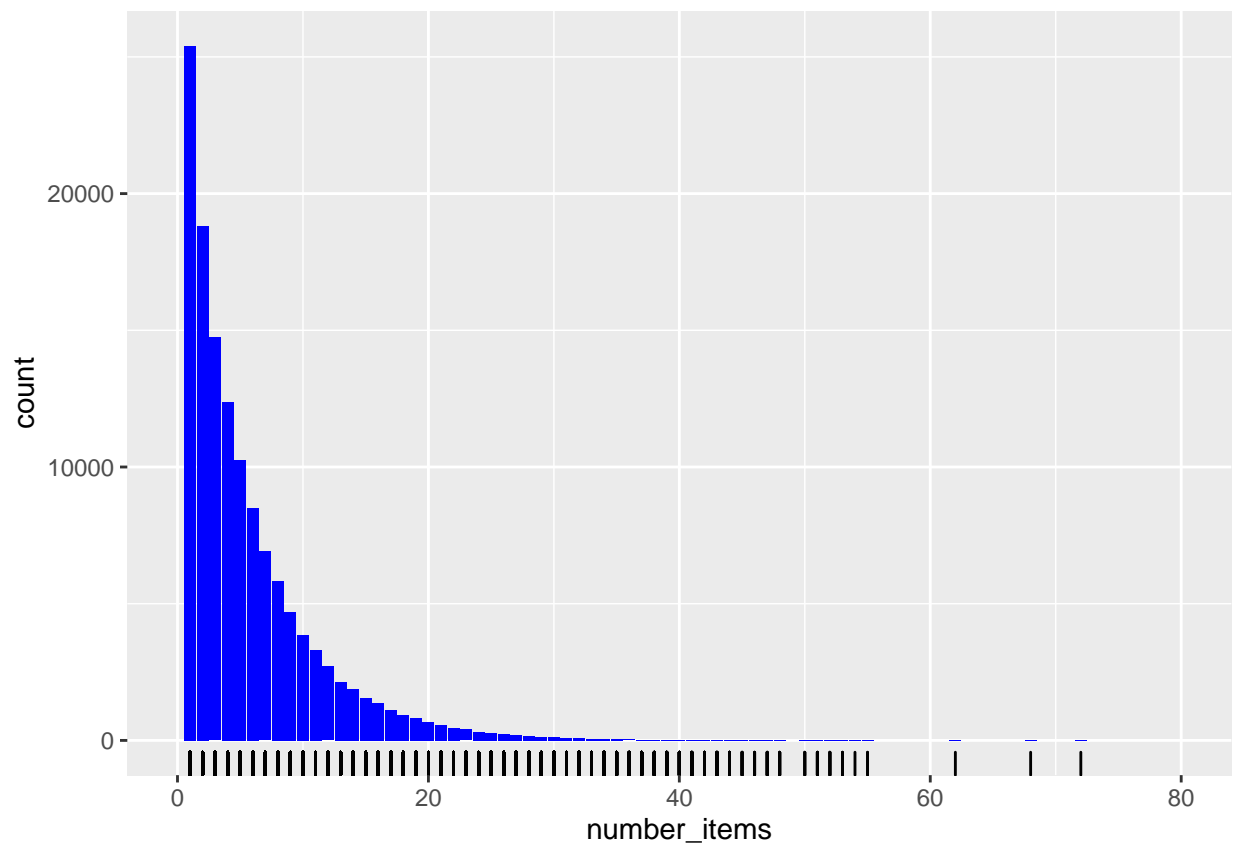


Figure 4: Histogram of number of items in each transaction for the Instacart training orders dataset. The histogram shows a skewed distribution to the right, where most of the transactions contain 0 - 5 items.

## Data Cleansing

X\_merge column is not needed for association rule mining, so can set to NULL:

```
X$X_merge <- NULL
```

Need to convert dataframe to transaction data so that all items bought together in one order is in one row. Currently different products from the same order are in their own rows (singles format).

```
library(plyr)
library(dplyr)

#ddply(dataframe, variables_to_be_used_to_split_data_frame, function_to_be_applied)

transactionData <- ddply(X, c("order_id", "user_id"),
                        function(df1) paste(df1$product_name,      #paste is used to concatenate vectors t
                        collapse = ",")      #collapse is used to separate the concatenated
```

Look at the transaction data. This is currently in the form of a basket format:

#set order id and user id to NULL in the transaction dataset since it will not be needed for item association

```
transactionData$order_id <- NULL
transactionData$user_id <- NULL
```

rename column to items

```
colnames(transactionData) <- c("items")
```

write the transaction data csv into a csv file:

```
#write.csv(transactionData, "C:/Users/qt09n/Desktop/Project/market_basket_transactions.csv", quote = FALSE)
```

take the transaction data file which is in basket format and convert it to an object of the transaction class

```
tr
```

```
## transactions in sparse format with
## 131210 transactions (rows) and
## 50153 items (columns)
```

```
summary(tr)
```

```
## transactions as itemMatrix in sparse format with
## 131210 rows (elements/itemsets/transactions) and
## 50153 columns (items) and a density of 0.00020449
##
```

```
## most frequent items:
```

```
##           Banana Bag of Organic Bananas   Organic Strawberries
##           17724                        14597                    10260
## Organic Baby Spinach           Large Lemon                (Other)
```

```
##          9318          7740          1286023
##
## element (itemset/transaction) length distribution:
## sizes
##   1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16
## 7750 8047 8474 8470 8887 8684 8471 7856 7104 6447 5943 5356 4770 4219 3645 3364
##   17   18   19   20   21   22   23   24   25   26   27   28   29   30   31   32
## 3073 2617 2390 2020 1771 1560 1408 1245 1085  932  812  637  557  553  434  387
##   33   34   35   36   37   38   39   40   41   42   43   44   45   46   47   48
##  299  289  246  190  178  151  126  116   84   82   71   63   49   43   35   28
##   49   50   51   52   53   54   55   56   57   58   59   60   61   62   63   65
##   21   22   20   23   17   13    8   11    5    5    5    8    5    3    3    1
##   66   67   68   69   72   75   76   78   80   82   84
##    4    3    2    5    1    1    1    2    1    1    1
##
##   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   1.00   5.00    8.00   10.26   14.00   84.00
##
## includes extended item information - examples:
##               labels
## 1                   #2
## 2                   #2 Coffee Filters
## 3 #2 Cone White Coffee Filters
```

131210 transactions (rows) and 50153 items (columns). 50153 is the product names. Density is the percentage of non-zero cells in a sparse matrix, which is the total number of items purchased divided by a possible number of items in that matrix.

To calculate how many items were purchased:  $131210 \times 50153 \times 0.00020449 = 1345662$

A sparse matrix is a matrix in which most elements are zero.

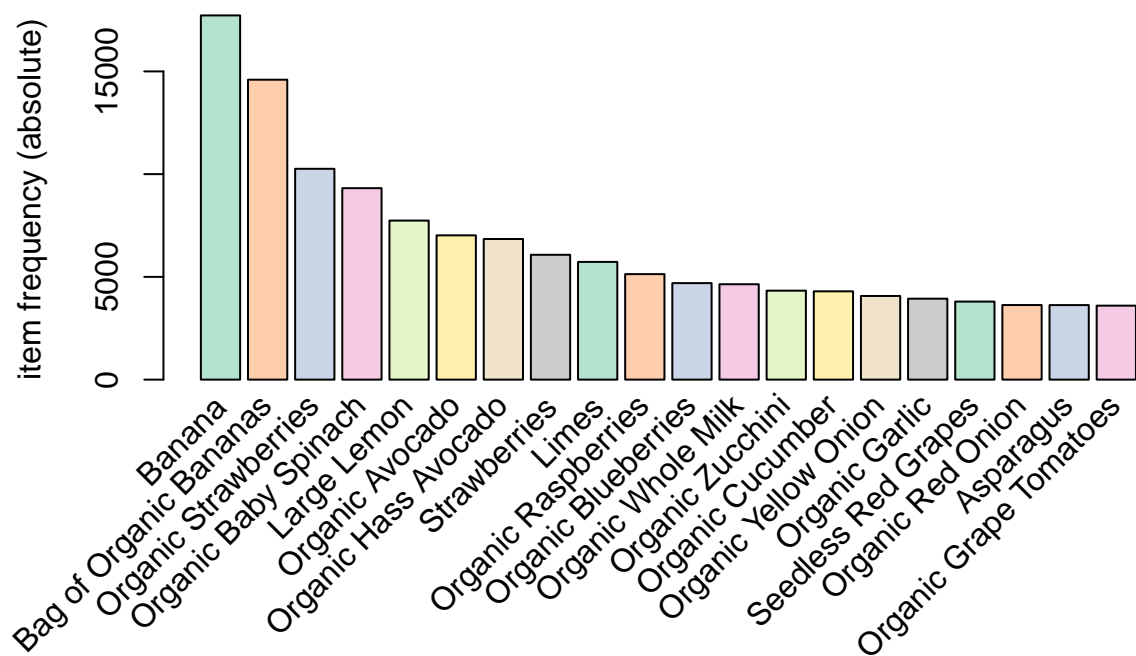
Element (itemset/transaction) length distribution. This section is about how many transactions containing a certain number of items. The first row is the number of items in a transaction, and the second row is the number of transactions with that number of items. ie. There are 1877502617 transactions with only 1 item. There are 1980472390 transactions with 2 items.

