Database, Data Warehouse Technology for U.S. Chain-Restaurant Menu Item Nutrition Data Analysis

Foroozan Akhavan, Minh-Tam Pham, Zhe Li, Chloe(Chau) Ngo, and Taoli Zhen

***Abstract*—Using a data set of nutrition facts, this project tries to help people to choose the best meals in order to reduce health risks with dining out or choosing fast foods as their source of meals. We worked on a dataset that has nutrition facts of each item in chain restaurants from 2008 to 2018. The questions we answered are where to avoid, what to avoid, healthy changes in the menus. To answer these questions it was needed to set up and use a data warehouse cloud server to enable the analysts to analyze the data collected simultaneously. We chose a star schema as our data model and loaded the database from MySQL to the MariaDB cloud server. In this project, we used a Hybrid Database for both transactional operation and analytics operation, which simulates a real-time OLTP data input process and the auto-replication engine replicates the new data in the transactional database to the analytical database. This setup enables transactional data to feed to the data warehouse in real-time. The results will help people living in the USA to have healthy options. In the future with gathering more data, we will find more trends in fast food meals.**

***Keywords*—Analysis, data, database design, database processing, data warehouse and repository, query design and implementation languages**

I. Introduction

Nowadays dining out is an integral part of city life. More than $\frac{1}{3}$ of Americans dine out at chain restaurants. Studies [9] show that the fast-food chain restaurants' contribution to obesity is significant. For people who don't have time to prepare meals by themselves, ordering meals that contain enough macro nutrients while ensuring calories and unhealthy fat are under the daily consumption limit becomes the key to address the obesity issue. Although we know fast food restaurants are convenient, is it currently possible for Americans to eat nutritiously at these restaurants as well?

As more people start to care about the nutrition in the food they consume, a number of major chain restaurants responded by including some healthy options on their menu. Additionally, some restaurants voluntarily labeled their menus with calorie information and provided a fair amount of nutrition information on their website since 2008. As mentioned in [9],in 2010, the U.S. government passed the Affordable Care Act, which includes a law requiring chain restaurants to display calories information on menus. With this requirement, there is a sufficient amount of menu nutrition data available from menustat.org [8] for us to explore this topic. The dataset enables us to investigate in what ways chain restaurants had altered their menu items in order to provide healthier food over the years.

In this paper, we will go through and explore the technologies that enable data analytics on our topic, as well as data cleansing procedures and operations that are needed to store and manage the menu nutrition data. These operations and database technologies enable us to perform efficient analytics on the menu dataset while keeping the cost at a minimum. We will employ a cloud database management platform to store and organize the data we gathered, which data can be replicated into an analytics platform to improve efficiency when performing On-Line Analytical Processing.

II. Methods and Implementation

A. Data cleansing and Transform

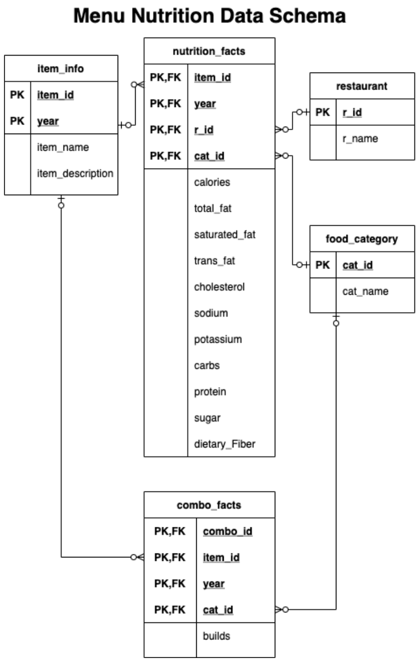


Fig. 1. Galaxy Schema for the Menu Nutrition Data. Serve as a data warehouse schema.

The dataset files from menustat.org [8] were in CSV format and the menu nutrition data was stored in separate files, by year. A star or galaxy schema would be suitable for the dataset.

F. Akhavan, M. Pham, Z. Li, C. Ngo and T. Zhen are with the San Jose State University, San Jose, CA 95192. E-mail: *foroozan.akhavan@sjsu.edu*, *minh-tam.pham@sjsu.edu*, *zhe.li01@sjsu.edu*, *chau.ngo@sjsu.edu* and *taoli.zhen@sjsu.edu*.

Detailed code for extracting the data, normalizing the data, and transforming the data is in the data_transform.ipynb notebook file, located in the Appendix Github link.

The 2018 (latest) dataset was used as the base case for all other years. All attributes were in one single large table, which was in the 1st normal form. The first step is to transform the table to 3rd normal form for the galaxy schema. A Python package Pandas was used in the cleansing and processing stage.

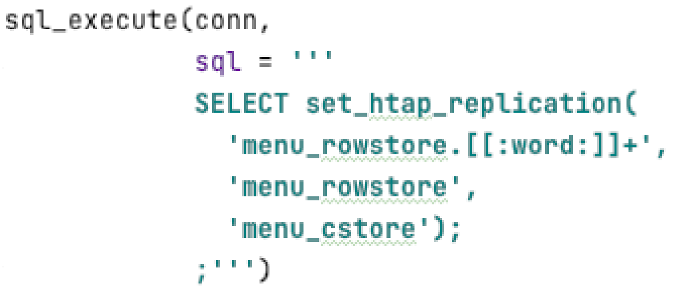
For our schema, there is a restaurant dimension, a food category dimension, an item information dimension, a nutrition fact table and a combo data fact table.

For the restaurant and food category dimensions, the first step was to extract the restaurant name and food category name from the main table. For each of the dimensions, we only retained the number of unique restaurant and food category names and assigned a primary key (surrogate key) for each unique name. These dimension tables were ready to load after the above processing.

For the item information dimension, we selected the item_id, year, item_name, and item_description column from the main table and retained the unique rows only. The item_id and year attributes comprise the composite key for this dimension.

Once we have the meta data transformed into dimension tables, we can transform the main table into the nutrition fact table. First, we joined the restaurant dimension and food category dimension with the main table to obtain the restaurant id and food category id for each item. With the item_id, year, restaurant_id, and category_id as the composite key in the fact table. Restaurant_id and category_id is also the foreign key to the corresponding dimensions. Each transaction records the nutrition record for a menu item for the specific year.

Finally, for the combo meal fact table, we have combo_id, year, item_id, and category_id as the composite primary key. The attribute, 'builds', records whether the item in a combo is the main item or an accompanying item. Each combo can have multiple main items and accompanying items, the logic for the combo is that people can only choose one main item and one accompanying item for each food category.



```
sql_execute(conn,
            sql = '''
            SELECT set_htap_replication(
              'menu_rowstore.[[:word:]]+',
              'menu_rowstore',
              'menu_cstore');
            ;''')
```

Fig. 2. Example sql query to set up the replication filter function.

With the base case data extracted and transformed, we created a transform_data(dat, year) function reusing the code for the 2018 year to transform the rest of the years' data. Note that there was a small amount of NA values (under 200 rows) in the restaurant_id column in the nutrition fact table in 2008, 2010, and 2012; which means that these restaurants were no longer in the menu data record in later years. Thus, these NA values can be ignored as we can't compare the nutrition data with later years.

