EECS E6893 Big Data Analytics
HW1: Clustering, Classification, and Spark MLlib

Hritik Jain, hj2533@columbia.edu

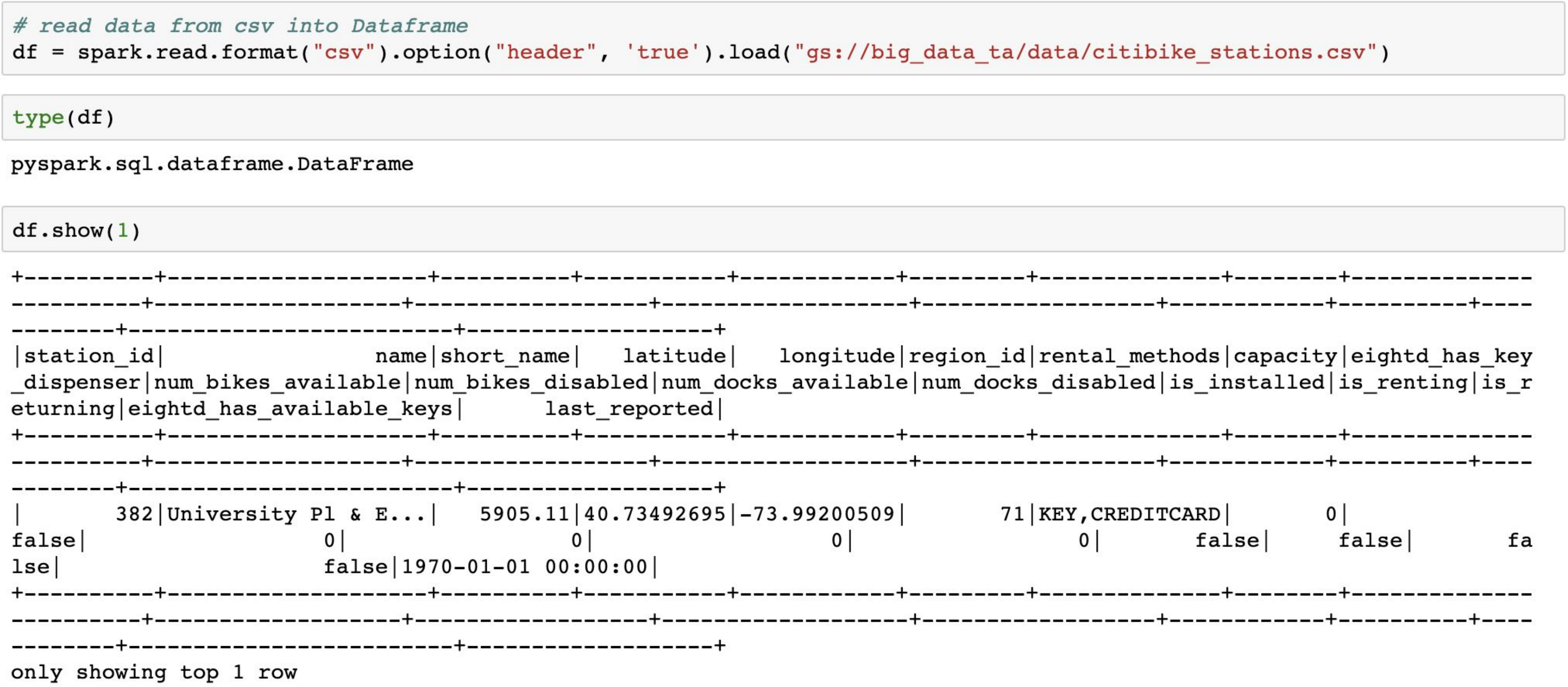
Agenda

- Spark Dataframe
- Spark SQL
- Spark MLlib
- HW1
    - Iterative K-means clustering
    - Logistic Regression

Spark Dataframe

- An *abstraction*, an immutable distributed collection of data like RDD
- Data is organized into named columns, like a table in DB
- Create from RDD, Hive table, or other data sources
- Easy conversion to and from Pandas Dataframe

Spark Dataframe: read from csv file



```
# read data from csv into Dataframe
df = spark.read.format("csv").option("header", 'true').load("gs://big_data_ta/data/citibike_stations.csv")
```