To generate an item Frequency Plot to view the distribution of objects basedon itemMatrix.

Create an item frequency plot for the top 50 items.

```
itemFrequencyPlot(tr, topN=20, type="absolute", col=brewer.pal(8, 'Pastel2'), main="Absolute Item Frequ
```

## Absolute Item Frequency Plot



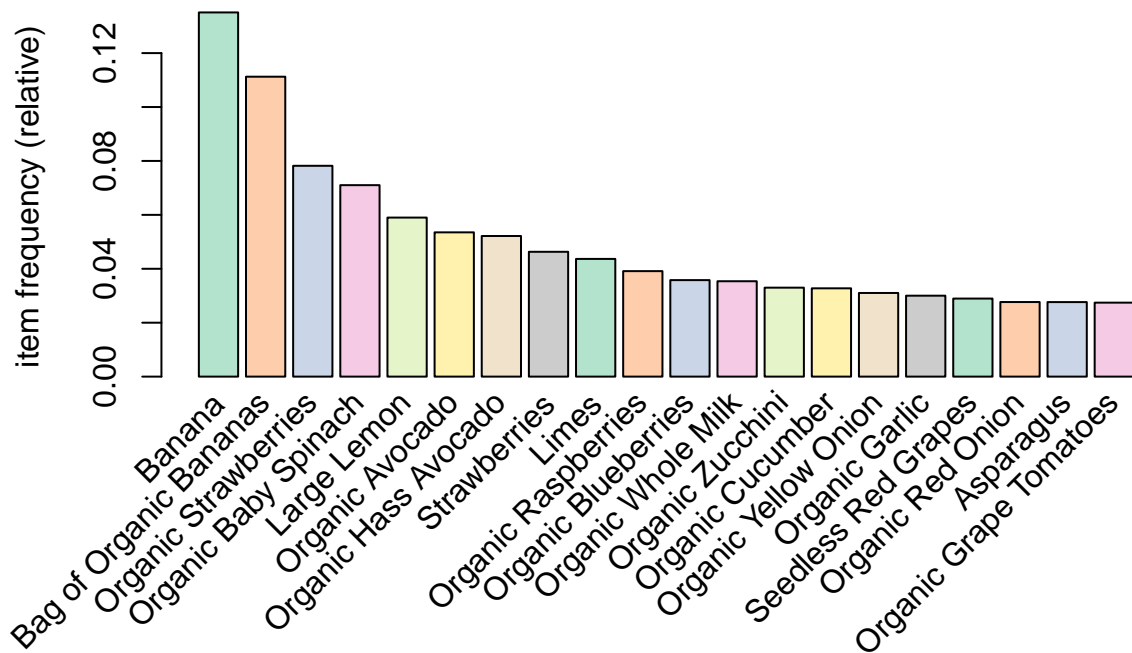
According to the frequency plot, the top 20 products bought in Instacart are banana, bag of organic bananas, organic strawberries, organic baby spinach, large lemon, organic avocado, organic hass avocado, strawberries, limes, organic raspberries, organic blueberries, organic whole milk, organic zucchini, organic cucumber, organic yellow onion, organic garlic, seedless red grapes, organic red onion, asparagus and organic grape tomatoes.

This plot shows absolute frequency which are independent numeric frequencies for each item.

To look at relative frequencies (how many times an item appears in comparison to others):

```
itemFrequencyPlot(tr, topN=20, type="relative", col=brewer.pal(8, 'Pastel2'), main="Relative Item Frequ
```

## Relative Item Frequency Plot



##Generating Association Rules using APRIORI algorithm

Mine the rules using APRIORI algorithm.

```
association.rules <- apriori(tr, parameter= list(supp=0.001, conf=0.8, maxlen=10))
```

```
## Apriori
```

```
##
```

```
## Parameter specification:
```

```
## confidence minval smax arem aval originalSupport maxtime support minlen
```

```
## 0.8 0.1 1 none FALSE TRUE 5 0.001 1
```

```
## maxlen target ext
```

```
## 10 rules TRUE
```

```
##
```

```
## Algorithmic control:
```

```
## filter tree heap memopt load sort verbose
```

```
## 0.1 TRUE TRUE FALSE TRUE 2 TRUE
```

```
##
```

```
## Absolute minimum support count: 131
```

```
##
```

```
## set item appearances ...[0 item(s)] done [0.00s].
```

```
## set transactions ...[50153 item(s), 131210 transaction(s)] done [0.71s].
```

```
## sorting and recoding items ... [1812 item(s)] done [0.02s].
```

```
## creating transaction tree ... done [0.07s].
```

```
## checking subsets of size 1 2 3 4 done [0.05s].
```

```
## writing ... [255 rule(s)] done [0.01s].
```

```
## creating S4 object ... done [0.01s].
```

The apriori will take tr as the transaction object to apply the rule mining. Parameters allow you to set min\_sup and min\_confidence and min confidence of 0.8, maximum of 10 items(maxlen).

```
summary(association.rules)
```

```
## set of 255 rules
##
## rule length distribution (lhs + rhs):sizes
##   2   3   4
## 132 111  12
##
##   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##  2.000  2.000   2.000   2.529   3.000   4.000
##
## summary of quality measures:
##      support      confidence      coverage      lift
##  Min.   :0.001021  Min.   :0.8017  Min.   :0.001021  Min.   : 39.52
## 1st Qu.:0.001143 1st Qu.:0.9917 1st Qu.:0.001174 1st Qu.:185.06
## Median :0.001296 Median :1.0000 Median :0.001364 Median :394.02
## Mean   :0.001892 Mean   :0.9800 Mean   :0.001940 Mean   :438.96
## 3rd Qu.:0.002043 3rd Qu.:1.0000 3rd Qu.:0.002058 3rd Qu.:701.98
## Max.   :0.007522 Max.   :1.0000 Max.   :0.007522 Max.   :979.18
##      count
##  Min.   :134.0
## 1st Qu.:150.0
## Median :170.0
## Mean   :248.3
## 3rd Qu.:268.0
## Max.   :987.0
##
## mining info:
## data ntransactions support confidence
##   tr          131210  0.001      0.8
```

set of 255 rules were generated from the apriori algorithm.

to look at just the top 10 rules:

```
inspect(association.rules[1:10])
```

```
##      lhs      rhs      support      confidence
## [1] {Mini & Mobile} => {Natural Artesian Water} 0.001036506 1
## [2] {Americano}    => {Prosciutto}           0.001021264 1
## [3] {1000 Sheet Rolls} => {1â??Ply}           0.001036506 1
## [4] {1â??Ply}      => {1000 Sheet Rolls}       0.001036506 1
## [5] {1000 Sheet Rolls} => {Bathroom Tissue}    0.001036506 1
## [6] {1â??Ply}      => {Bathroom Tissue}    0.001036506 1
## [7] {Twin Pack}     => {French Baguettes}       0.001021264 1
## [8] {French Baguettes} => {Twin Pack}           0.001021264 1
## [9] {Twin Pack}     => {Take & Bake}           0.001021264 1
## [10] {Take & Bake}   => {Twin Pack}           0.001021264 1
##      coverage lift count
## [1] 0.001036506 198.8030 136
```

```
## [2] 0.001021264 372.7557 134
## [3] 0.001036506 964.7794 136
## [4] 0.001036506 964.7794 136
## [5] 0.001036506 493.2707 136
## [6] 0.001036506 493.2707 136
## [7] 0.001021264 979.1791 134
## [8] 0.001021264 979.1791 134
## [9] 0.001021264 979.1791 134
## [10] 0.001021264 979.1791 134
```

136 transactions where customers who bought Mini and Mobile also bough Natural Artesian Water. 136 transactions where people who bought 1000 sheet Rolls also bought 1a Ply, and 136 transactions where people who bought 1000 Sheet Rolls also bought Bathroom tissue.