B. Loading Data to MySQL

Initially, we loaded the data to the local MySQL server using sqlalchemy. To enable the ability for team members to connect to the database remotely and optimize the data warehouse for analytics, we decided to employ MariaDB and SkySQL platforms to run our data warehouse. To migrate the database to MariaDB Cloud, we exported the menu nutrition database from MySQL to a dump file.

C. MariaDB, SkySQL, and HTAP Platforms

According to [7], MariaDB is a fork of MySQL and the process of replacing MySQL with MariaDB can be as easy as importing a dump file to MariaDB from MySQL. When compared to MySQL, MariaDB has the capability to support a variety of storage engines. And in many cases, performance on MariaDB is better than MySQL.

SkySQL is the cloud service for MariaDB, and there are four platforms available in SkySQL. They include the following: the Transactions Platform, which is optimized for fast transaction processing (OLTP), the Analytics Platform, which is optimized for running ad hoc queries on data warehouses (OLAP), and the Hybrid Transactional-Analytical Processing Platform which supports both OLTP and OLAP using different storage engines for OLTP and OLAP [5]. Here in this project, we used the Hybrid Transactional-Analytical Processing Platform to simulate the real-life work environment. We can have a seamless data movement from the transaction database to the analytics data warehouse.

As documented in [6], transaction databases can handle OLTP queries "using row-based transactional storage engines, such as InnoDB or MyRocks," and analytics data warehouse can handle OLAP queries "using the MariaDB ColumnStore storage engine." The MariaDB server uses MariaDB MaxScale to handle client connections. Another function of MaxScale is to differentiate between SQL queries for RowStore and SQL queries for ColumnStore. In MariaDB, regular SQL queries can be used to query from the ColumnStore databases. MaxScale can route queries to the right server [6].

D. HTAP Data Warehouse Setup and Loading Data

In this project, we created a RowStore database for transactional processing and a ColumnStore database to serve as the data warehouse to store historical data for analytics.

To enable auto replication, the MariaDB server replicates "writes from InnoDB tables to the MariaDB ColumnStore tables" using MariaDB Replication. According to the MariaDB Enterprise Documentation [6],, "MariaDB Replication with MariaDB MaxScale configured as a Binlog Server, MariaDB Enterprise Server can host InnoDB and ColumnStore on the same Server."

In our practice, we specified the Row Store tables with certain prefixes to automatically replicate to Column Store, which fed data directly from the transaction RowStore to the data warehouse ColumnStore. As demonstrated in the mariadb_cloud_load_data.ipynb notebook file in the Github link under Appendix, we set up the replication filter using the set_htap_replication() UDF.

The next step was to create two databases with distinguishable names, one named as for menu_rowstore, another one named as menu_cstore. Create tables for our data model in the menu_rowstore database and check if tables in the RowStore were auto replicated to the ColumnStore. We verified that the auto replication was working properly. Then we deleted the tables in the ColumnStore and re-created the same tables with the engine specified as ColumnStore in table creation queries. Finally, we imported the dump file exported from MySQL into the RowStore database and verified that the data was replicated to ColumnStore in nearly real time.

E. DB Connectivity and Analytic Tools

The MariaDB Enterprise Cloud Server provided an easy solution for connecting to the data warehouse. With the username, password, host domain, and the certificate authority chain, any whitelisted IP addresses would be able to connect to the server and query the data warehouse. We can either use a graphical application such as MySQL Workbench or Python to run DML, DDL, DCL, and TCL to manage and control the data warehouse, define or alter database schemas, and manipulate the data in the warehouse. We used Python as the main scripting language to perform data analytics. Because MariaDB is a fork of MySQL, we used the MySQL Connector for Python to connect with the data warehouse on the server.

F. Data Aggregation

Our data warehouse is OLAP ready. We used the ROLLUP function to get aggregate data for both two-dimensional and three-dimensional cubes. Although MariaDB doesn't support the CUBE function, we used the Pivot table function in the Pandas to make the ROLLUP results into a CUBE-like structure. With the GROUP BY clause, we sliced and diced to select the data we need to investigate and answer questions in our research topics.

G. Filtering to Find the Best/Worst Restaurants in Certain Aspects

In our analysis, we applied filters based on daily nutrition requirements and daily intake limits to different nutrition facts features in order to build a recommendation list or restaurant to avoid list.

H. Visualization

Python package Seaborn was used in visualizing the data. Even though we used the ROLLUP function to perform data aggregation on the data warehouse server directly, there were still too many categories in the Restaurant and Food Category attribute. There were 96 restaurants and 12 categories in 2018. The CUBE structure was too hard to read and keep track of the information. Therefore, we used the seaborn package to visualize the query results such that it would be easier for us to interpret and compare.

I. Clustering

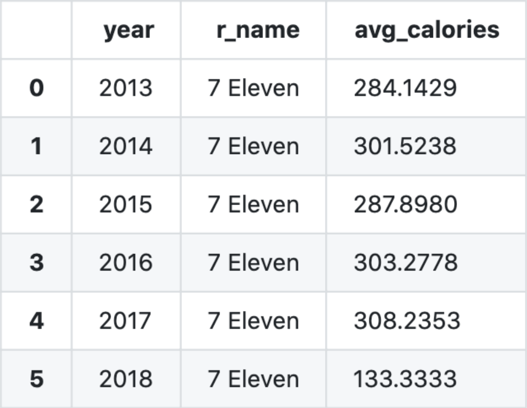
We will find the worst restaurant to avoid from our analysis. However, it's hard to set up solid criteria for building a bad-restaurant list since all restaurants have multidimensional nutrition factors. Clustering - an unsupervised machine learning technique is introduced here. It helps us identify groups of restaurants based on their nutrient pattern and segment these into a certain number of groups according to the level of inertia. After that, we are able to find out the avoid list from the group that has a bad nutritional pattern as in the worst restaurant we found before.

J. Null Value Handling

When using aggregate function AVG() in queries, having Null values handled properly is crucial in making sure that the aggregation results are not biased. MariaDB server processes AVG() by summing up every transaction and dividing by the total number of transaction rows. For the nutrition attributes that contain Null values, we de-selected rows with Null Values. Because of the fact that some restaurants don't have records for every nutrition attribute, we ran queries on one nutrition attribute at a time to ensure that we didn't include any Null values or dropped any non-Null values by accident.