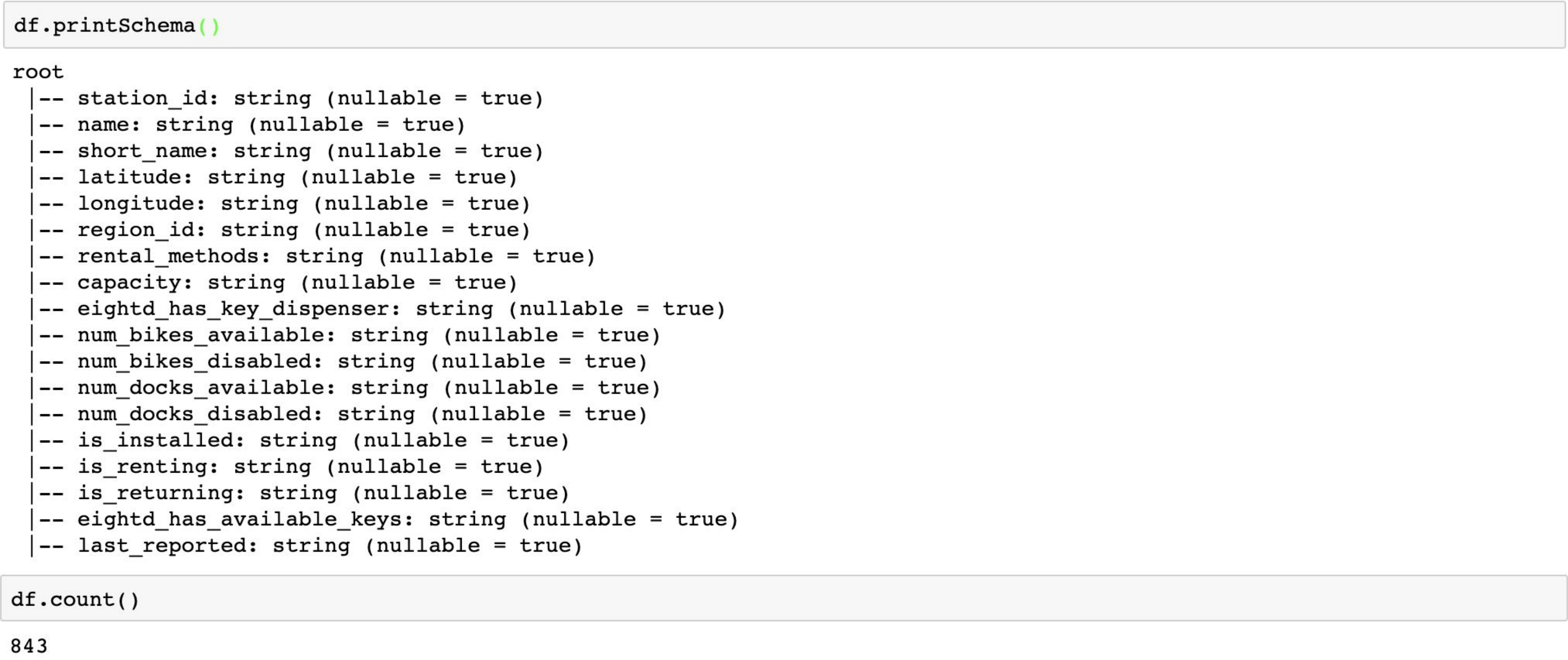
```
type(df)
```

```
pyspark.sql.dataframe.DataFrame
```

```
df.show(1)
```

```
+----------+--------------------+----------+-----------+------------+---------+--------------+--------+--------------
----------+-------------------+------------------+-------------------+------------------+------------+----------+----
--------+-------------------------+-------------------+
|station_id|                name|short_name|   latitude|   longitude|region_id|rental_methods|capacity|eightd_has_key
_dispenser|num_bikes_available|num_bikes_disabled|num_docks_available|num_docks_disabled|is_installed|is_renting|is_r
eturning|eightd_has_available_keys|      last_reported|
+----------+--------------------+----------+-----------+------------+---------+--------------+--------+--------------
----------+-------------------+------------------+-------------------+------------------+------------+----------+----
--------+-------------------------+-------------------+
|       382|University Pl & E...|   5905.11|40.73492695|-73.99200509|       71|KEY,CREDITCARD|       0|
false|                  0|                 0|                  0|                 0|       false|     false|       fa
lse|                    false|1970-01-01 00:00:00|
+----------+--------------------+----------+-----------+------------+---------+--------------+--------+--------------
----------+-------------------+------------------+-------------------+------------------+------------+----------+----
--------+-------------------------+-------------------+
only showing top 1 row
```