### Limiting the number and size of rules

Setting the the conf value and maxlen parameter to higher values will give stronger rules.

```
shorter_association_rules <- apriori(tr, parameter = list(supp=0.001, conf=0.9, maxlen=5))
```

```
## Apriori
##
## Parameter specification:
## confidence minval smax arem aval originalSupport maxtime support minlen
##      0.9      0.1      1 none FALSE          TRUE      5   0.001      1
## maxlen target  ext
##      5 rules TRUE
##
## Algorithmic control:
## filter tree heap memopt load sort verbose
##    0.1 TRUE TRUE  FALSE TRUE     2    TRUE
##
## Absolute minimum support count: 131
##
## set item appearances ...[0 item(s)] done [0.00s].
## set transactions ...[50153 item(s), 131210 transaction(s)] done [0.72s].
## sorting and recoding items ... [1812 item(s)] done [0.02s].
## creating transaction tree ... done [0.05s].
## checking subsets of size 1 2 3 4 done [0.05s].
## writing ... [231 rule(s)] done [0.00s].
## creating S4 object ... done [0.01s].
```

```
summary(shorter_association_rules)
```

```
## set of 231 rules
##
## rule length distribution (lhs + rhs):sizes
##    2    3    4
## 121  98  12
##
##      Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##    2.000  2.000   2.000  2.528   3.000   4.000
```

```
##
## summary of quality measures:
##      support      confidence      coverage      lift
## Min.   :0.001021  Min.   :0.9066  Min.   :0.001021  Min.   : 55.65
## 1st Qu.:0.001143  1st Qu.:1.0000  1st Qu.:0.001158  1st Qu.:202.80
## Median :0.001296  Median :1.0000  Median :0.001303  Median :435.52
## Mean   :0.001871  Mean   :0.9932  Mean   :0.001885  Mean   :452.06
## 3rd Qu.:0.002043  3rd Qu.:1.0000  3rd Qu.:0.002050  3rd Qu.:720.96
## Max.   :0.007522  Max.   :1.0000  Max.   :0.007522  Max.   :979.18
##      count
## Min.   :134.0
## 1st Qu.:150.0
## Median :170.0
## Mean   :245.5
## 3rd Qu.:268.0
## Max.   :987.0
##
## mining info:
## data ntransactions support confidence
## tr          131210  0.001      0.9
```

```
inspect(shorter_association_rules[1:10])
```

```
##      lhs      rhs      support      confidence
## [1] {Mini & Mobile} => {Natural Artesian Water} 0.001036506 1
## [2] {Americano}    => {Prosciutto}          0.001021264 1
## [3] {1000 Sheet Rolls} => {1â??Ply}          0.001036506 1
## [4] {1â??Ply}      => {1000 Sheet Rolls}      0.001036506 1
## [5] {1000 Sheet Rolls} => {Bathroom Tissue}      0.001036506 1
## [6] {1â??Ply}      => {Bathroom Tissue}      0.001036506 1
## [7] {Twin Pack}     => {French Baguettes}      0.001021264 1
## [8] {French Baguettes} => {Twin Pack}          0.001021264 1
## [9] {Twin Pack}     => {Take & Bake}          0.001021264 1
## [10] {Take & Bake}   => {Twin Pack}          0.001021264 1
##      coverage lift count
## [1] 0.001036506 198.8030 136
## [2] 0.001021264 372.7557 134
## [3] 0.001036506 964.7794 136
## [4] 0.001036506 964.7794 136
## [5] 0.001036506 493.2707 136
## [6] 0.001036506 493.2707 136
## [7] 0.001021264 979.1791 134
## [8] 0.001021264 979.1791 134
## [9] 0.001021264 979.1791 134
## [10] 0.001021264 979.1791 134
```

From the results we can see that customers that buy Mini & Mobile usually also buy Natural Artesian Water, while people who buy Americano often also buy prosciutto.

To remove redundant rules:

```
subset.rules <- which(colSums(is.subset(association.rules, association.rules))>1) #get subset rules in
length(subset.rules)
```



```
## [1] 200
```

```
#which() - gives you the position of elements in the vector where value = TRUE  
#colSums() - row and column sums for dataframes and numeric arrays  
#is.subset() - find out if elements of one vector contain all elements of other vector
```

To remove the subset rules:

```
subset.association.rules <- association.rules[-subset.rules] #remove subset rules
```

To find out what customers buy before buying a certain product, use the appearance option in the apriori command. ie. to find out what people buy before buying French baguettes:

```
baguette.association.rules <- apriori(tr, parameter = list(supp=0.001, conf=0.8), appearance = list(def
```

```
## Apriori  
##  
## Parameter specification:  
## confidence minval smax arem aval originalSupport maxtime support minlen  
##          0.8    0.1    1 none FALSE                TRUE      5  0.001      1  
## maxlen target  ext  
##          10 rules TRUE  
##  
## Algorithmic control:  
## filter tree heap memopt load sort verbose  
##      0.1 TRUE TRUE  FALSE TRUE      2      TRUE  
##  
## Absolute minimum support count: 131  
##  
## set item appearances ...[1 item(s)] done [0.00s].  
## set transactions ...[50153 item(s), 131210 transaction(s)] done [0.66s].  
## sorting and recoding items ... [1812 item(s)] done [0.02s].  
## creating transaction tree ... done [0.06s].  
## checking subsets of size 1 2 3 4 done [0.06s].  
## writing ... [3 rule(s)] done [0.01s].  
## creating S4 object ... done [0.02s].
```

To find out how many customers buy French baguettes along with other items:

```
inspect(head(baguette.association.rules))
```

```
##      lhs                      rhs          support    confidence  
## [1] {Take & Bake}              => {French Baguettes} 0.001021264 1  
## [2] {Twin Pack}                => {French Baguettes} 0.001021264 1  
## [3] {Take & Bake,Twin Pack} => {French Baguettes} 0.001021264 1  
## coverage lift    count  
## [1] 0.001021264 979.1791 134  
## [2] 0.001021264 979.1791 134  
## [3] 0.001021264 979.1791 134
```

To find out answer to “What other items did customers who bought X item also buy?” ...ie. for French baguettes again:

```
baguette.association.rules <- apriori(tr, parameter = list(supp=0.001, conf=0.8), appearance = list(lhs
```

```
## Apriori
##
## Parameter specification:
## confidence minval smax arem aval originalSupport maxtime support minlen
##          0.8    0.1    1 none FALSE          TRUE      5  0.001      1
## maxlen target  ext
##          10  rules TRUE
##
## Algorithmic control:
## filter tree heap memopt load sort verbose
##    0.1 TRUE TRUE  FALSE TRUE    2    TRUE
##
## Absolute minimum support count: 131
##
## set item appearances ...[1 item(s)] done [0.00s].
## set transactions ...[50153 item(s), 131210 transaction(s)] done [0.66s].
## sorting and recoding items ... [1812 item(s)] done [0.02s].
## creating transaction tree ... done [0.06s].
## checking subsets of size 1 2 done [0.00s].
## writing ... [2 rule(s)] done [0.00s].
## creating S4 object ... done [0.01s].
```

Keep lhs as French Baguettes because you want to find out the probability of how many customers buy French baguettes with other items:

```
inspect(head(baguette.association.rules))
```

```
##      lhs                      rhs          support    confidence coverage
## [1] {French Baguettes} => {Take & Bake} 0.001021264 1          0.001021264
## [2] {French Baguettes} => {Twin Pack}   0.001021264 1          0.001021264
##      lift      count
## [1] 979.1791 134
## [2] 979.1791 134
```

