Shopper Behavior Exploration and Market Basket Analysis using Apache Spark


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In this blog, I will talk about my Shopper Behavior Exploration on a real Instacart Dataset of 3MM+ records. I will discuss how you can quickly run your market basket analysis using Apache Spark ML `FP-growth` algorithm on Databricks.

Market Basket Analysis is a technique used by large retailers to discover associations between their items. It works by looking for combinations of items that are bought together frequently, providing information to understand the purchase behavior. Association Rules Mining is one of the very important concepts of machine learning being used in Market Basket Analysis. Let's understand what it is.

Association Rule Mining

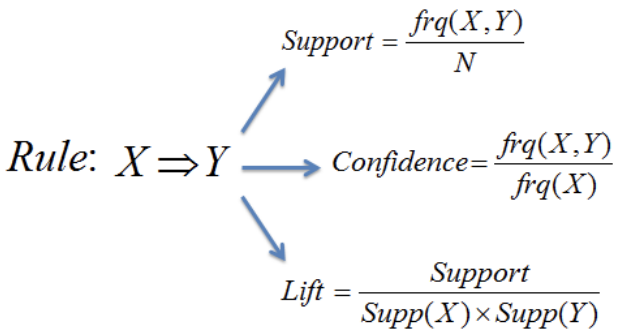
Association rules can be thought of as an 'If-Then' relationship. In simple words, if a customer has an item **A** in a basket, the Association Rules help in identifying the other item **B** that the customer is most likely to buy. For

instance, if a customer buys bread then it is likely that it will buy butter as well.

Supermarkets with thousands of different products in their store can boost their revenues and profits by accessing these untapped opportunities for identifying the relationship between the items purchased. They can do so by placing items frequently bought together in the same aisle, optimizing their catalog design, cross-selling items with collective discounts on their websites and analyzing customer behavior analysis, etc.

Two important metrics used in defining association rules are **Support** and **Confidence**. Every association rule should have minimum Confidence and minimum Support at the same time and these are usually user-specified.

Now, let's look at what are Support, Confidence, and Lift metrics with 2 items (suppose) ***X*** and ***Y***.



Support:- Support is defined as the frequency with which items ***X*** and ***Y*** are purchased together over the total number of transactions. This metric tells us how frequent an itemset is in all the transactions.

Confidence:- Confidence is the frequency with which **X** and ***Y*** are purchased together over the frequency with which ***X*** is purchased alone.

Lift:- Lift is defined as the Support over the Support for ***X*** times the Support for *Y*. Think of lift as the rise in the probability of having ***Y*** on the cart with the knowledge of ***X*** being present over the probability of having ***Y*** on the cart without any knowledge about the presence of ***X***.

I would be using these metrics later while implementing `FP-growth` algorithm.

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Dataset

In this blog, the dataset I am using comes is **Instacart's real dataset** which was released on Kaggle in 2017.

This is an anonymized dataset containing a sample of over 3 million grocery orders from more than 200,000 Instacart users. For each user, there are about 4 to 100 orders, with the sequence of products purchased in each order.

The dataset can be downloaded from here.

Platform I used

I would be using Apache Spark for the implementation of this project and using **PySpark**, **SparkSql** and later **Scala** programming languages for coding.

Note that you can try Apache Spark on the Databricks cloud for free from this link.

Ok, enough for the theory, let's get to the code.