Spark Dataframe: common operations



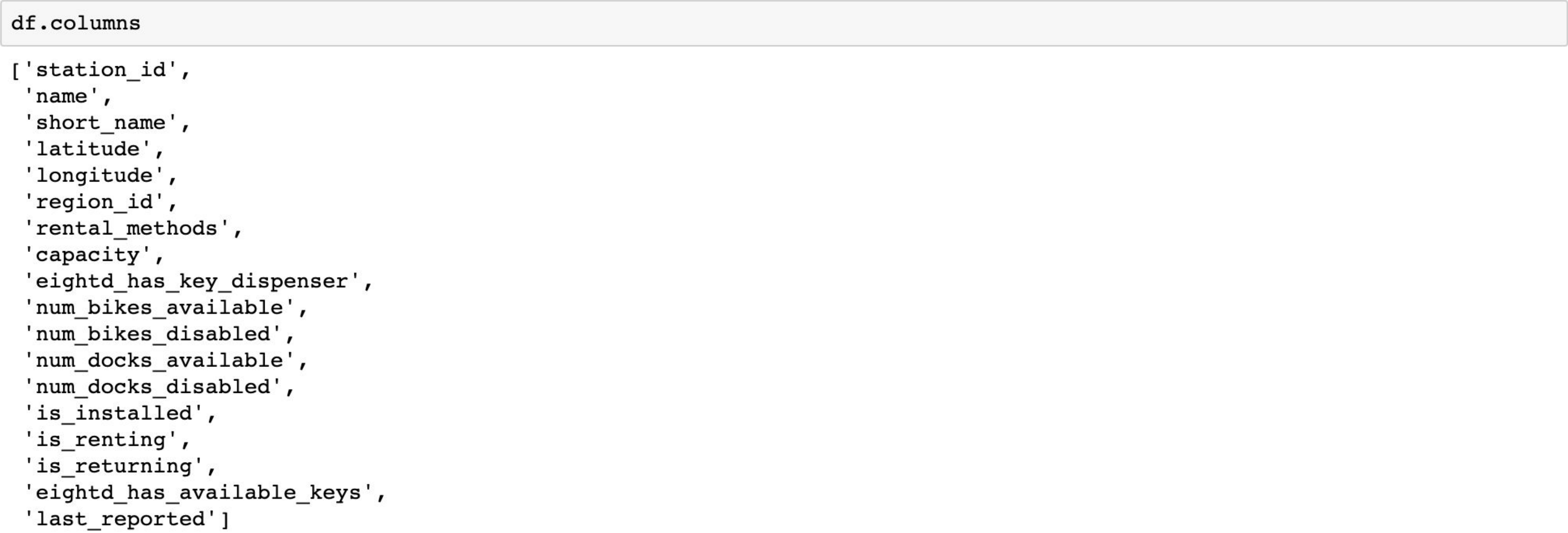
```
df.printSchema()
```

```
root
 |-- station_id: string (nullable = true)
 |-- name: string (nullable = true)
 |-- short_name: string (nullable = true)
 |-- latitude: string (nullable = true)
 |-- longitude: string (nullable = true)
 |-- region_id: string (nullable = true)
 |-- rental_methods: string (nullable = true)
 |-- capacity: string (nullable = true)
 |-- eightd_has_key_dispenser: string (nullable = true)
 |-- num_bikes_available: string (nullable = true)
 |-- num_bikes_disabled: string (nullable = true)
 |-- num_docks_available: string (nullable = true)
 |-- num_docks_disabled: string (nullable = true)
 |-- is_installed: string (nullable = true)
 |-- is_renting: string (nullable = true)
 |-- is_returning: string (nullable = true)
 |-- eightd_has_available_keys: string (nullable = true)
 |-- last_reported: string (nullable = true)
```

```
df.count()
```

```
843
```