Scatterplot

```
#filter rules with confidence greater than 0.6 or 60%
subRules <- association.rules[quality(association.rules)$confidence>0.6]

#plot subrules
plot(subRules)
```

```
## To reduce overplotting, jitter is added! Use jitter = 0 to prevent jitter.
```

Rules with high lift have low support

Plot options: rulesObject = rules object to be plotted measure= measures for rule interestingness ie. support, confidence, lift or combination of these depending on method value shading = measure used to color points (support, confidence, lift); default=lift method=visualization method to be used(scatterplot, 2 key plot, matrix3D)

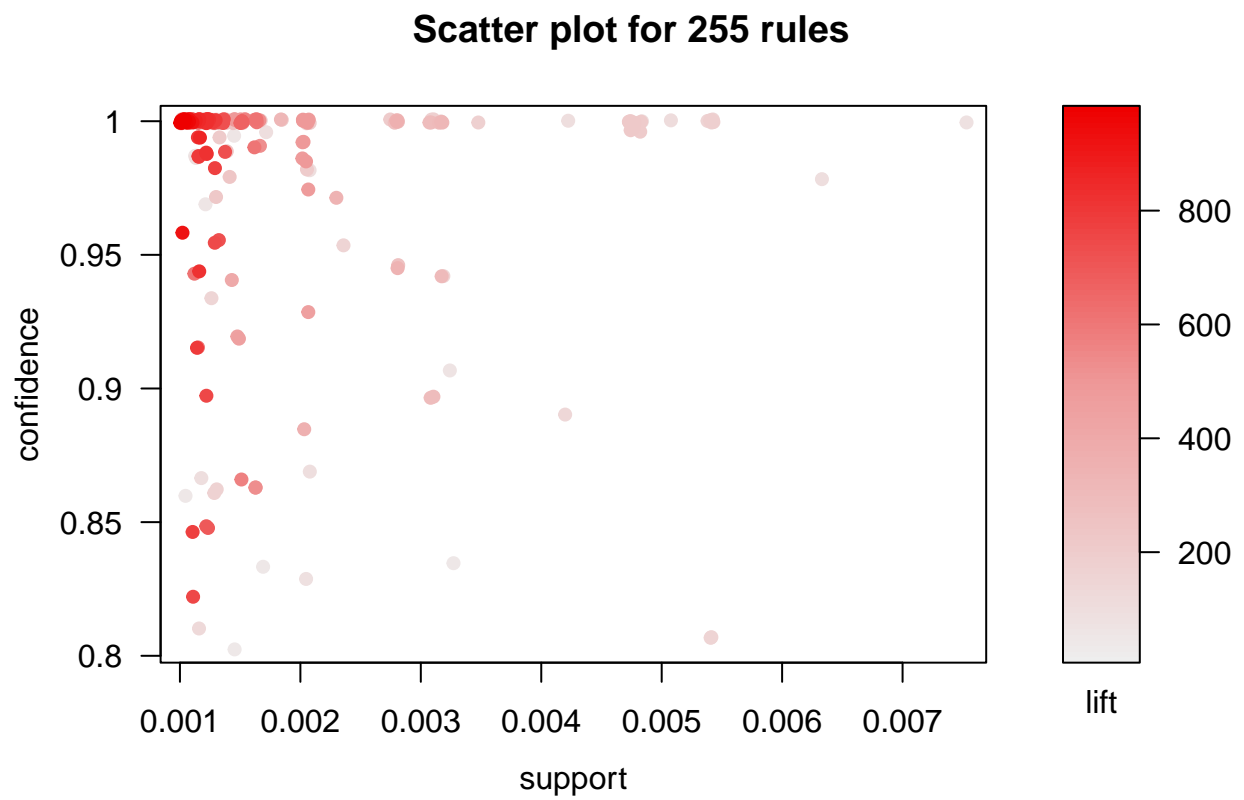


Figure 5: Scatterplot for association rules filtered for confidence over 60%, produced using Apriori algorithm, with Instacart Orders training data

```
plot(subRules, method="two-key plot")
```

## To reduce overplotting, jitter is added! Use jitter = 0 to prevent jitter.

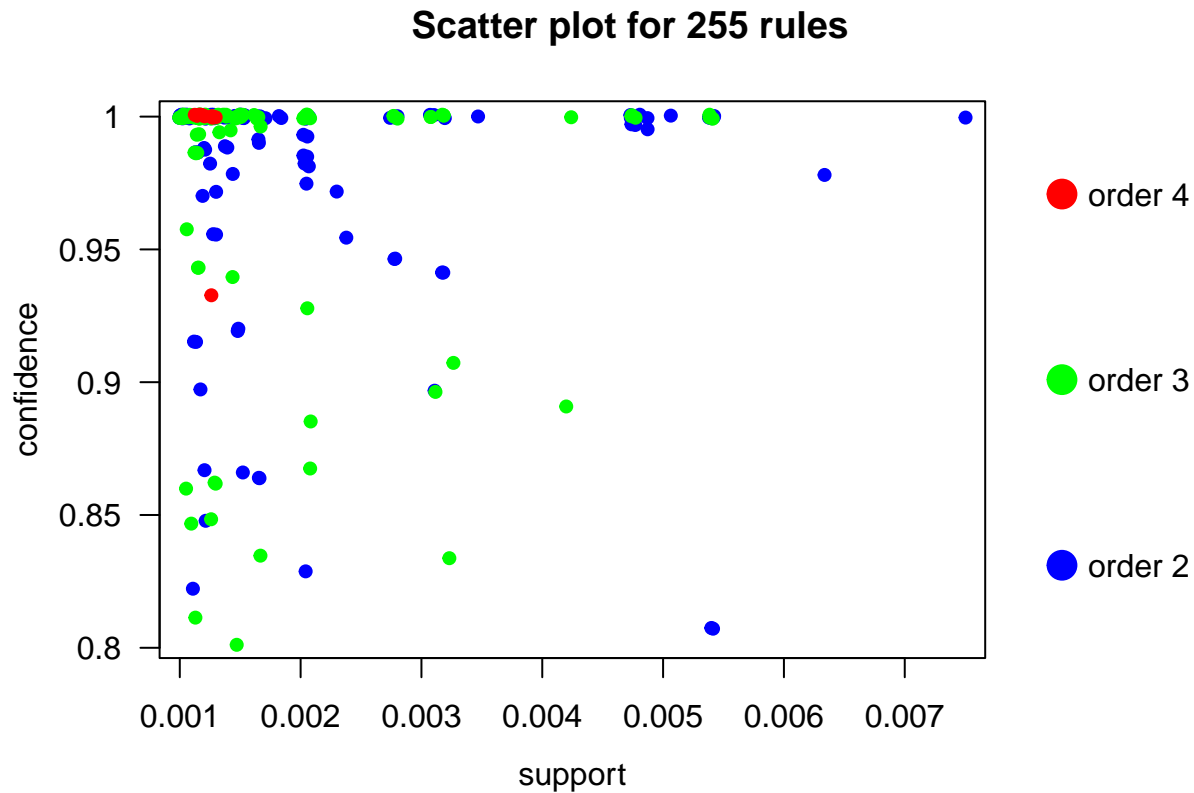


Figure 6: 2 key plot for association rules filtered for confidence greater than 60% using Apriori algorithm, from Instacart training orders dataset

Two key plot has support on x axis and confidence on y-axis. It uses order for coloring. Order is the number of items in the rule.

### Interactive Scatterplot

Users can hover over rules and see the quality measures(support, confidence and lift).

```
plot(subRules)
```

## To reduce overplotting, jitter is added! Use jitter = 0 to prevent jitter.

Graph based methods: vertices are labeled with item names; item sets or rules are indicated with a second set of vertices: arrows point from items to rule vertices = LHS; arrow from rule to an item = RHS. Size & color = interest measure.