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Importing all the available files into the Spark DataFrame and creating temporary tables

The dataset comes with six different .csv files that can be merged together to perform analyses. To begin with, I imported all the 6 files in the Spark environment and created temporary tables to run Spark SQL queries on them.

```
aisles = spark.read.csv("/FileStore/tables/aisles.csv", header=True, inferSchema=True)
departments = spark.read.csv("/FileStore/tables/departments.csv", header=True, inferSche
order_products_prior = spark.read.csv("/FileStore/tables/order_products__prior.csv", hea
order_products_train = spark.read.csv("/FileStore/tables/order_products__train.csv", hea
orders = spark.read.csv("/FileStore/tables/orders.csv", header=True, inferSchema=True)
products = spark.read.csv("/FileStore/tables/products.csv", header=True, inferSchema=Tru

aisles.createOrReplaceTempView("aisles")
departments.createOrReplaceTempView("departments")
order_products_prior.createOrReplaceTempView("order_products_prior")
order_products_train.createOrReplaceTempView("order_products_train")
orders.createOrReplaceTempView("orders")
products.createOrReplaceTempView("products")
```

importing_files.py hosted with ❤ by GitHub view raw

Files import into Spark DataFrame

Let's take a look at the **top 5 rows** of each of the imported file along with their **Data Dictionary**:

`orders` (3.4m rows, 206k users):

- `order_id` : order identifier
- `user_id` : customer identifier
- `eval_set` : which evaluation set this order belongs to
- `order_number` : the order sequence number for this user (1 = first, n = nth)
- `order_dow` : the day of the week the order was placed on
- `order_hour_of_day` : the hour of the day the order was placed on
- `days_since_prior` : days since the last order, capped at 30 (with NAs for `order_number` = 1)

```
orders.show(n=5)
```

▸ (1) Spark Jobs

```
+--------+-------+--------+------------+---------+-----------------+-----------------------+
|order_id|user_id|eval_set|order_number|order_dow|order_hour_of_day|days_since_prior_order|
+--------+-------+--------+------------+---------+-----------------+-----------------------+
| 2539329|      1|   prior|           1|        2|                8|                   null|
| 2398795|      1|   prior|           2|        3|                7|                   15.0|
|  473747|      1|   prior|           3|        3|               12|                   21.0|
| 2254736|      1|   prior|           4|        4|                7|                   29.0|
|  431534|      1|   prior|           5|        4|               15|                   28.0|
+--------+-------+--------+------------+---------+-----------------+-----------------------+
```

`products` (50k rows):

- `product_id` : product identifier
- `product_name` : name of the product
- `aisle_id` : foreign key
- `department_id` : foreign key

```
products.show(n=5)
```

▸ (1) Spark Jobs

```
+----------+--------------------+--------+-------------+
|product_id|        product_name|aisle_id|department_id|
+----------+--------------------+--------+-------------+
|         1|Chocolate Sandwic...|      61|           19|
|         2|    All-Seasons Salt|     104|           13|
|         3|Robust Golden Uns...|      94|            7|
|         4|Smart Ones Classi...|      38|            1|
|         5|Green Chile Anyti...|       5|           13|
+----------+--------------------+--------+-------------+
```

`aisles` (134 rows):

- `aisle_id` : aisle identifier
- `aisle` : the name of the aisle

```
aisles.show(n=5)
```

```
▸ (1) Spark Jobs
+--------+--------------------+
|aisle_id|               aisle|
+--------+--------------------+
|       1|prepared soups sa...|
|       2|   specialty cheeses|
|       3| energy granola bars|
|       4|       instant foods|
|       5|marinades meat pr...|
+--------+--------------------+
```

`deptartments` (21 rows):

- `department_id` : department identifier
- `department` : the name of the department

```
departments.show(n=5)
```

```
▸ (1) Spark Jobs
+-------------+----------+
|department_id|department|
+-------------+----------+
|            1|    frozen|
|            2|     other|
|            3|    bakery|
|            4|   produce|
|            5|   alcohol|
+-------------+----------+
```

`order_products_train` (131K+ rows):

Training data supplied to participants of Kaggle

```
order_products_train.show(n=5)
```

```
▸ (1) Spark Jobs
+--------+----------+-----------------+---------+
|order_id|product_id|add_to_cart_order|reordered|
+--------+----------+-----------------+---------+
|       1|     49302|                1|        1|
|       1|     11109|                2|        1|
|       1|     10246|                3|        0|
|       1|     49683|                4|        0|
|       1|     43633|                5|        1|
+--------+----------+-----------------+---------+
```