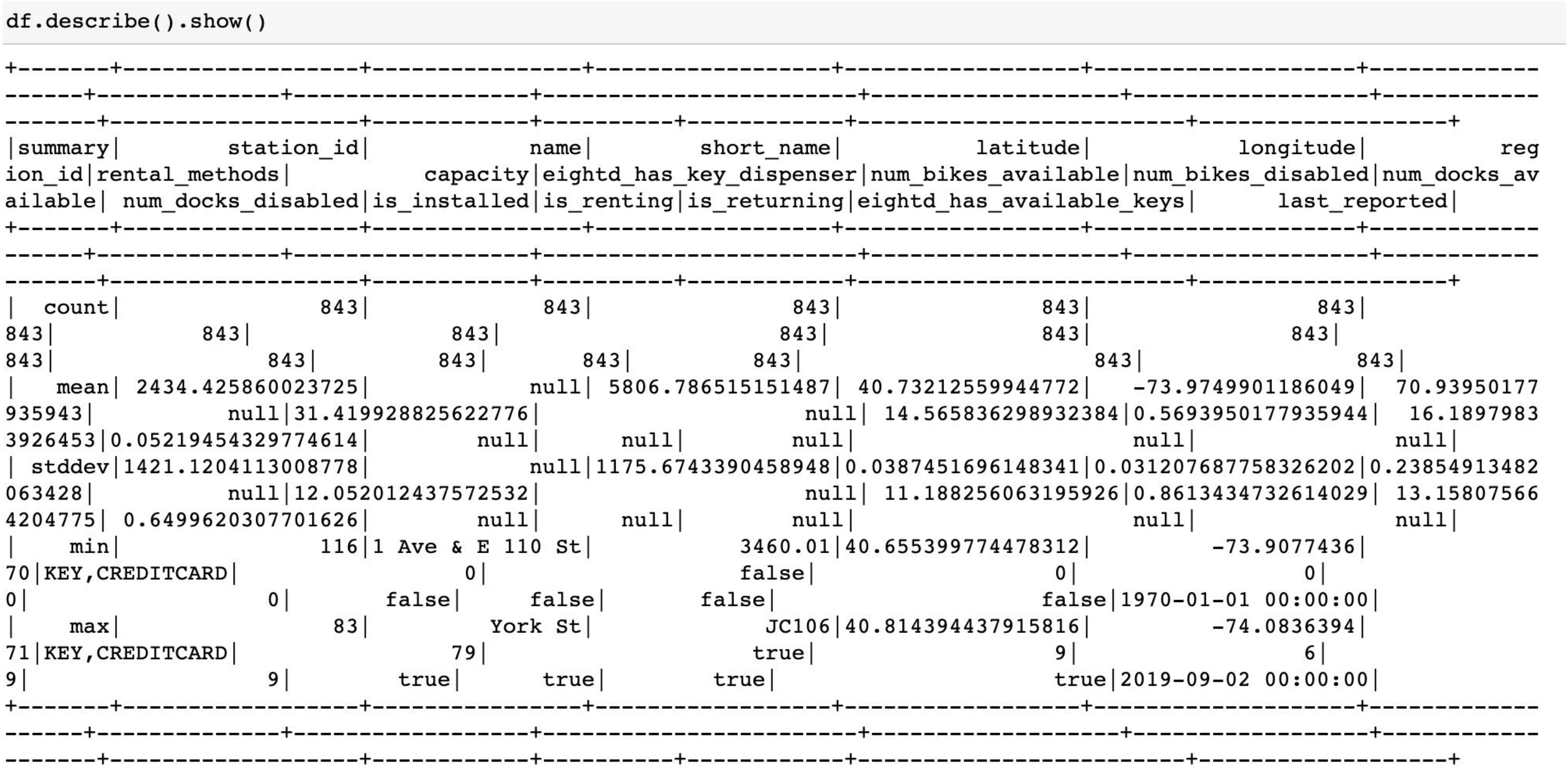
Spark Dataframe: common operations



```
df.columns
```

```
['station_id',
 'name',
 'short_name',
 'latitude',
 'longitude',
 'region_id',
 'rental_methods',
 'capacity',
 'eightd_has_key_dispenser',
 'num_bikes_available',
 'num_bikes_disabled',
 'num_docks_available',
 'num_docks_disabled',
 'is_installed',
 'is_renting',
 'is_returning',
 'eightd_has_available_keys',
 'last_reported']
```

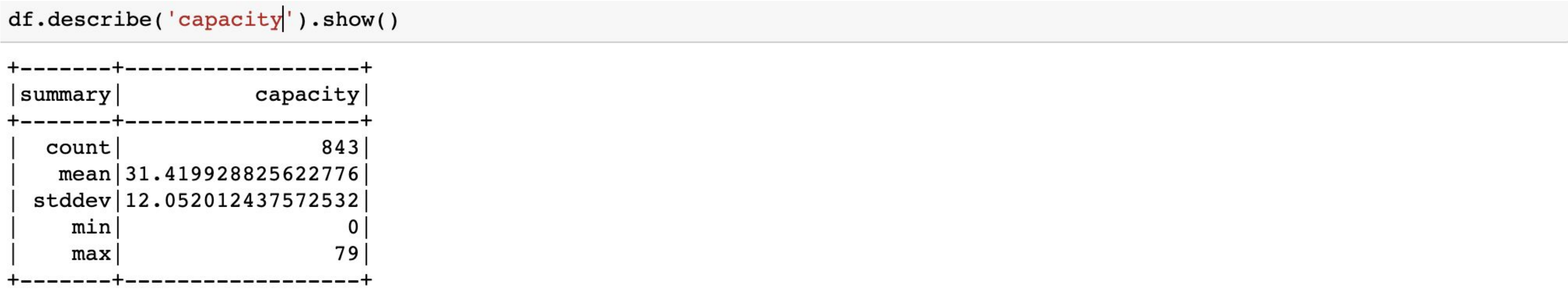
Spark Dataframe: common operations



```
df.describe().show()
```