III. Results

A. Trends



	year	r_name	avg_calories
0	2013	7 Eleven	284.1429
1	2014	7 Eleven	301.5238
2	2015	7 Eleven	287.8980
3	2016	7 Eleven	303.2778
4	2017	7 Eleven	308.2353
5	2018	7 Eleven	133.3333

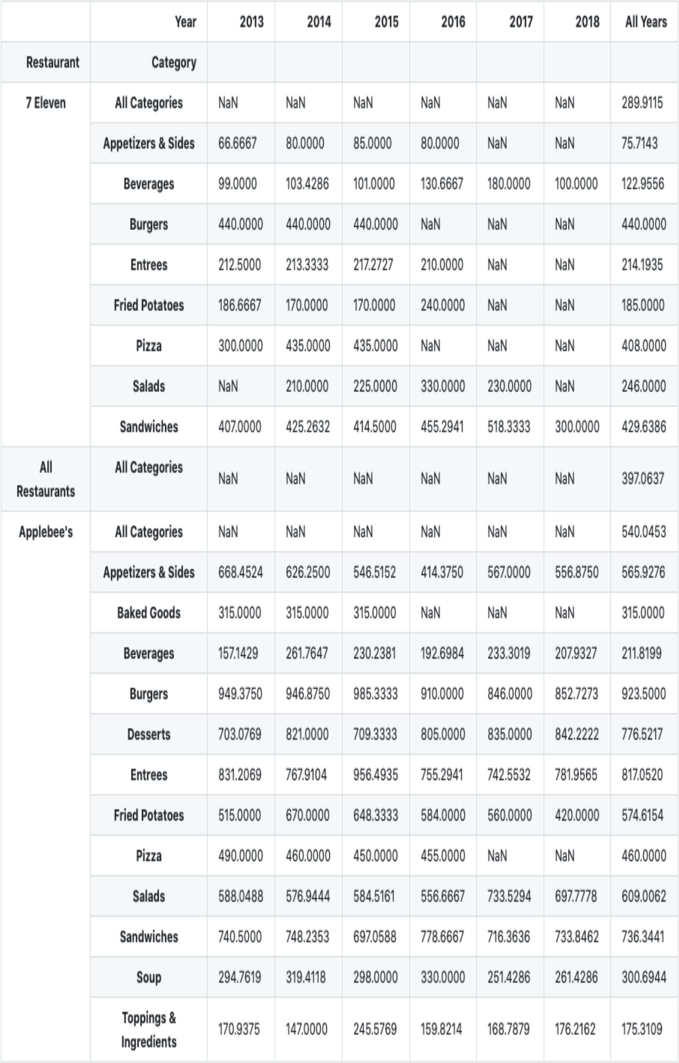
Fig. 3. Avg. calories for 7 Eleven from 2013 to 2018.

We have menu nutrition data from 2008 to 2018. Among the 10 years, there were only 55 restaurants recorded in 2008 while there were 96 restaurants recorded in the menu data in 2018. We decided to ignore years prior to 2013 and only focus on the most recent five years.

Fig. 3 shows the average calories of all menu items for 7-Eleven from 2013 to 2018. The result shows that for 7-Eleven, their average calories for all menu items were decreasing over the five-year period. The average calories decreased 55% in 2018 compared to the previous year.

B. 3 Dimension Cube Rollup for 7-Eleven

Fig. 4 is the table format of the 3-d cube structure representation of the average calories group by each restaurant and food category. There are much more details in this 3-dimensional cube. In 2017, 7-Eleven altered its menu and only remained beverages, salads and sandwiches. In 2018, they stopped serving salads.



	Year	2013	2014	2015	2016	2017	2018	All Years
Restaurant	Category							
7 Eleven	All Categories	NaN	NaN	NaN	NaN	NaN	NaN	289.9115
	Appetizers & Sides	66.6667	80.0000	85.0000	80.0000	NaN	NaN	75.7143
	Beverages	99.0000	103.4286	101.0000	130.6667	180.0000	100.0000	122.9556
	Burgers	440.0000	440.0000	440.0000	NaN	NaN	NaN	440.0000
	Entrees	212.5000	213.3333	217.2727	210.0000	NaN	NaN	214.1935
	Fried Potatoes	186.6667	170.0000	170.0000	240.0000	NaN	NaN	185.0000
	Pizza	300.0000	435.0000	435.0000	NaN	NaN	NaN	408.0000
	Salads	NaN	210.0000	225.0000	330.0000	230.0000	NaN	246.0000
	Sandwiches	407.0000	425.2632	414.5000	455.2941	518.3333	300.0000	429.6386
All Restaurants	All Categories	NaN	NaN	NaN	NaN	NaN	NaN	397.0637
Applebee's	All Categories	NaN	NaN	NaN	NaN	NaN	NaN	540.0453
	Appetizers & Sides	668.4524	626.2500	546.5152	414.3750	567.0000	556.8750	565.9276
	Baked Goods	315.0000	315.0000	315.0000	NaN	NaN	NaN	315.0000
	Beverages	157.1429	261.7647	230.2381	192.6984	233.3019	207.9327	211.8199
	Burgers	949.3750	946.8750	985.3333	910.0000	846.0000	852.7273	923.5000
	Desserts	703.0769	821.0000	709.3333	805.0000	835.0000	842.2222	776.5217
	Entrees	831.2069	767.9104	956.4935	755.2941	742.5532	781.9565	817.0520
	Fried Potatoes	515.0000	670.0000	648.3333	584.0000	560.0000	420.0000	574.6154
	Pizza	490.0000	460.0000	450.0000	455.0000	NaN	NaN	460.0000
	Salads	588.0488	576.9444	584.5161	556.6667	733.5294	697.7778	609.0062
	Sandwiches	740.5000	748.2353	697.0588	778.6667	716.3636	733.8462	736.3441
	Soup	294.7619	319.4118	298.0000	330.0000	251.4286	261.4286	300.6944
	Toppings & Ingredients	170.9375	147.0000	245.5769	159.8214	168.7879	176.2162	175.3109

Fig. 4. Cube structure table for 3-dimensional cube: average calories for each restaurant by food categories

Applebee's has a lower average calorie across almost all food categories over the five-year period except for salads. The two examples offer a better overview of the aggregate data, and we will elaborate on the results more in the discussion section.

C. Aggregation Results - Determining Trends

Fig. 5 displays a line plot for average calories from protein in all food categories. We can see that there is an upward trend in the Burgers, the Sandwiches, the Appetizers Sides, and the Soup category. Which is a good indicator of good ingredients. The average of calories from carbohydrates doesn't seem to have a clear trend from line plots and so does the average calories and the average amount of dietary fibers.

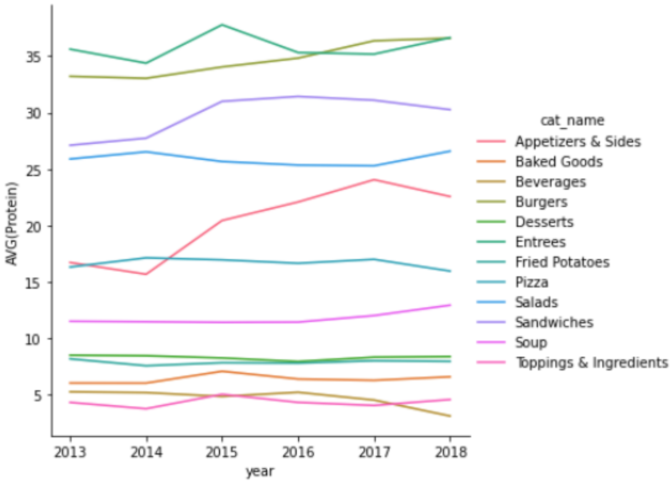


Fig. 5. Line plot for the average protein for all categories from 2013 to 2018.

If we look at Fig. 6, which is a grid of lm plots fitted with a simple linear regression line for the number of average calories across all categories, none of the categories have a down trend over the years. Appetizers Sides, Entrees, Desserts, Sandwiches, Burgers, Pizza, and Fried Potatoes categories all have a mild to moderate increase over the years.