To get the top 10 rules with highest confidence:

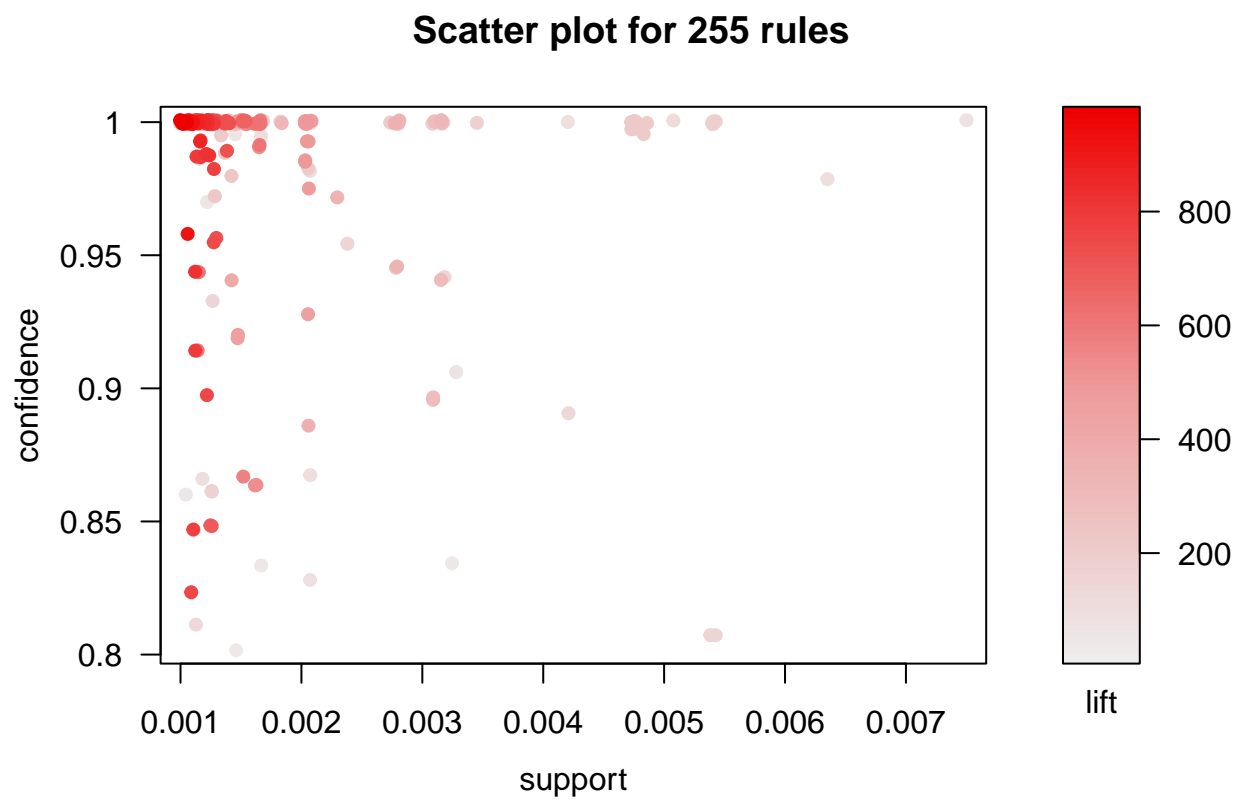


Figure 7: scatterplot for association rules using apriori algorithm, from Instacart orders training dataset.

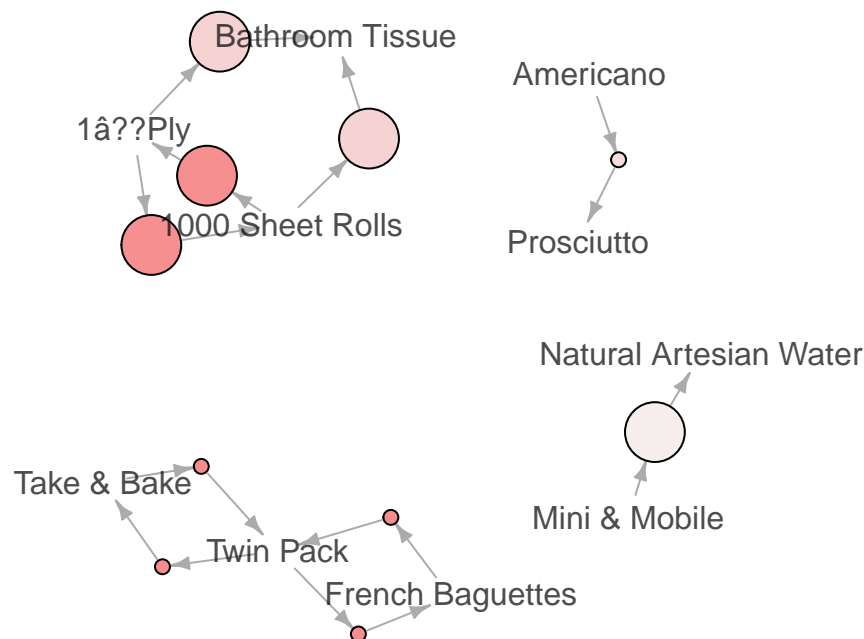
```
top10subRules <- head(subRules, n= 10, by="confidence")
```

Make interactive plot with engine=htmlwidget parameter in plot

```
# plot(top10subRules, method="graph", engine="htmlwidget") #html widget can not be shown in pdf
plot(top10subRules, method="graph")
```

## Graph for 10 rules

size: support (0.001 – 0.001)  
color: lift (198.803 – 979.179)



To export graphs for sets of association rules in GraphML format (which you can open with Gephi tool):

```
saveAsGraph(head(subRules, n=1000, by="lift"), file="rules.graphml")
```

## Individual Rule Representation

This is Parallel Coordinates Plot, used to visualize products with items and types of sales: RHS = consequent, which is item that is suggested for customers to buy: positions are LHS, where 2 = most recent item; and 1=item previously bought

```
#filter top 20 rules with highest lift:
subRules2 <-head(subRules, n=20, by="lift")
plot(subRules2, method="paracoord")
```

If someone has mango, and pear baby food in their cart, they are likely to buy Happy Baby Spinach as well.

### Parallel coordinates plot for 20 rules

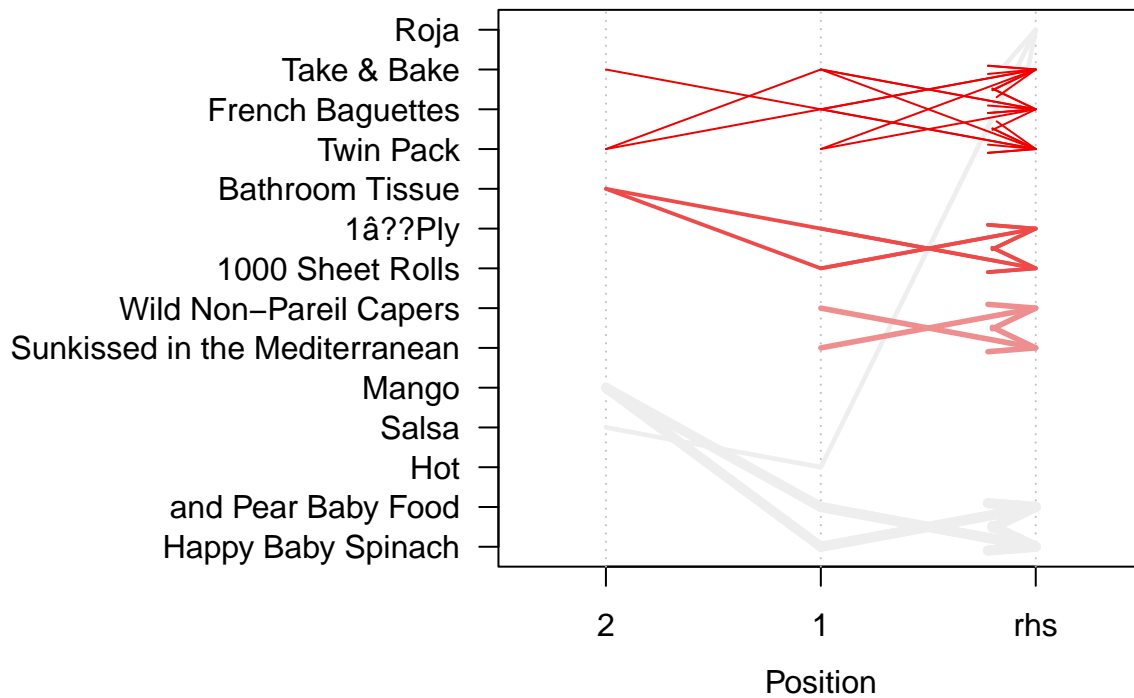


Figure 8: Parallel coordinates plot for 20 association rules. RHS is the item suggested for customers, based on the items already in the cart at 1, and 2.