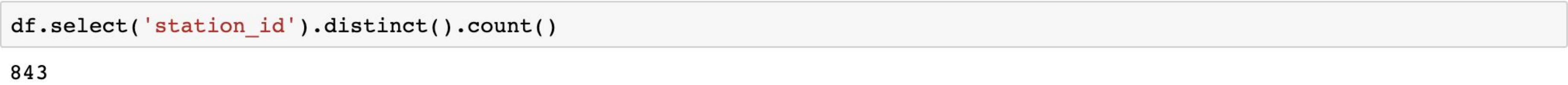
```
+-------+------------------+----------------+------------------+------------------+--------------------+-------------
------+--------------+------------------+------------------------+-------------------+------------------+------------
-------+-------------------+------------+----------+------------+-------------------------+-------------------+
|summary|        station_id|            name|        short_name|          latitude|           longitude|          reg
ion_id|rental_methods|          capacity|eightd_has_key_dispenser|num_bikes_available|num_bikes_disabled|num_docks_av
ailable| num_docks_disabled|is_installed|is_renting|is_returning|eightd_has_available_keys|      last_reported|
+-------+------------------+----------------+------------------+------------------+--------------------+-------------
------+--------------+------------------+------------------------+-------------------+------------------+------------
-------+-------------------+------------+----------+------------+-------------------------+-------------------+
|  count|               843|             843|               843|               843|                 843|
843|           843|               843|                     843|                843|               843|
843|                843|         843|       843|         843|                      843|                843|
|   mean| 2434.425860023725|            null| 5806.786515151487| 40.73212559944772|   -73.9749901186049|  70.93950177
935943|          null|31.419928825622776|                    null| 14.565836298932384|0.5693950177935944|  16.1897983
3926453|0.05219454329774614|        null|      null|        null|                     null|               null|
| stddev|1421.1204113008778|            null|1175.6743390458948|0.0387451696148341|0.031207687758326202|0.23854913482
063428|          null|12.052012437572532|                    null| 11.188256063195926|0.8613434732614029| 13.15807566
4204775| 0.6499620307701626|        null|      null|        null|                     null|               null|
|    min|               116|1 Ave & E 110 St|           3460.01|40.655399774478312|         -73.9077436|
70|KEY,CREDITCARD|                 0|                   false|                  0|                 0|
0|                  0|       false|     false|       false|                    false|1970-01-01 00:00:00|
|    max|                83|         York St|             JC106|40.814394437915816|         -74.0836394|
71|KEY,CREDITCARD|                79|                    true|                  9|                 6|
9|                  9|        true|      true|        true|                     true|2019-09-02 00:00:00|
+-------+------------------+----------------+------------------+------------------+--------------------+-------------
------+--------------+------------------+------------------------+-------------------+------------------+------------
-------+-------------------+------------+----------+------------+-------------------------+-------------------+
```

Spark Dataframe: common operations



```
df.describe('capacity').show()
```

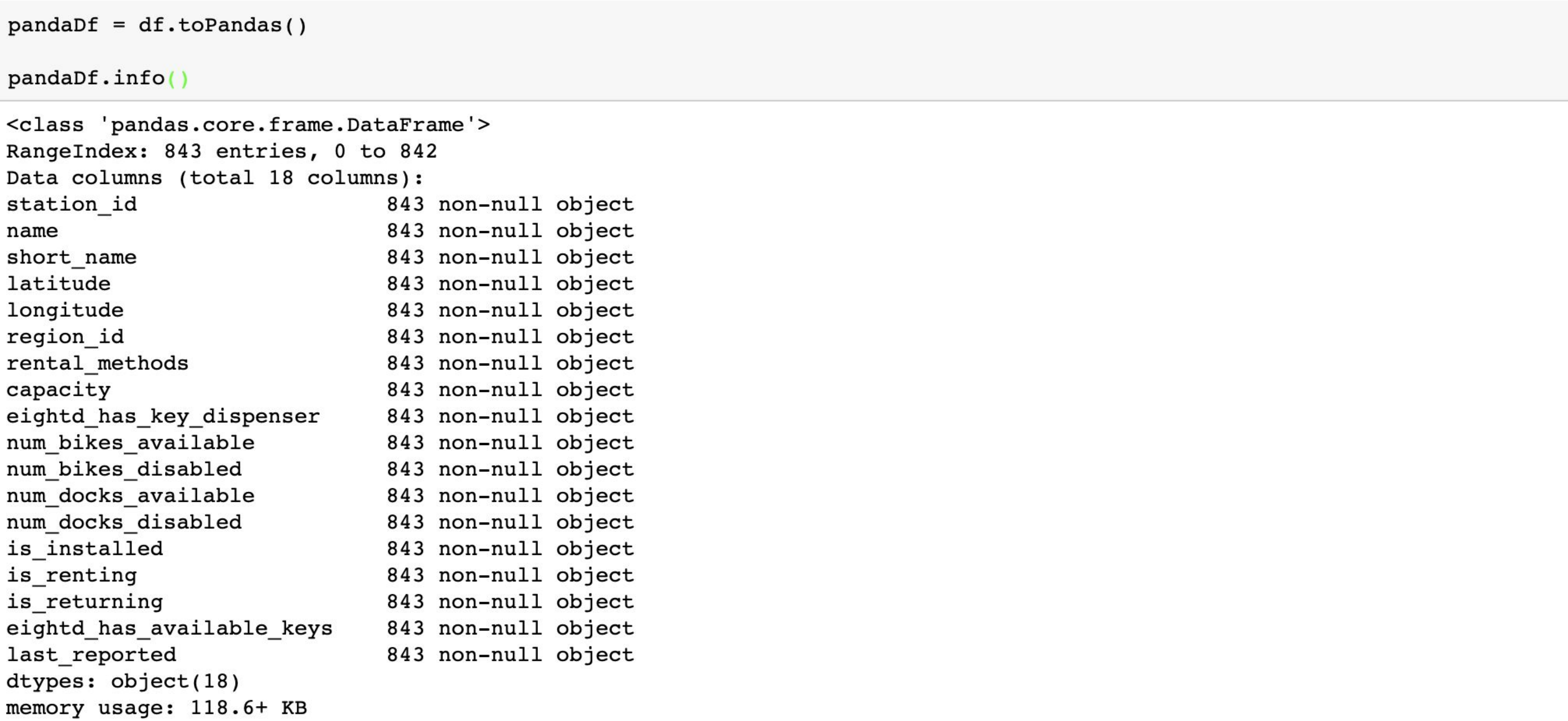
```
+-------+------------------+
|summary|          capacity|
+-------+------------------+
|  count|               843|
|   mean|31.419928825622776|
| stddev|12.052012437572532|
|    min|                 0|
|    max|                79|
+-------+------------------+
```



```
df.select('station_id').distinct().count()
```

```
843
```