Fig. 7 is a grid of lm plots fitted with a simple linear regression model for the amount of average cholesterol across all categories. From the grid of visualization, it is obvious that there is a clear uptrend in Appetizers Sides, Entrees, Desserts, and Pizza categories. Others seem to be consistent over the 5-year timeframe.

Based on the result from Fig. 6 and Fig. 7, there seems to be a correlation between the amount of cholesterol and calories. We will provide a correlation heat map in the following section and explore the correlation relationship in the discussion section.

D. Worst Restaurant to Avoid

We want to view the restaurants that have the highest trans fat/fat ratio. And by grouping items by restaurant and filtering, we found that Long John Silver's and Arby's are the highest in this ratio. Of all restaurants, these two restaurants historically have more than 15% of trans fat in the total fat. Long John Silver's restaurant events have 27.45% of trans fat in the total fat.

For the sugar to total calories ratio, we find that two of the five worst restaurants are beverage stores: Jamba Juice and Starbucks. Long John Silver's, KFC, and Krispy Kreme are also in the top five in the sugar: calories ratio.

Restaurants that offer high amounts of fibers are Chipotle, Qdoba, Round Table Pizza, Jamba Juice, and Carrabba's

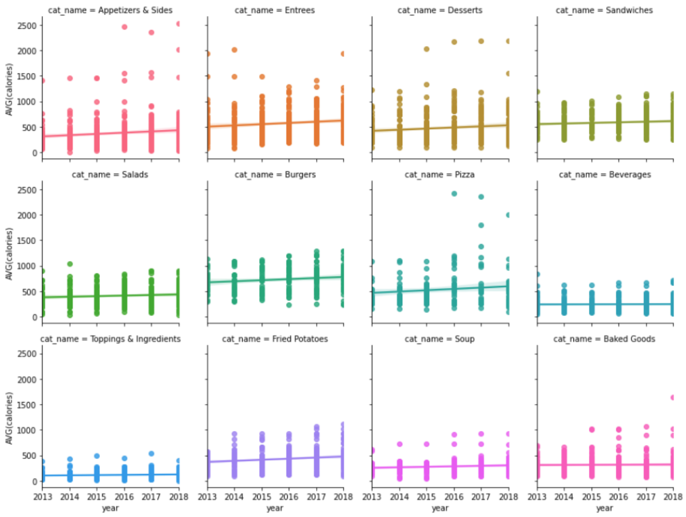


Fig. 6. The grid of lm plots fitted with simple linear regression line for the amount of average calories across all categories

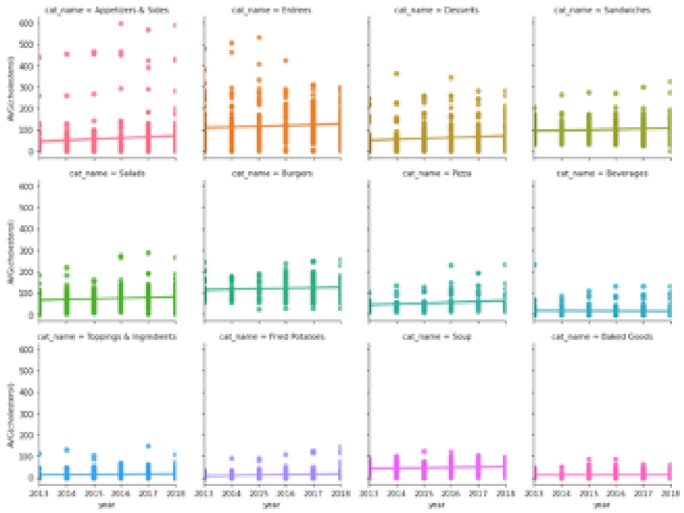


Fig. 7. The grid of lm plots fitted with simple linear regression line for the amount of average cholesterol across all categories

Italian Grill. While Long John Silver's is one of the top five restaurants, it offers the least fibers in its items.

E. Clustering - A List of Worst Restaurants to Avoid

After handling NA values, data cleansing, and normalization, we ran clustering and found out k = 4 is the reasonable amount for groups since the decrease in distortion at 4 starts to level off.

From the previous analysis, we find out that Long John Silver's is the most unhealthy restaurant. We find out Long John Silver's and other fast-food chains like McDonald's, Starbucks are all in group1. Those are the restaurants with bad nutrient patterns that we would warn people not to eat for a healthy diet.

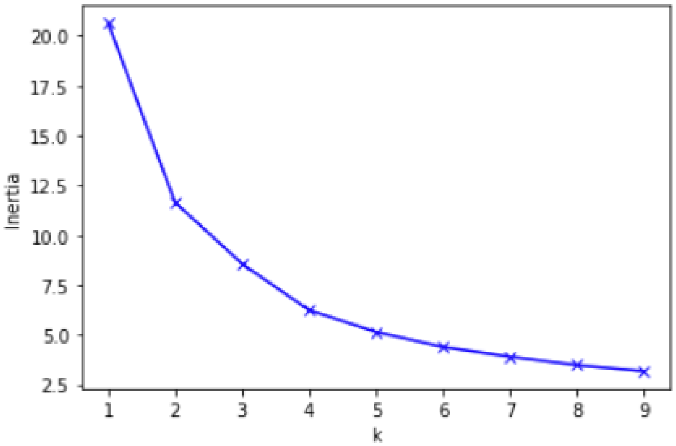


Fig. 8. Kmean Model: K vs Inertia.