`order_products_prior` (32MM+ rows):

Orders data prior to that user's most recent order

```
order_products_prior.show(n=5)
```

▸ (1) Spark Jobs

```
+--------+----------+-----------------+---------+
|order_id|product_id|add_to_cart_order|reordered|
+--------+----------+-----------------+---------+
|       2|     33120|                1|        1|
|       2|     28985|                2|        1|
|       2|      9327|                3|        0|
|       2|     45918|                4|        1|
|       2|     30035|                5|        0|
+--------+----------+-----------------+---------+
```

Now that we have created DataFrames and taken a glimpse at the top 5 rows of each file, let's proceed with **EDA using Spark SQL** to find insights and patterns from the Instacart dataset.

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Exploratory Data Analysis

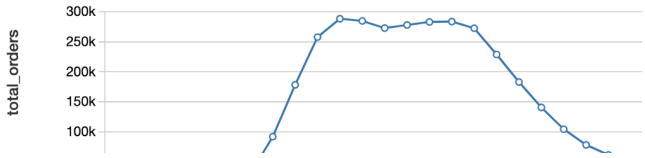
What time of day do customers purchase?

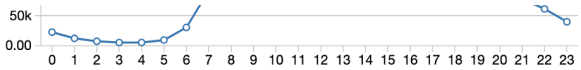
```
df = sqlContext.sql("select count(order_id) as total_orders,
order_hour_of_day as hour
from orders
group by order_hour_of_day
order by order_hour_of_day")
df.show()
```

> Note: With Databricks notebooks, we can use the `%sql` to execute SQL code within a new cell in the same Python notebook. For instance, the equivalent code of the above code snippet would be as below.

```
%sql
select count(order_id) as total_orders, order_hour_of_day as hour
from orders
group by order_hour_of_day
order by order_hour_of_day
```

Note: Databricks supports various types of DataFrame and SQL visualizations within notebook cells. You can learn more about them here.

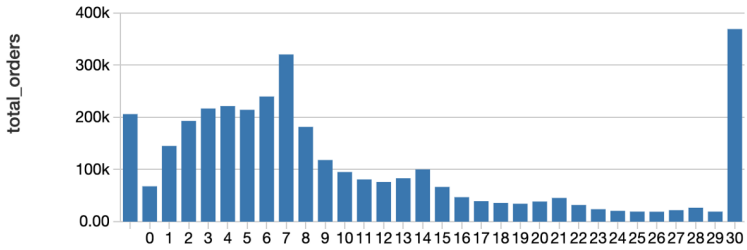




▶ Above line graph shows that the customers are more likely to place an order between 9 am to 6 pm

How often do customers place orders?

```
%sql
select days_since_prior_order,count(order_id) as total_orders
from orders
group by days_since_prior_order
order by days_since_prior_order
```

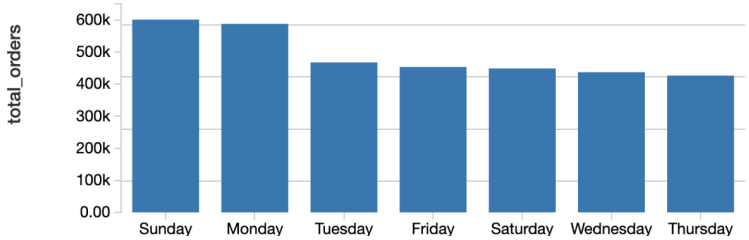


▶ It appears that most of the customers order once a week since the majority of records are concentrated between 0 to 7 days

▶Also, a large number of customer place their order 30 days or later days since because ‘days_since_prior’ column is capped at 30