## Recommender Method 2: Weighted Alternating Least Squares with Implicit Feedback Data

### Data Cleaning

```
#Extract columns for matrix
transactions<-X[,c("user_id", "product_id", "order_id")] #if using training orders data
transactions<-prior_order[,c("user_id", "product_id", "order_id")] #using prior orders data

#selecting 8K users for modeling
all_users<-unique(transactions$user_id)
randm_users<-sample(all_users, 8000L)

#selecting 16K products
all_products<-unique(transactions$product_id)
rand_products<-sample(all_products, 16000L)

#final data for matrix
interactions<-transactions %>%
  filter(user_id %in% randm_users & product_id %in% rand_products)

#find the total orders for each user per product
interactions_sample<-interactions %>%
  group_by(user_id, product_id) %>%
  dplyr::summarise(orders=n())
```

## 'summarise()' has grouped output by 'user\_id'. You can override using the '.groups' argument.

```
dim(interactions)
```

```
## [1] 295692      3
```

### Encoding Users and Products

```
user_enc <- interactions_sample %>%
  distinct(user_id) %>%
  rowid_to_column()

names(user_enc)[names(user_enc) == "rowid"]<- "uid_enc"

product_enc<- interactions_sample %>%
  distinct(product_id) %>%
  rowid_to_column()

names(product_enc)[names(product_enc) == "rowid"]<- "pid_enc"
```



Sparse matrices are special data structures that allows for efficient storage of sparse data (such as large matrices with few non-zero elements). Sparse matrices are able to store the same data as a dense matrix using much less memory.

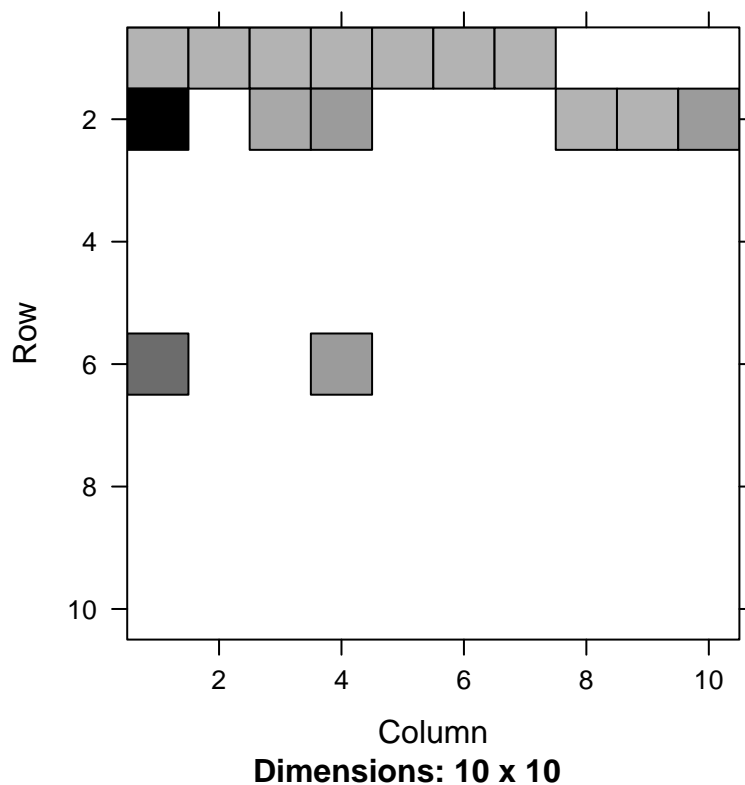
One way to store data in sparse format is by keeping just the co-ordinates of non-zero elements (cmdline, 2019). Three vectors of the same size are used: i, j, and x. Vectors i, and j specify the coordinates of the non-zero elements, where i is the row index and j is the column index. The vector x stores the actual non-zero values.

```
#sparse matrix
data<-interactions_sample %>%
  inner_join(user_enc, by = 'user_id') %>%
  inner_join(product_enc, by = 'product_id')

X = sparseMatrix(i = data$uid_enc, j = data$pid_enc, x = data$orders,
  dimnames = list(user_enc$user_id, product_enc$product_id))
```

To visualize a small portion of the sparse matrix using the image function in R:

```
image(X[1:10, 1:10])
```



The majority of the graph should be white, indicating sparse with no data.

```

#test set

n_test <- 2000L
test_uid <- sample(nrow(user_enc), n_test)

X_train <- X[-test_uid, ]
X_test <- X[test_uid, ]

# Split our test set into "history" or "future"
temp = as(X_test, "TsparseMatrix")
temp = data.table(i = temp@i, j = temp@j, x = temp@x)

temp <- temp %>%
  group_by(i) %>%                                # group by user
  mutate(ct = length(j),                          # number of products each user has
         history =
           sample(c(TRUE, FALSE), ct, replace = TRUE, prob = c(.5, .5))) %>%
  select(-ct)

X_test_history <- temp %>% filter(history == TRUE)
X_test_future <- temp %>% filter(history == FALSE)

X_test_history <- sparseMatrix(i = X_test_history$i,
                              j = X_test_history$j,
                              x = X_test_history$x,
                              dims = dim(X_test),
                              dimnames = dimnames(X_test),
                              index1 = FALSE)

X_test_future <- sparseMatrix(i = X_test_future$i,
                              j = X_test_future$j,
                              x = X_test_future$x,
                              dims = dim(X_test),
                              dimnames = dimnames(X_test),
                              index1 = FALSE)

# confidence functions and create matrices

lin_conf <- function(x, alpha) {
  x_confidence <- x
  stopifnot(inherits(x, "sparseMatrix"))
  x_confidence@x = 1 + alpha * x@x
  return(x_confidence)
}

```

```

alpha <- .1
lambda <- 10
components <- 10L

#factor matrices for train and test

X_train_conf <- lin_conf(X_train, alpha)
X_test_history_conf <- lin_conf(X_test_history, alpha)

# Initialize a model
# Define hyper parameters
#rank=the number of latent factors in the model (defaults to 10)
#value of alpha is calculated using cross validation

model <- WRMF$new(rank = components,
                  lambda = lambda,
                  feedback = 'implicit',
                  solver = 'conjugate_gradient')

# Calculate user factors
train_user_factors <- model$fit_transform(X_train_conf)

## INFO [21:55:18.623] starting factorization with 8 threads
## INFO [21:55:19.722] iter 1 loss = 0.5421
## INFO [21:55:20.678] iter 2 loss = 0.3145
## INFO [21:55:21.632] iter 3 loss = 0.2907
## INFO [21:55:22.521] iter 4 loss = 0.2817
## INFO [21:55:23.486] iter 5 loss = 0.2757
## INFO [21:55:24.388] iter 6 loss = 0.2712
## INFO [21:55:25.291] iter 7 loss = 0.2677
## INFO [21:55:26.204] iter 8 loss = 0.2648
## INFO [21:55:27.096] iter 9 loss = 0.2624
## INFO [21:55:27.998] iter 10 loss = 0.2604

# Products matrix and recommendations are made by selecting the top 10 items for which P(ui) is great

test_predictions <- model$predict(X_test_history_conf, k = 10)

#Loss and Score or fixed product factors
trace = attr(train_user_factors, "trace")
ggplot(trace) +
  geom_line(aes(x = iter, y = value, col = scorer)) +
  labs(title = "Loss and Scoring Metrics by iteration") +
  theme(plot.title = element_text(hjust = .5))

```

## Recommenderlab for Evaluation of Different Recommender Algorithms in R

Using Recommenderlab in R we can compare common algorithms typically used to create recommendery systems. In Recommenderlab, 2 types of rating matrix for modelling is available; we will be using the binary rating matrix type where 0 indicates product is not purchased, while 1 indicates product is purchased.