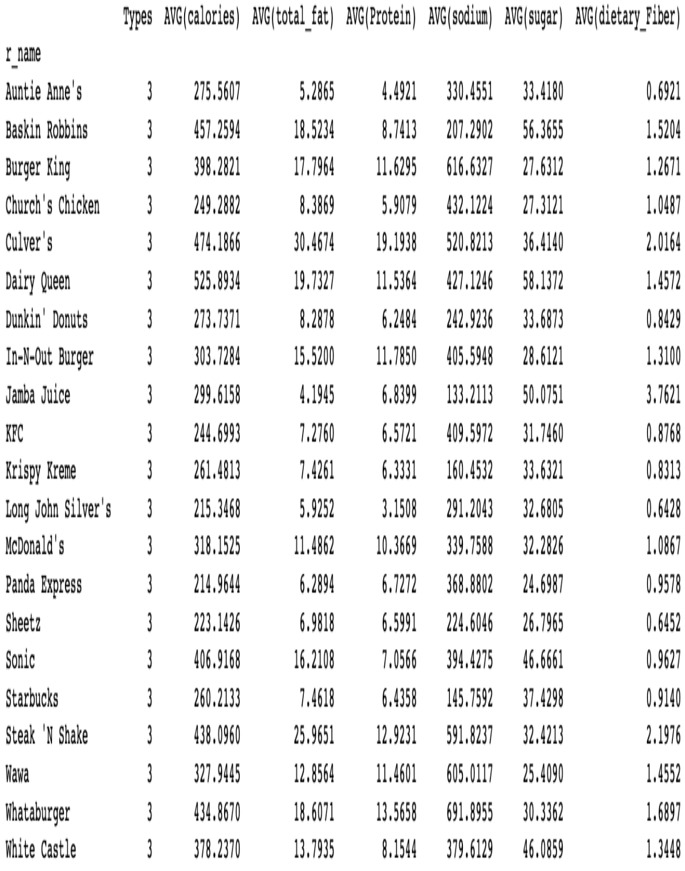
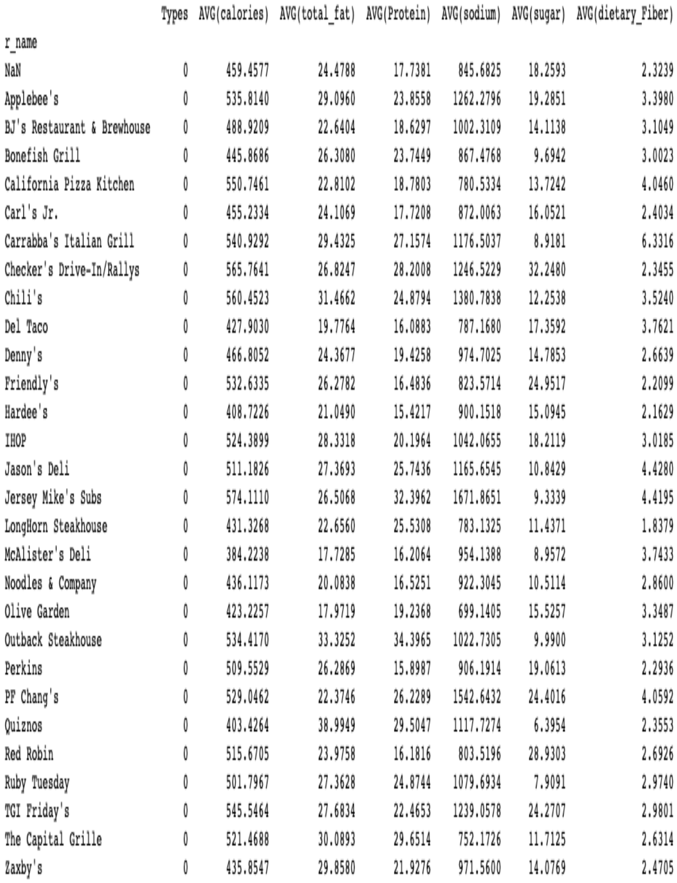

```
                  Types AVG(calories) AVG(total_fat) AVG(Protein) AVG(sodium) AVG(sugar) AVG(dietary_Fiber)
r_name
Auntie Anne's         3      275.5607         5.2865       4.4921    330.4551    33.4180             0.6921
Baskin Robbins        3      457.2594        18.5234       8.7413    207.2902    56.3655             1.5204
Burger King           3      398.2821        17.7964      11.6295    616.6327    27.6312             1.2671
Church's Chicken      3      249.2882         8.3869       5.9079    432.1224    27.3121             1.0487
Culver's              3      474.1866        30.4674      19.1938    520.8213    36.4140             2.0164
Dairy Queen           3      525.8934        19.7327      11.5364    427.1246    58.1372             1.4572
Dunkin' Donuts        3      273.7371         8.2878       6.2484    242.9236    33.6873             0.8429
In-N-Out Burger       3      303.7284        15.5200      11.7850    405.5948    28.6121             1.3100
Jamba Juice           3      299.6158         4.1945       6.8399    133.2113    50.0751             3.7621
KFC                   3      244.6993         7.2760       6.5721    409.5972    31.7460             0.8768
Krispy Kreme          3      261.4813         7.4261       6.3331    160.4532    33.6321             0.8313
Long John Silver's    3      215.3468         5.9252       3.1508    291.2043    32.6805             0.6428
McDonald's            3      318.1525        11.4862      10.3669    339.7588    32.2826             1.0867
Panda Express         3      214.9644         6.2894       6.7272    368.8802    24.6987             0.9578
Sheetz                3      223.1426         6.9818       6.5991    224.6046    26.7965             0.6452
Sonic                 3      406.9168        16.2108       7.0566    394.4275    46.6661             0.9627
Starbucks             3      260.2133         7.4618       6.4358    145.7592    37.4298             0.9140
Steak 'N Shake        3      438.0960        25.9651      12.9231    591.8237    32.4213             2.1976
Wawa                  3      327.9445        12.8564      11.4601    605.0117    25.4090             1.4552
Whataburger           3      434.8670        18.6071      13.5658    691.8955    30.3362             1.6897
White Castle          3      378.2370        13.7935       8.1544    379.6129    46.0859             1.3448
```

Fig. 9. Group 1 from clustering: Restaurants to avoid.

From the 3-d cube, we also find that Applebee's indeed have reduced their unhealthy nutrients over the years. With the same clustering model, we have located the group for Applebee's. Fig. 10 displays a list of restaurants with similar nutrient patterns as in Applebee's.



```
                            Types  AVG(calories)  AVG(total_fat)  AVG(Protein)  AVG(sodium)  AVG(sugar)  AVG(dietary_Fiber)
r_name
NaN                             0       459.4577         24.4788       17.7381     845.6825     18.2593              2.3239
Applebee's                      0       535.8140         29.0960       23.8558    1262.2796     19.2851              3.3980
BJ's Restaurant & Brewhouse     0       488.9209         22.6404       18.6297    1002.3109     14.1138              3.1049
Bonefish Grill                  0       445.8686         26.3080       23.7449     867.4768      9.6942              3.0023
California Pizza Kitchen        0       550.7461         22.8102       18.7803     780.5334     13.7242              4.0460
Carl's Jr.                      0       455.2334         24.1069       17.7208     872.0063     16.0521              2.4034
Carrabba's Italian Grill        0       540.9292         29.4325       27.1574    1176.5037      8.9181              6.3316
Checker's Drive-In/Rallys       0       565.7641         26.8247       28.2008    1246.5229     32.2480              2.3455
Chili's                         0       560.4523         31.4662       24.8794    1380.7838     12.2538              3.5240
Del Taco                        0       427.9030         19.7764       16.0883     787.1680     17.3592              3.7621
Denny's                         0       466.8052         24.3677       19.4258     974.7025     14.7853              2.6639
Friendly's                      0       532.6335         26.2782       16.4836     823.5714     24.9517              2.2099
Hardee's                        0       408.7226         21.0490       15.4217     900.1518     15.0945              2.1629
IHOP                            0       524.3899         28.3318       20.1964    1042.0655     18.2119              3.0185
Jason's Deli                    0       511.1826         27.3693       25.7436    1165.6545     10.8429              4.4280
Jersey Mike's Subs              0       574.1110         26.5068       32.3962    1671.8651      9.3339              4.4195
LongHorn Steakhouse             0       431.3268         22.6560       25.5308     783.1325     11.4371              1.8379
McAlister's Deli                0       384.2238         17.7285       16.2064     954.1388      8.9572              3.7433
Noodles & Company               0       436.1173         20.0838       16.5251     922.3045     10.5114              2.8600
Olive Garden                    0       423.2257         17.9719       19.2368     699.1405     15.5257              3.3487
Outback Steakhouse              0       534.4170         33.3252       34.3965    1022.7305      9.9900              3.1252
Perkins                         0       509.5529         26.2869       15.8987     906.1914     19.0613              2.2936
PF Chang's                      0       529.0462         22.3746       26.2289    1542.6432     24.4016              4.0592
Quiznos                         0       403.4264         38.9949       29.5047    1117.7274      6.3954              2.3553
Red Robin                       0       515.6705         23.9758       16.1816     803.5196     28.9303              2.6926
Ruby Tuesday                    0       501.7967         27.3628       24.8744    1079.6934      7.9091              2.9740
TGI Friday's                    0       545.5464         27.6834       22.4653    1239.0578     24.2707              2.9801
The Capital Grille              0       521.4688         30.0893       29.6514     752.1726     11.7125              2.6314
Zaxby's                         0       435.8547         29.8580       21.9276     971.5600     14.0769              2.4705
```

Fig. 10. Group 0 from clustering: Restaurants to dine in.