On which day of the week customers purchase the most?

```
%sql
select count(order_id) as total_orders,
  (case
     when order_dow = '0' then 'Sunday'
     when order_dow = '1' then 'Monday'
     when order_dow = '2' then 'Tuesday'
     when order_dow = '3' then 'Wednesday'
     when order_dow = '4' then 'Thursday'
     when order_dow = '5' then 'Friday'
     when order_dow = '6' then 'Saturday'
   end) as day_of_week
  from orders
 group by order_dow
 order by total_orders desc
```



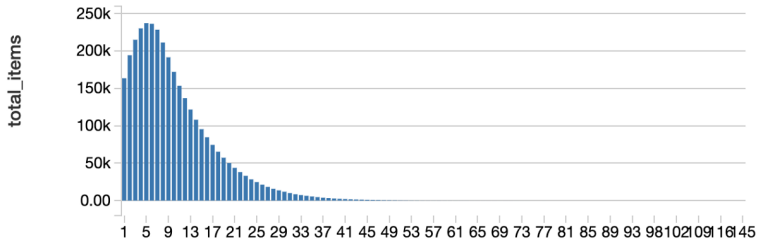
▶ Sunday and Monday have the most orders, while Thursday has the least orders in a week

How many items do customers purchase in an order?

Let's create a Master Dataset by merging together products, departments, order_products_train, and order_products_prior datasets together and run the query on top of that.

```
%sql
create table master_table as
(select op.*,p.product_name,p.aisle_id,p.department_id,d.department
from
 (select * from order_products_train
 union
 select * from order_products_prior) as op
 inner join products as p
 on op.product_id = p.product_id
 inner join departments as d
 on p.department_id = d.department_id)
```

```
%sql
select order_id,count(product_id) as total_items
from master_table
group by order_id
```



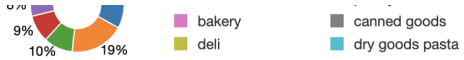
▶ The above bar chart depicts that the most common number of items purchased in order by customers is 4

▶ Majority of customers prefer to purchase between 1 to 15 items per order

Which are the top departments from which orders are placed?

```
%sql
select department, count(*) as orders_count from master_table
group by department
order by orders_count desc
limit 10
```

▸ (1) Spark Jobs



▶ If we take a look at top 10 departments from which most items are purchased, we would infer that almost 50% of the items purchased belong from just 2 departments which are '*produce*' and '*dairy eggs*'

Which are the most purchased items?

```
%sql
select product_name, count(*) as orders_count from master_table
group by product_name
order by orders_count desc
limit 200
```

product_name	orders_count
Banana	491291
Bag of Organic Bananas	394930
Organic Strawberries	275577
Organic Baby Spinach	251705
Organic Hass Avocado	220877
Organic Avocado	184224
Large Lemon	160792
Strawberries	149445

▶ These are the top 8 items bought by Instacart customers in their orders. Banana seems to be most bought commonly bought item in baskets followed by *strawberries*, *baby spinach*, *avocado*, etc.

Let's also make a word cloud of the top 200 items bought by Instacart customers.

```
# !pip install wordcloud
from wordcloud import WordCloud
import matplotlib.pyplot as plt

df = sqlContext.sql("SELECT product_name FROM (select product_name,
count(*) as orders_count from master_table group by product_name
order by orders_count desc limit 200)")
df2 = df.rdd.flatMap(lambda x: x).collect()
fullStr = ' '.join(df2)

wordcloud = WordCloud(background_color="white").generate(fullStr)

# Display the generated image:
plt.figure(figsize=(14, 10))
plt.imshow(wordcloud, interpolation='bilinear')
plt.axis("off")
plt.show()
display()
```

From the word cloud, it appears that Americans buy ***organic food*** and ***veggies*** a lot as words like *Organic, Milk, Water, Apple, Sparling, Egg, Green, Cheese*, etc. are getting highlighted the most.