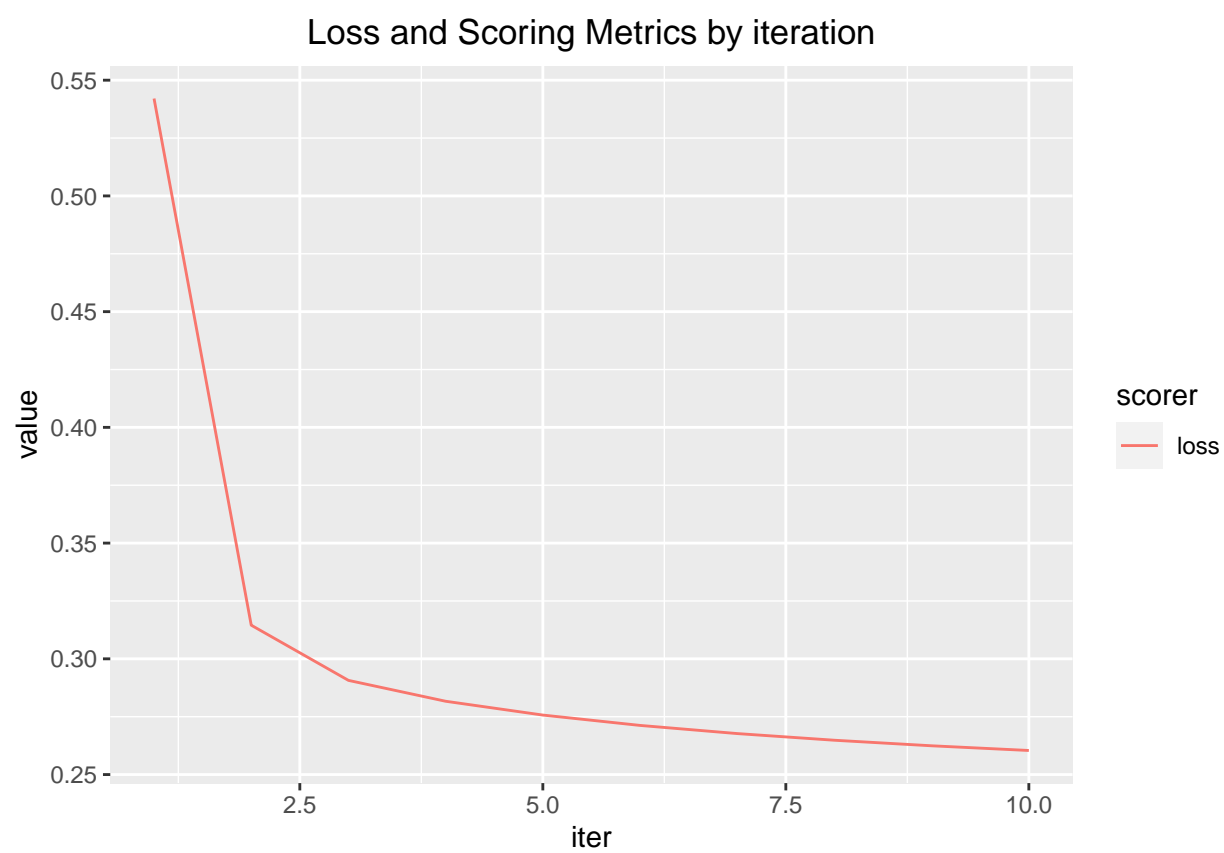


Figure 9: Plot of Loss and Scoring metrics by Iteration

Binary rating matrix is useful when no actual user ratings is available, and it also does not require normalisation.

The rating matrix must be rearranged with orders in rows and products in columns.

```
# train users for top 50
```

```
train_users<- X %>%  
  filter(product_id %in% top_products_train$product_id) %>%  
  group_by(user_id,product_id, .groups='keep') %>%  
  dplyr::summarise(tot=n()) %>%  
  ungroup() %>%  
  group_by(user_id) %>%  
  dplyr::summarise(count2=n()) %>%  
  arrange(desc(count2))
```

## 'summarise()' has grouped output by 'user\_id', 'product\_id'. You can override using the '.groups' argument

```
View(train_users)
```

```
#transaction for top 50 products (train)
```

```
train_top_50 <- X %>%  
filter(user_id %in%train_users$user_id & product_id %in% top_products_train$product_id)
```

```
dim(train_top_50)
```

```
## [1] 225084      16
```

Check if products are ordered multiple times within the same transaction:

```
retail <- train_top_50 %>%  
  #create a unique identifier for each product in a transaction using the order id and product name info  
  mutate(orderID_product = paste(order_id, product_name, sep=' '))  
#225084 entries
```

```
#filter out duplicates and drop unique identifier  
retail <- retail[!duplicated(retail$orderID_product), ] %>%  
  select(-orderID_product)  
#still 225084 entries, so customers generally do not buy multiples of a single product within the same
```

```
ratings_matrix <- retail %>%  
  select(order_id, product_name) %>%  
  mutate(value=1) %>% #add a column of 1s  
  spread(product_name, value, fill=0) %>% #spread into user-item format  
  select(-order_id) %>%  
  as.matrix() %>%  
  as("binaryRatingMatrix") #convert to recommenderlab class binary matrix  
  
ratings_matrix
```

## 81751 x 50 rating matrix of class 'binaryRatingMatrix' with 225084 ratings.

## Evaluation scheme and Model validation

Evaluate the model's effectiveness using recommenderlab's evaluation schemes.

Split the data into a training set and test set with train taking 80% of the data and test taking 20% of the data.

Set method="cross" and k=5 for 5 fold cross-validation. Data will be split into k subsets of equal size, and 80% of data will be used for training and last 20% for evaluation. Models are then estimated recursively 5 times, and a different train/test split is used each time. Results are then averaged to produce a single evaluation set.

```
scheme <- ratings_matrix %>%  
  evaluationScheme(method="cross",  
                  k = 5,  
                  train = 0.8,  
                  given = -1) #selecting given = -1 means that for the test users 'all but 1' random  
  
scheme
```

```
## Evaluation scheme using all-but-1 items  
## Method: 'cross-validation' with 5 run(s).  
## Good ratings: NA  
## Data set: 81751 x 50 rating matrix of class 'binaryRatingMatrix' with 225084 ratings.
```

## Set up a list of algorithms

Create a list of algorithms from recommenderlab and specify model parameters. Consider schemes which evaluate on the binary rating matrix and include random items algorithm for benchmarking.

```
algorithms <- list(  
  "association rules" = list(name = "AR",  
                           param = list(supp=0.001, conf=0.01)),  
  "random items" = list(name = "RANDOM", param=NULL), #randomly chosen items for comparison  
  "popular items" = list(name = "POPULAR", param = NULL), #recommender based on item popularity  
  "item-based CF" = list(name = "IBCF", param = list(k=5)) #recommender based on item-based CF  
)
```

Pass the scheme and algorithms to the evaluate() function, to evaluate several recommender algorithms using an evaluation scheme. The end product is a evaluation result list.

elect type= topNList to evaluate a Top N List of product recommendations and specify how many recommendations to calculate with the parameter n = c(1,3,5,10,15,20)

Note:It is important to allocate enough memory in RStudio for processing.