F. Correlation

Fig. 11 is the heatmap for the correlation of average nutrition attributes grouped by the restaurant, category, and year. The result from the data warehouse is already included year, restaurant, and food category variances. From the correlation heatmap, calories and total fat have the highest correlation which is 0.93. Protein, carbohydrates, sodium, cholesterol, and trans fat all have a relatively strong correlation with calories between the range of 0.61 to 0.75.

With beverage items included, there is no correlation between sugar and other nutrients except for carbohydrates. One of the reasons for the low correlation between sugar and calories is that the weight of the beverage category is small while beverages have the highest amount of sugar in any given category. We will discuss the relationship of correlation and the implication on other results later in the discussion.

IV. Discussion

A. Trends in Nutrition Composition

To answer the question of whether or not restaurants made their menu items healthier, we need to find trends in nutrition composition. We were not able to determine the trend of average calories, the average amount of carbohydrates, and the average amount of dietary fibers through the line plot for the average nutritional composition for all categories from 2013 to 2018. However, Fig. 5 showed an upward trend for the average protein content in all categories. This is a sign that chain restaurants made their items more nutritious by increasing the amount of protein (meat) in their food.

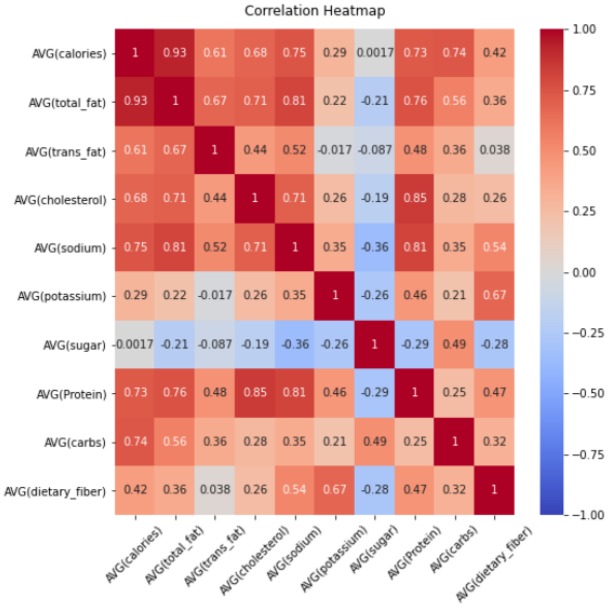


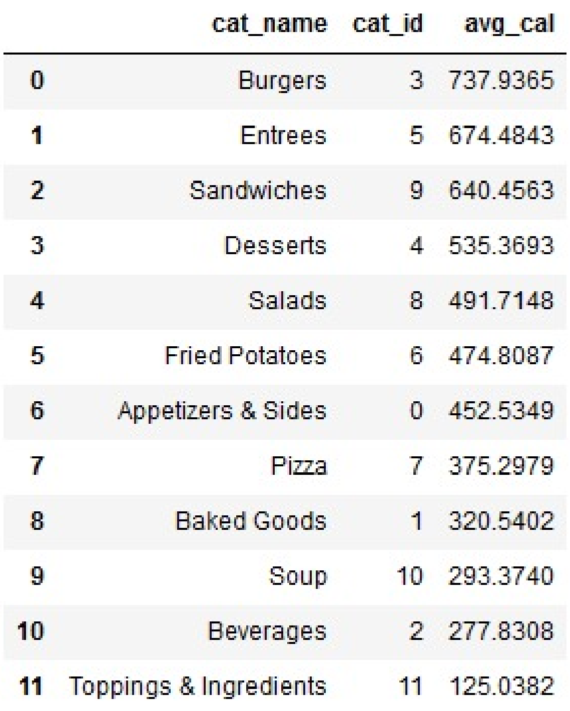
Fig. 11. Correlation heatmap for nutrient features grouped by year, restaurant, and food category.

Having more protein can better satisfy people's daily protein requirements. To consider a trend of healthier food in the industry, we need to check that calories and fat/cholesterol were maintained at the same level over the years. Based on Fig. 6 and Fig. 7, with a simple linear regression line drawn in each time vs average nutrition scatter plot by food category, the trend becomes distinguishable. Six main categories have an identifiable upward trend in the average category while the regression line for the remaining calories was flat. The same pattern also appeared in Fig. 7 which is showing trends for the average cholesterol in all categories.

The correlation heatmap showed a strong positive correlation between protein, calories, total fat, cholesterol, and sodium. This further suggested the theory of increasing protein content doesn't make the food healthier. One explanation for this result might be that the protein source is not clean enough (the proportion of fat in meat is high). To combine the findings in the Methods Sec. III-C and III-F, we can say that there isn't a clear trend of chain restaurants making their food healthier. While they might be increasing the content of proteins and other nutrients in their food, the proportion of unhealthy nutrients such as cholesterol and trans fat also increased. Resulting in the overall calories increase over the years.

B. Unhealthy Categories

The reason behind this question is what people should avoid. Sometimes people order foods that have lower rates of calories and they think by ordering low-calorie foods they stay healthy and not gaining weight, but we can show from our data that this belief is not right all the time. First, we started to explore the data to find out what category of foods has higher average calories. In the table below we can see “Burgers” have higher average calories than any other categories.



	cat_name	cat_id	avg_cal
0	Burgers	3	737.9365
1	Entrees	5	674.4843
2	Sandwiches	9	640.4563
3	Desserts	4	535.3693
4	Salads	8	491.7148
5	Fried Potatoes	6	474.8087
6	Appetizers & Sides	0	452.5349
7	Pizza	7	375.2979
8	Baked Goods	1	320.5402
9	Soup	10	293.3740
10	Beverages	2	277.8308
11	Toppings & Ingredients	11	125.0382

Fig. 12. Result of the query which shows average calorie per food category.

C. *Unhealthy Restaurants(Filtering and Clustering)*

The question that comes to mind immediately is what chain restaurants have high-calorie burgers so people can avoid ordering burgers from these restaurants. The chart below shows 10 restaurants that have average high-calorie burgers.