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FP-Growth Algorithm

The FP-growth algorithm is described in the paper Han et al., Mining frequent patterns without candidate generation, where “FP” stands for frequent pattern. Given a dataset of transactions, the first step of FP-growth is to calculate item frequencies and identify frequent items. Different from Apriori-like algorithms designed for the same purpose, the second step of FP-growth uses a suffix tree (FP-tree) structure to encode transactions without generating candidate sets explicitly, which are usually expensive to generate. After the second step, the frequent itemsets can be extracted from the FP-tree.

> *You can learn more about the **steps involved in the FP-growth Algorithm** here.*

Organizing the data by the shopping basket

For implementing FP-growth, first, we would be creating baskets of each order in our dataset. We would do so by creating a *baskets* data frame having 2 columns: first, the *order_id* and second, the list of items bought in that particular order.

```
from pyspark.sql.functions import collect_set, col, count
rawData = spark.sql("select p.product_name, o.order_id from products p
                    inner join order_products_train o
                    where o.product_id = p.product_id")
baskets = rawData.groupBy('order_id').agg(collect_set('product_name').alias('items'))
baskets.createOrReplaceTempView('baskets')
rawData.show(5)
baskets.show(5)
display(baskets)
```

create_baskets.py hosted with ❤ by GitHub view raw

Below are the top 5 rows of the *baskets* data frame, to be fed into the FP-growth algorithm.

order_id	items
1342	["Raw Shrimp","Seedless Cucumbers","Versatile Stain Remover","Organic Strawberries","Organic Mandarins","Chicken Apple Sausage","Pink Lady Apples","Bag of Organic Bananas"]
1591	["Cracked Wheat","Strawberry Rhubarb Yoghurt","Organic Bunny Fruit Snacks Berry Patch","Goodness Grapeness Organic Juice Drink","Honey Graham Snacks","Spinach","Granny Smith Apples","Oven Roasted Turkey Breast","Pure Vanilla Extract","Chewy 25% Low Sugar Chocolate Chip Granola","Banana","Original Turkey Burgers Smoke Flavor Added","Twisted Tropical Tango Organic Juice Drink","Navel Oranges","Lower Sugar Instant Oatmeal Variety","Ultra Thin Sliced Provolone Cheese","Natural Vanilla Ice Cream","Cinnamon Multigrain Cereal","Garlic","Goldfish Pretzel Baked Snack Crackers","Original Whole Grain Chips","Medium Scarlet Raspberries","Lemon Yogurt","Original Patties (100965) 12 Oz Breakfast","Nutty Bars","Strawberry Banana Smoothie","Green Machine Juice Smoothie","Coconut Dreams Cookies","Buttermilk Waffles","Uncured Genoa Salami","Organic Greek Whole Milk Blended Vanilla Bean Yogurt"]
4519	["Beet Apple Carrot Lemon Ginger Organic Cold Pressed Juice Beverage"]
4935	["Vodka"]
6357	["Globe Eggplant","Panko Bread Crumbs","Fresh Mozzarella Ball","Grated Parmesan","Gala Apples","Italian Pasta Sauce Basilico Tomato, Basil & Garlic","Organic Basil","Banana","Provolone"]

Implementation of FP-growth algorithm using Scala

Here, we would be using `spark.ml`'s FP-growth package for implementation.

```
%scala
import org.apache.spark.ml.fpm.FPGrowth

// Extract out the items
val baskets_ds = spark.sql("select items from baskets").as[Array[String]].toDF("items")

// Use FPGrowth
val fpgrowth = new FPGrowth().setItemsCol("items").setMinSupport(0.001).setMinConfidence(
val model = fpgrowth.fit(baskets_ds)
```