Conversion to a Pandas dataframe

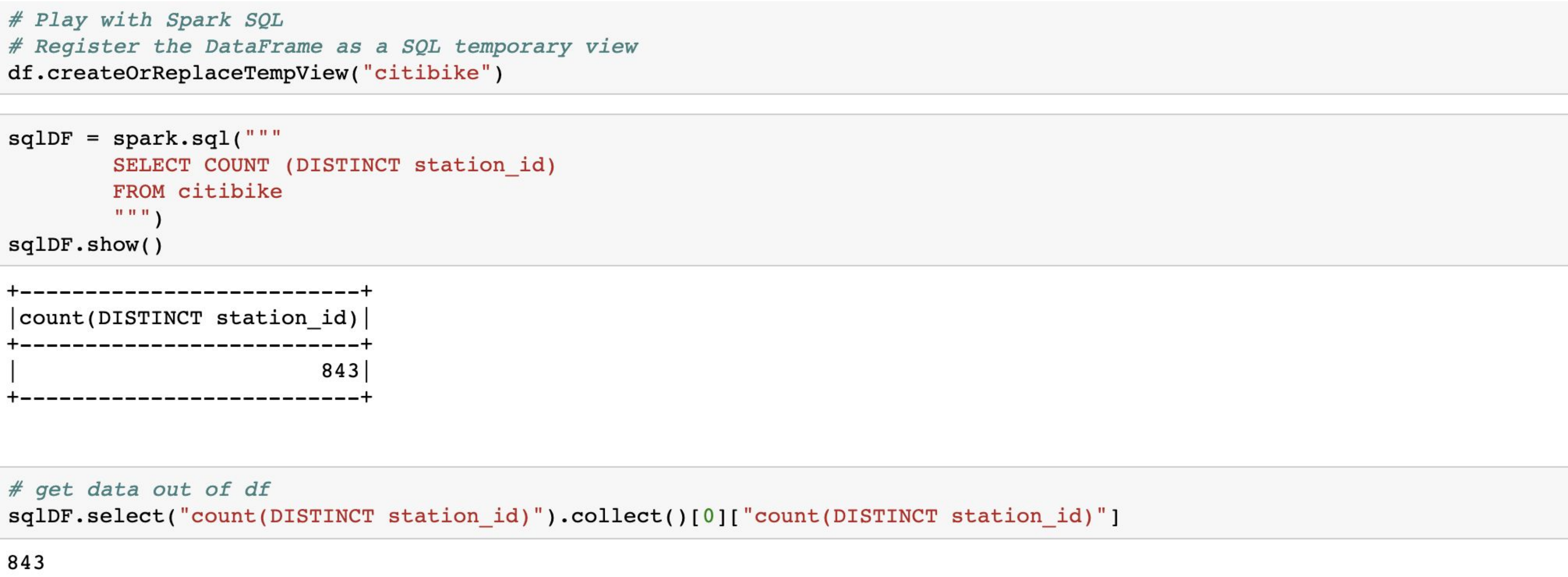


```
pandaDf = df.toPandas()

pandaDf.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 843 entries, 0 to 842
Data columns (total 18 columns):
station_id                     843 non-null object
name                           843 non-null object
short_name                     843 non-null object
latitude                       843 non-null object
longitude                      843 non-null object
region_id                      843 non-null object
rental_methods                 843 non-null object
capacity                       843 non-null object
eightd_has_key_dispenser       843 non-null object
num_bikes_available            843 non-null object
num_bikes_disabled             843 non-null object
num_docks_available            843 non-null object
num_docks_disabled             843 non-null object
is_installed                   843 non-null object
is_renting                     843 non-null object
is_returning                   843 non-null object
eightd_has_available_keys      843 non-null object
last_reported                  843 non-null object
dtypes: object(18)
memory usage: 118.6+ KB
```