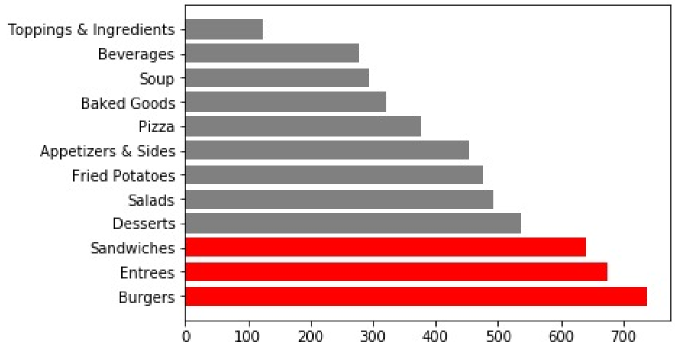
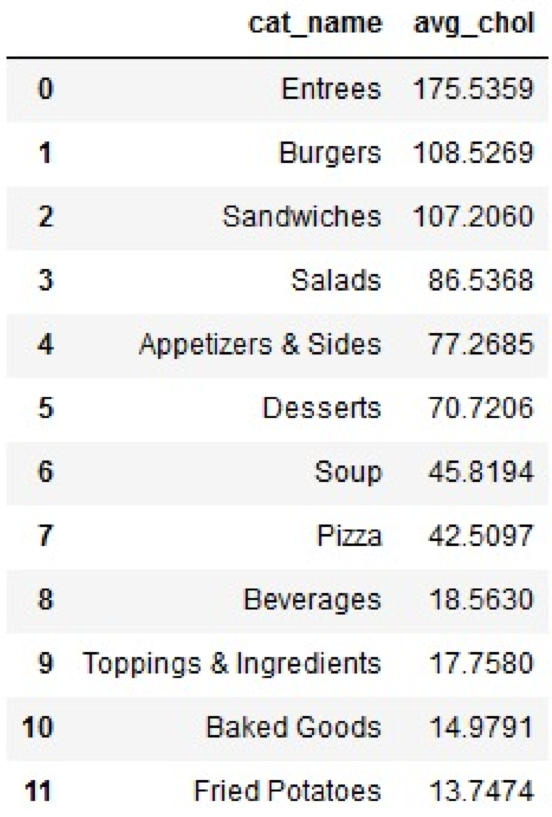


Fig. 13. Result of the query which shows 10 restaurants that have higher-calorie burgers.

The next unhealthy factor is high cholesterol in meals. The table below shows the average cholesterol in each food category.



	cat_name	avg_chol
0	Entrees	175.5359
1	Burgers	108.5269
2	Sandwiches	107.2060
3	Salads	86.5368
4	Appetizers & Sides	77.2685
5	Desserts	70.7206
6	Soup	45.8194
7	Pizza	42.5097
8	Beverages	18.5630
9	Toppings & Ingredients	17.7580
10	Baked Goods	14.9791
11	Fried Potatoes	13.7474

Fig. 14. Result of the query which shows entrees have the highest average cholesterol.

In the next step, we go through the restaurants that have higher cholesterol in their entrees. The diagram below is a result of the query which is designed to answer this question.

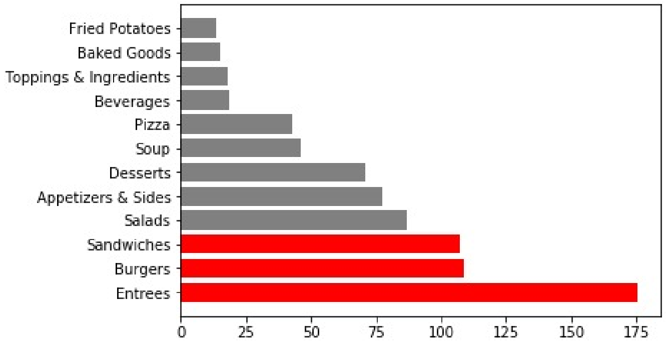
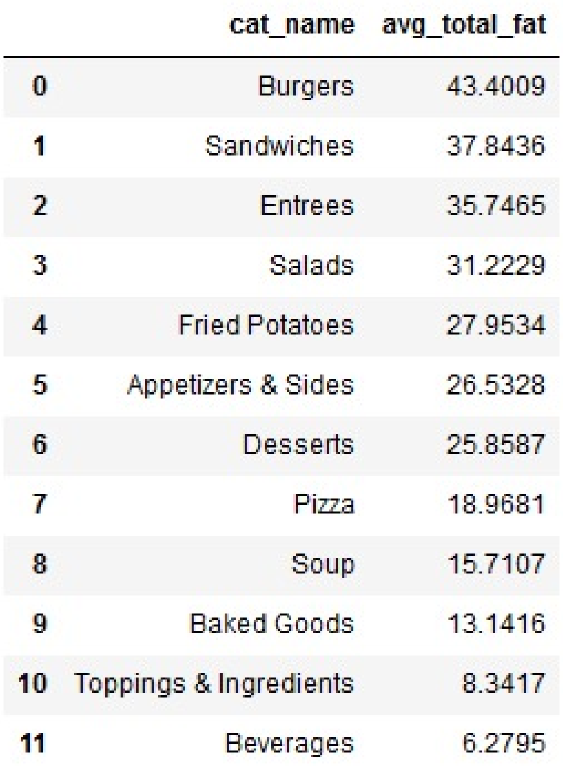


Fig. 15. Result of the query which shows 10 top restaurants that have higher cholesterol in their entrees.

For the next unhealthy option, we explored the data through the sodium column in our database. The average daily sodium intake according to the FDA is 2300 mg. But some restaurants will give people high sodium rates more than the suggested amount. The table below shows the average sodium in milligrams each food category has.



	cat_name	avg_total_fat
0	Burgers	43.4009
1	Sandwiches	37.8436
2	Entrees	35.7465
3	Salads	31.2229
4	Fried Potatoes	27.9534
5	Appetizers & Sides	26.5328
6	Desserts	25.8587
7	Pizza	18.9681
8	Soup	15.7107
9	Baked Goods	13.1416
10	Toppings & Ingredients	8.3417
11	Beverages	6.2795

Fig. 16. Result of the query which shows sandwiches have the highest average sodium.

Let's see what restaurants have the highest average sodium in their sandwiches in the diagram below.

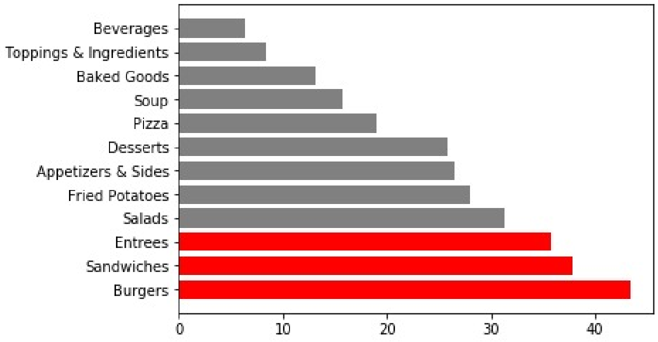


Fig. 17. Result of the query which shows 10 top restaurants that have higher sodium in their sandwiches.

D. Unhealthy and Healthy Restaurants(Filtering and Clustering)

Not all fats are created equal, as some foods such as olive oil, nuts, and fish contain good fats. However, trans fats are known to be artery-clogging, and so are bad for people who are suffering from heart diseases. We are interested to know which restaurants should be avoided by people who have/are prone to heart problems. We want to view the restaurants that have the highest trans_fat/fat ratio. And we find that Long John Silver's and Arby's are the worst in the trans_fat/fat ratio. Similarly, we would like to look at restaurants that should be avoided by those who have type 2 diabetes. We do this by examining restaurants that have the highest sugar/calories ratio. Interestingly, we find that two of the five worst restaurants are beverage stores: Jamba Juice and Starbucks. And Long John Silver's is still one of the five worst restaurants in high sugar levels. Now we are interested in restaurants that, on average, offer food with high amounts of fiber. Fiber is known to have the opposite effects of trans fats and sugar. It lowers blood sugars and lowers cholesterol levels. Long John Silver's is still one of the worst five.