To check the current limit in R session use memory.limit(); and then to increase the size of memory use memory.limit(size=n) ie. memory.limit(size=56000)

```
#run garbage collection to free up memory for analysis:  
gc()
```

```
##          used   (Mb) gc trigger   (Mb) max used   (Mb)  
## Ncells  4091634 218.6  11325956 604.9  11325956 604.9  
## Vcells 405108453 3090.8  719386521 5488.5  719157653 5486.8
```

```
#remove from global environment variables which are not needed for the analysis:
# rm(X, transactionData, train_users, tr, top10subRules, top_products_train, subset.association.rules, .

#change memory limit to 56000 Mb to prevent problems with memory limit ("cannot allocate vector of size
memory.limit(size=56000)
```

```
## [1] 56000
```

```
results <- recommenderlab::evaluate(scheme,
                                   algorithms,
                                   type= "topNList",
                                   n = c(1,3,5,10, 15, 20))
```

```
## AR run fold/sample [model time/prediction time]
## 1 [0.08sec/171.79sec]
## 2 [0.05sec/208.9sec]
## 3 [0.08sec/185.39sec]
## 4 [0.03sec/187.95sec]
## 5 [0.08sec/190.02sec]
## RANDOM run fold/sample [model time/prediction time]
## 1 [0sec/1.59sec]
## 2 [0sec/1.56sec]
## 3 [0sec/1.63sec]
## 4 [0sec/1.71sec]
## 5 [0sec/2.05sec]
## POPULAR run fold/sample [model time/prediction time]
## 1 [0.01sec/10.38sec]
## 2 [0sec/11.51sec]
## 3 [0sec/12.16sec]
## 4 [0sec/11.85sec]
## 5 [0sec/10.23sec]
## IBCF run fold/sample [model time/prediction time]
## 1 [0.22sec/1.13sec]
## 2 [0.3sec/1.18sec]
## 3 [0.24sec/1.12sec]
## 4 [0.22sec/1.33sec]
## 5 [0.22sec/1.41sec]
```

```
results
```

```
## List of evaluation results for 4 recommenders:
##
## $'association rules'
## Evaluation results for 5 folds/samples using method 'AR'.
##
## $'random items'
## Evaluation results for 5 folds/samples using method 'RANDOM'.
##
## $'popular items'
## Evaluation results for 5 folds/samples using method 'POPULAR'.
##
```

```
## $'item-based CF'
## Evaluation results for 5 folds/samples using method 'IBCF'.
```

```
names(results)
```

```
## [1] "association rules" "random items"      "popular items"
## [4] "item-based CF"
```

```
#Access individual results by list subsetting using an index or the name specified when calling evaluate
results[["item-based CF"]]
```

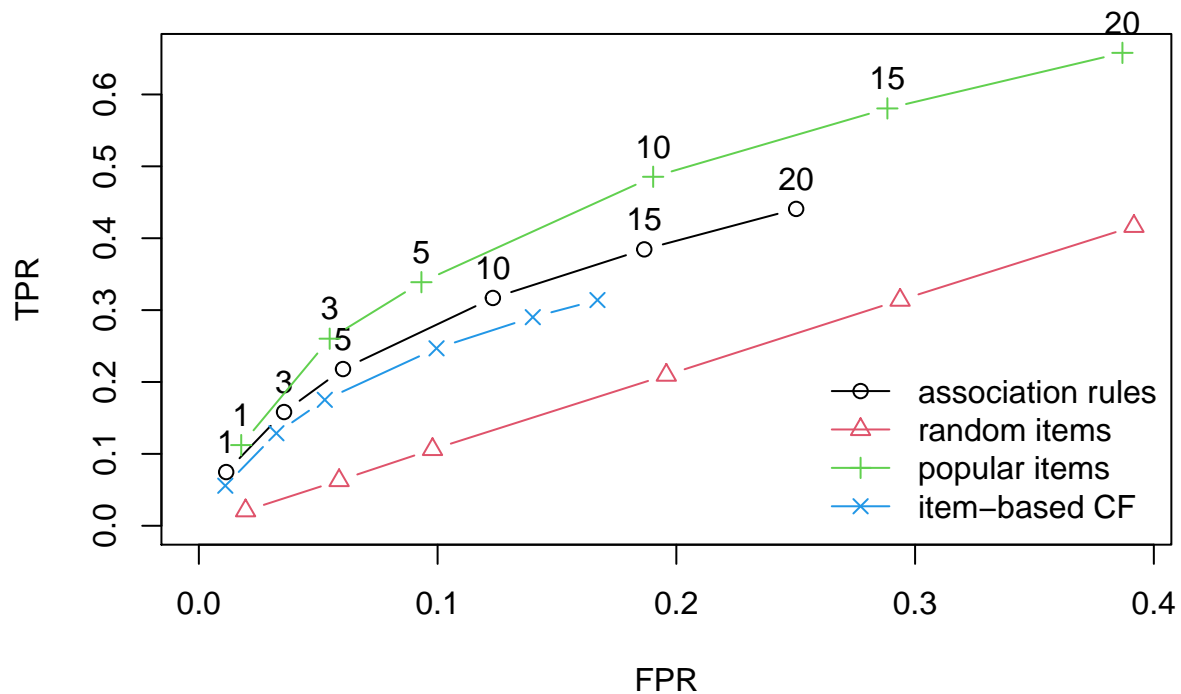
```
## Evaluation results for 5 folds/samples using method 'IBCF'.
```

## Visualise the Results

Use plot function from recommenderlab to compare model performance

Arrange confusion matrix for one model in a convenient format:

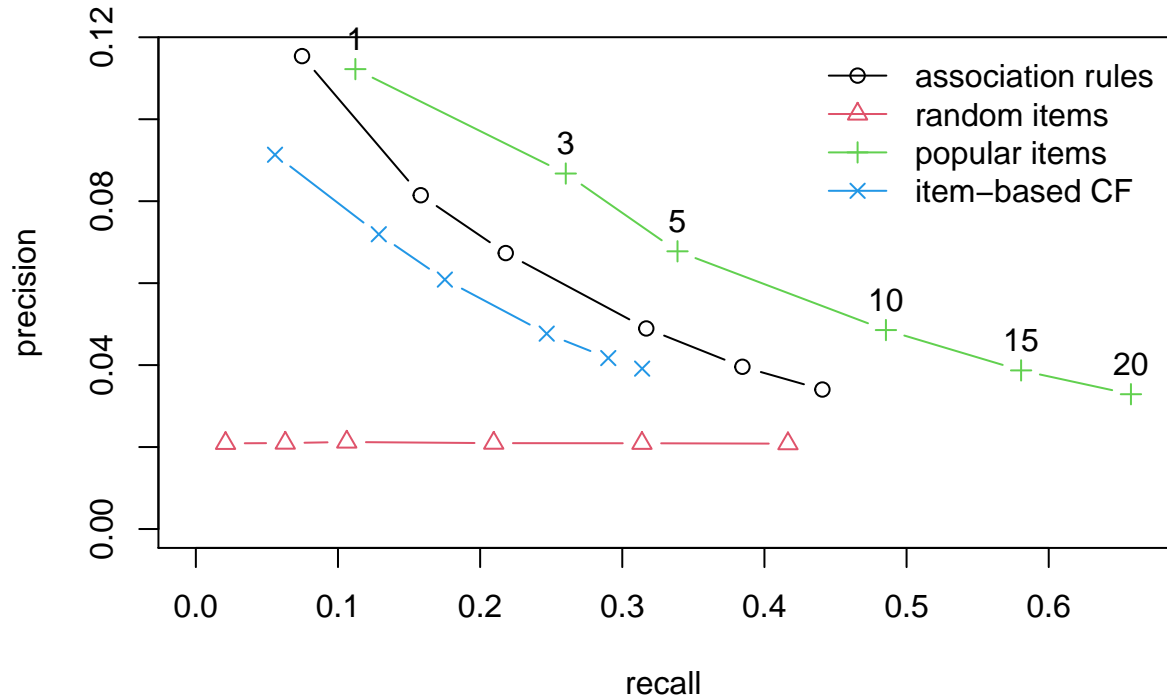
```
plot(results, annotate=c(1,3), legend="bottomright")
```



Comparison of ROC curves. For this dataset and the given evaluation scheme, popular items and association rules outperform the other methods, in providing a better combination of TPR and FPR amongst the 4 algorithms evaluated for the top-N list recommendations.



```
plot(results, "prec/rec", annotate=3, legend="topright")
```



Comparison of precision vs. recall curves for the 4 recommender algorithms shows that Popular items and association rules performed the best for the given evaluation scheme.

## Deployment

Instacart can use our recommendation models to recommend products to customers while they do their shopping, through a “Frequently bought with x (item)” suggestions. Additionally, our other model using Weighted Alternating Least Squares with Implicit Feedback model can also make suggestions for grocery products, based on the implicit feedback given when customers previously bought a product to suggest products for future purchases.

Other data that can be collected include product price, and transaction date. In other recommendation systems, user ratings of products can also be used to recommend new products, using different algorithms such as user-based collaborative filtering. The current model is based on customer transactions buying groceries from Instacart in 2017, and thus recommendations are based on those transactions. The model could be updated every 2 years or so with new transaction data because in that time, new products may be added, new food trends would also mean customers may make different product choices based on new food trends in the future. For example, plant-based products, breakfast foods, pasta, pickling and fermenting kits, meal kits are predicted to become very popular in 2021 (Hearst Magazine, 2021), and customer purchases may reflect those trends (which may be different from what they typically bought in 2017).

## References

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