Work with Spark SQL



```
# Play with Spark SQL
# Register the DataFrame as a SQL temporary view
df.createOrReplaceTempView("citibike")
```

```
sqlDF = spark.sql("""
        SELECT COUNT (DISTINCT station_id)
        FROM citibike
        """)
sqlDF.show()
```

```
+--------------------------+
|count(DISTINCT station_id)|
+--------------------------+
|                       843|
+--------------------------+
```

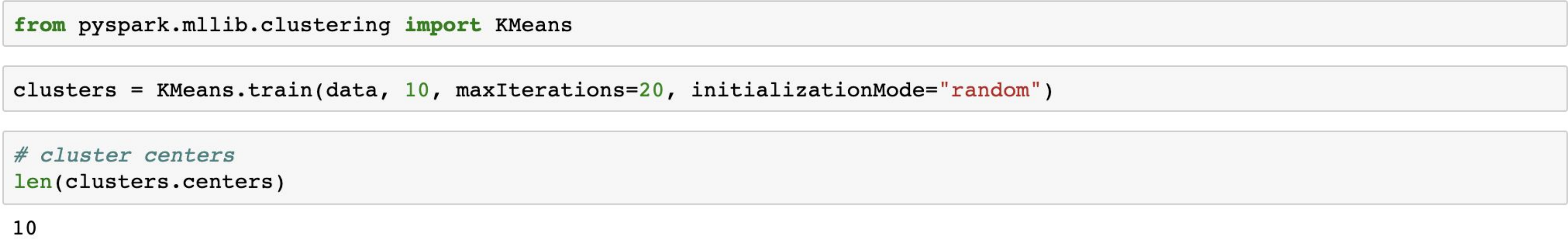
```
# get data out of df
sqlDF.select("count(DISTINCT station_id)").collect()[0]["count(DISTINCT station_id)"]
```

```
843
```

Spark MLlib

- Spark's scalable machine learning library
- Tools:
  - ML Algorithms: classification, regression, clustering, topic modeling, collaborative filtering
  - Feature transformations: normalization, hashing, dimensionality reduction (PCA, ...) etc.
  - Pipelines: tools for constructing, evaluating, and tuning ML Pipelines
  - Persistence: saving and load algorithms, models, and Pipelines
  - Utilities: linear algebra, statistics, data handling, etc.

Example: K-means clustering with Spark MLlib



```
from pyspark.mllib.clustering import KMeans
```

```
clusters = KMeans.train(data, 10, maxIterations=20, initializationMode="random")
```

```
# cluster centers
len(clusters.centers)
```

```
10
```

API Reference: https://spark.apache.org/docs/2.2.0/api/python/pyspark.mllib.html#pyspark.mllib.clustering.KMeans

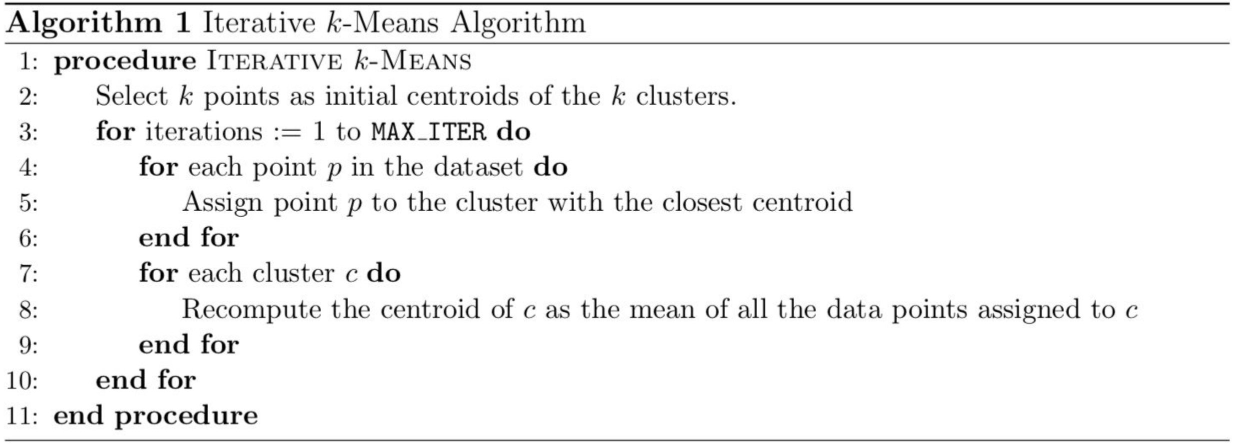
HW1

HW1

- Document clustering with K-means
    - “Implement” iterative K-means clustering in Spark
    - L1, L2 distance functions
    - Different initialization strategies
    - Plot the cluster assignment result with T-SNE dimensionality reduction
- Binary classification with Spark MLlib
    - Preprocess df with ML Pipeline
    - Logistic regression