Overall, it seems like Long John Silver's is the worst restaurant to eat at, especially for a person struggling with type 2 diabetes as well as heart problems. Their food doesn't seem to be nutritious (low fiber). In this analysis, we note that Long John Silver's is consistently the least nutritious for you.

With Long John Silver's satisfied the criteria for the worst restaurant, we classified restaurants with similar nutritional patterns as shown in Fig. 9. They are the restaurants that people should avoid. Although we determined that there isn't a trend of chain restaurants making their food healthier, there are still restaurants that have signs of making their food healthier such as Applebee's. In Fig. 10, we also provided a list of restaurants that have a similar pattern with Applebee's and they are the restaurants we recommend.

V. Lession Learned

A. The Effect of Null Values and Aggregation

Null values can have a huge impact on the aggregate results we obtained. In Fig. 3, the average calories decreased 55% in 2018 for 7-Eleven. In this case, the aggregate data is misleading in the interpretation of the result. When we drilled down one level in the 3-d cube structure representation in Fig. 4, we discovered that the reason for the 55% average calories decrease in 2018 for 7-Eleven is because 6 out of 8 food categories were missing in the data. We couldn't conclude that the trend for calories was decreasing because either 7-Eleven stopped selling these categories or the data collector failed to collect data for these categories.

The lesson we learned from this is that we have to be very careful in dealing with NA values. NA values can be dropped while the data is big enough. For aggregate data generated from only one dimension, e.g. Restaurants, there needs to be an exploration in the other dimensions to make sure the data in the later years are consistent. Also, examining 3-dimensional data cubes can be helpful in finding the root cause for missing values. To decide what to do with missing values, we have to drill down to see it in a finer grind level in order to determine what happened.

VI. Conclusion

The population who consumes food regularly from chain-restaurants is still growing. Our analysis suggests that, in aggregate, chain-restaurants are not making their menu items healthier. Despite the fact that restaurants were trying to make their meals and items more nutritious, the accompanying increment in cholesterol, calories, total fat, and sodium didn't make their food any healthier. Regardless, it is still possible to avoid the worst food categories to choose in specific restaurants and we have provided a list of relatively healthier restaurants. More data is needed in order to analyze the latest trends in chain-restaurants' menu items nutrition. Furthermore, while the aggregate data didn't show any healthier trends, there can be more in depth research to investigate the nutrition facts in newly introduced items in later years.

References

[1] https://github.com/TaoliZhen/DATA225Project.

[2] https://www.youtube.com/watch?v=p3vSs-9zXhAt=1sab$_{c}hannel = horacezhen$.

[3] Eating out for lots of meals increases your risk of heart disease or stroke. https://www.insider.com/what-dining-out-does-to-your-body-2018-6eating-out-for-lots-of-meals-increases-your-risk-of-heart-disease-or-stroke-3.

[4] Hybrid warehouse model and solutions for climate data analysis. https://www.scirp.org/journal/paperinformation.aspx?paperid=103821.

[5] Mariadb enterprise documentation. https://mariadb.com/docs/.

[6] Mariadb hybrid transactional-analytical processing. https://mariadb.com/docs/multi-node/htap/.

[7] Mariadb vs mysql, a database technologies rundown. https://kinsta.com/blog/mariadb-vs-mysql/.

[8] Menustat. http://www.menustat.org/.

[9] Alvin Tran, Alyssa Moran, and Sara N Bleich. Calorie changes among food items sold in us convenience stores and pizza restaurant chains from 2013 to 2017. *Preventive medicine reports*, 15:100932, 2019.

Appendices

Presentation Skills, includes time management: Will demonstrate in the project presentation

Significance to the real world: In Sec. I "Introduction" of this report, we emphasized the significance of dining out for people who are living in the cities. According to the report from an insider news webpage [3], dining out may increase your amount of food intake, raise sodium and cholesterol levels, increase the risk of heart disease, and in some cases increases weight gaining. But, we found ways to eat more healthy and avoid unhealthy foods to decrease the risks of dining out for our bodies.

Code Walkthrough

Will demonstrate in the project presentation

Report

This report is the proof.

Version Control:

Our Github page is a great proof of this, it can be found on this [1].

Discussion / Q&A

We have a discussion section in this report, and we will reserve time for QA at the end of the presentation.

Lessons learned:

Can be found in Sec. V of this report.

Innovation:

Implemented the significant paper in our project. Explanation of the implementation can be found in Sec. II-C and Sec. II-D of this report and the paper can be found in [4]. The significant paper helped us to use Hybrid Transactional-Analytical Processing. The coding details about the transformation to this method can be found in the project [1].

Teamwork: In this project every member had specific jobs to do, starting from the project we had meetings to distribute the work and make decisions on how to move forward with the project. Every member of the group worked on the code part from extracting the data, cleansing, and loading to the database to analyze the data. Afterward, each member worked on a specific part from preparing the documents and writings to making the slides and videos.

Technical difficulty

We used a new database and implemented a hybrid database/data warehouse design in our project.

Practiced pair programming

The link to our github page can be found here.

Practiced agile / scrum (1-week sprints)

Group chat history and meeting links and records are in [1]. Used Grammarly / other tools for language?: We used grammarly and google docs language tools to check for several types of errors.

Elevator pitch video

A youtube video is uploaded [2]

Slides

Demo

Will demo the connection to the cloud server and the python function used to access the query results.

Used unique tools

Jupyter Notebook, Cloud database and data warehouse, row store and column store techniques Hybrid Transactional-Analytical Processing), K-mean clustering.

Performed substantial analysis using database techniques:

Used aggregate functions, filtering and Rollup functions to analyze the data.

Used a new database or data warehouse tool not covered in the HW or class:

MariaDB is an open-source database used in our project. HTAP platform, row-store for writes, and column-store for analytics. Used appropriate data models: Can be found in Sec. II-A of this report. Also, accessible from this [1]. Used ETL tool: We didn't use ETL tools, we did the ETL process in our Jupyter Notebook that should be found in our Github.

Data Cleansing:

The explanation of the work can be found in Sec. II-A of this report. Also, the step by step coding of cleansing the data is accessible from [1]. Demonstrated how Analytic support business decisions: Our data warehouse platform supports real-time data monitoring and analysis. Anyone who wants to enter the chain-restaurant market can use our data warehouse and analysis to target customer pain points by providing healthy food, and showing what nutrients rivals currently provide.

Used NOSQL database:

We didn't use NOSQL in our project.

Used RDBMS:

Our row store MariaDB database is evidence to this section. To prove the usage of RDBMS can be found in [1]. Used Data Warehouse: Our star schema of data modeling shows the usage of data warehouses in our project. Evidence of such can be found in Sec. II "Methods and Implementation". Also, MariaDB roll up syntax example queries can be found in [1] to the Jupyter Notebook of the project.

DB Connectivity / API calls:

Examples of connection to the MariaDB database can be found in Jupyter Notebook [1]. There is a certificate needed to connect to the database under the name of "skysql_chain.pem" in the main repository[1].