FPGrowth.py hosted with ❤ by GitHub view raw

```
// Display frequent itemsets
val mostPopularItemInABasket = model.freqItemsets
mostPopularItemInABasket.createOrReplaceTempView("mostPopularItemInABasket")

// Display generated association rules.
val ifThen = model.associationRules
ifThen.createOrReplaceTempView("ifThen")
```

frequent_itemsets_scala.py hosted with ❤ by GitHub view raw

Now, let us explore the most frequent basket of items (containing at least 2 items).

```
%sql
select items, freq from mostPopularItemInABasket where size(items) >
2 order by freq desc limit 20
```

items	freq
["Organic Hass Avocado","Organic Strawberries","Bag of Organic Bananas"]	710
["Organic Raspberries","Organic Strawberries","Bag of Organic Bananas"]	649
["Organic Baby Spinach","Organic Strawberries","Bag of Organic Bananas"]	587
["Organic Raspberries","Organic Hass Avocado","Bag of Organic Bananas"]	531
["Organic Hass Avocado","Organic Baby Spinach","Bag of Organic Bananas"]	497
["Organic Avocado","Organic Baby Spinach","Banana"]	484
["Organic Avocado","Large Lemon","Banana"]	477
["Limes","Large Lemon","Banana"]	452

The most frequent basket of items comprises of *organic avocado, organic strawberries*, and *organic bananas* together.

A good way to think about *association rules* is that model determines that if you purchased something (i.e. the *antecedent*), then you will purchase this other thing (i.e. the *consequent*) with the following confidence.

```
%sql
select antecedent as `antecedent (if)`, consequent as `consequent
(then)`, confidence from ifThen order by confidence desc limit 20
```

(1) Spark Jobs

antecedent (if)	consequent (then)	confidence
["Organic Raspberries","Organic Hass Avocado","Organic Strawberries"]	["Bag of Organic Bananas"]	0.5984251968503937
["Organic Cucumber","Organic Hass Avocado","Organic Strawberries"]	["Bag of Organic Bananas"]	0.546875
["Organic Kiwi","Organic Hass Avocado"]	["Bag of Organic Bananas"]	0.5459770114942529
["Organic Navel Orange","Organic Raspberries"]	["Bag of Organic Bananas"]	0.5412186379928315
["Yellow Onions","Strawberries"]	["Banana"]	0.5357142857142857
["Organic Whole String Cheese","Organic Hass Avocado"]	["Bag of Organic Bananas"]	0.5314685314685315
["Organic Navel Orange","Organic Hass Avocado"]	["Bag of Organic Bananas"]	0.5283018867924528
["Organic Raspberries","Organic Hass Avocado"]	["Bag of Organic Bananas"]	0.521099116781158

If a customer has *organic raspberries, organic avocados*, and *organic strawberries* in its basket, then it may make sense to recommend organic bananas as well. Surprisingly, the top 10 purchase recommendations either organic bananas or bananas.

Implementation of FP-growth algorithm — Market basket analysis using PySpark

The FP-growth algorithm we implemented above using Scala can also be implemented using PySpark with equivalent code as below:

```
from pyspark.ml.fpm import FPGrowth

fpGrowth = FPGrowth(itemsCol="items", minSupport=0.001, minConfidence=0)
model = fpGrowth.fit(baskets)

model.freqItemsets.show() # Display frequent itemsets

model.associationRules.show() # Display generated association rules

model.transform(baskets).show() # transform examines the input items against all the ass
```

FPGrowth_pyspark.py hosted with ❤ by GitHub view raw

Summary

In this blog, we analyzed customer shopping behavior and performed Market Basket Analysis using Apache Spark on a huge dataset. If you want to implement the Market Basket Analysis in other environments, you can use *apyori* library in Python and *arules* library in R for the *Apriori algorithm*.

Well, that is all for this article. I hope you guys have enjoyed reading it, please share your suggestions/views/questions in the comment section.

Thanks for reading !!!

References: -

i) https://s3.us-east-2.amazonaws.com/databricks-dennylee/notebooks/Market+Basket+Analysis+using+Instacart+Online+Grocery+Dataset.html

ii) https://spark.apache.org/docs/latest/ml-frequent-pattern-mining.html

iii) https://towardsdatascience.com/association-rules-2-aa9a77241654

Market Basket Analysis Spark Data Science Machine Learning Association Rule