Iterative K-means

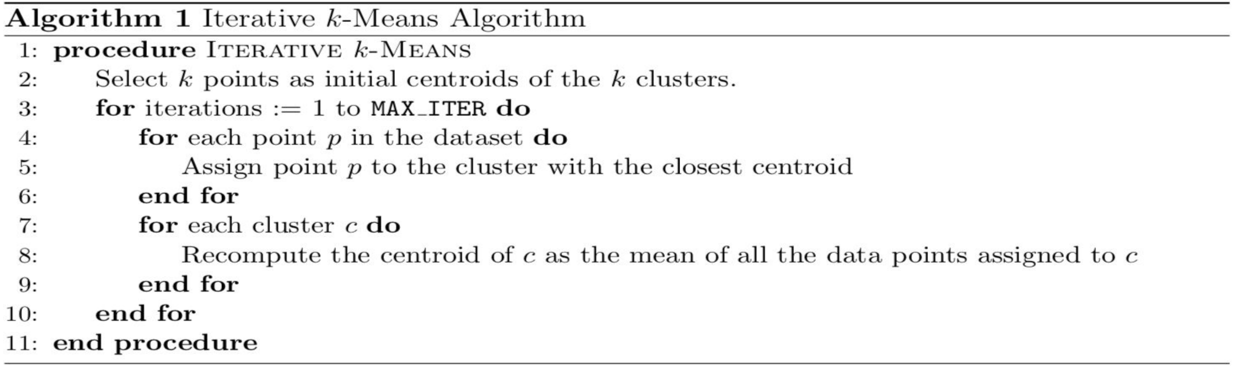
- In each iteration, k centroids are initialized, each point in the space is assigned to the nearest centroid, and the centroids are re-computed
- Pseudo code:



Algorithm 1 Iterative k-Means Algorithm

```
procedure ITERATIVE $k$-MEANS
    Select $k$ points as initial centroids of the $k$ clusters.
    for iterations := 1 to MAX_ITER do
        for each point $p$ in the dataset do
            Assign point $p$ to the cluster with the closest centroid
        end for
        for each cluster $c$ do
            Recompute the centroid of $c$ as the mean of all the data points assigned to $c$
        end for
    end for
end procedure
```

Iterative K-means in Spark



Algorithm 1 Iterative k-Means Algorithm

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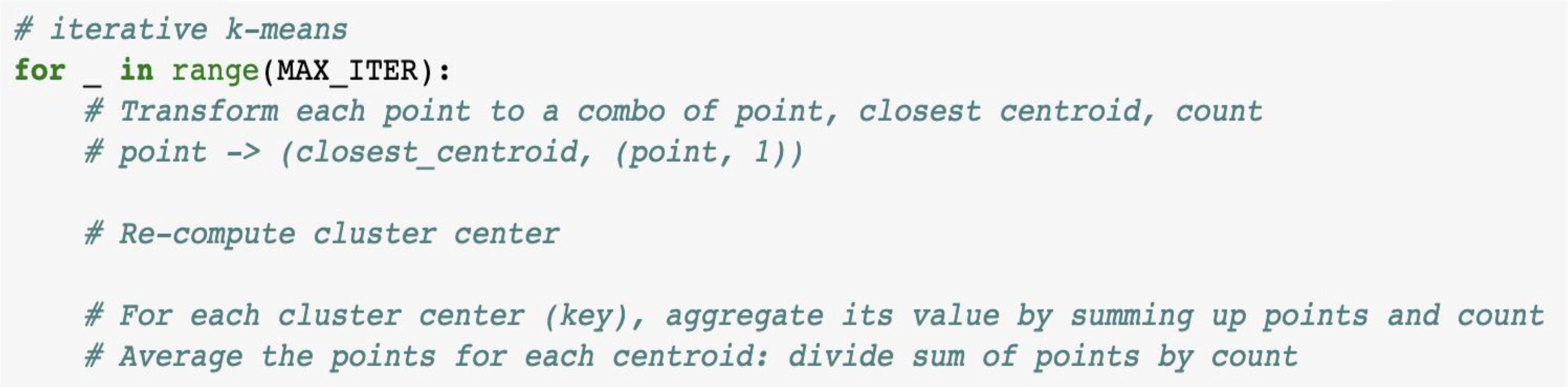
        end for
        for each cluster $c$ do
            Recompute the centroid of $c$ as the mean of all the data points assigned to $c$
        end for
    end for
end procedure
```



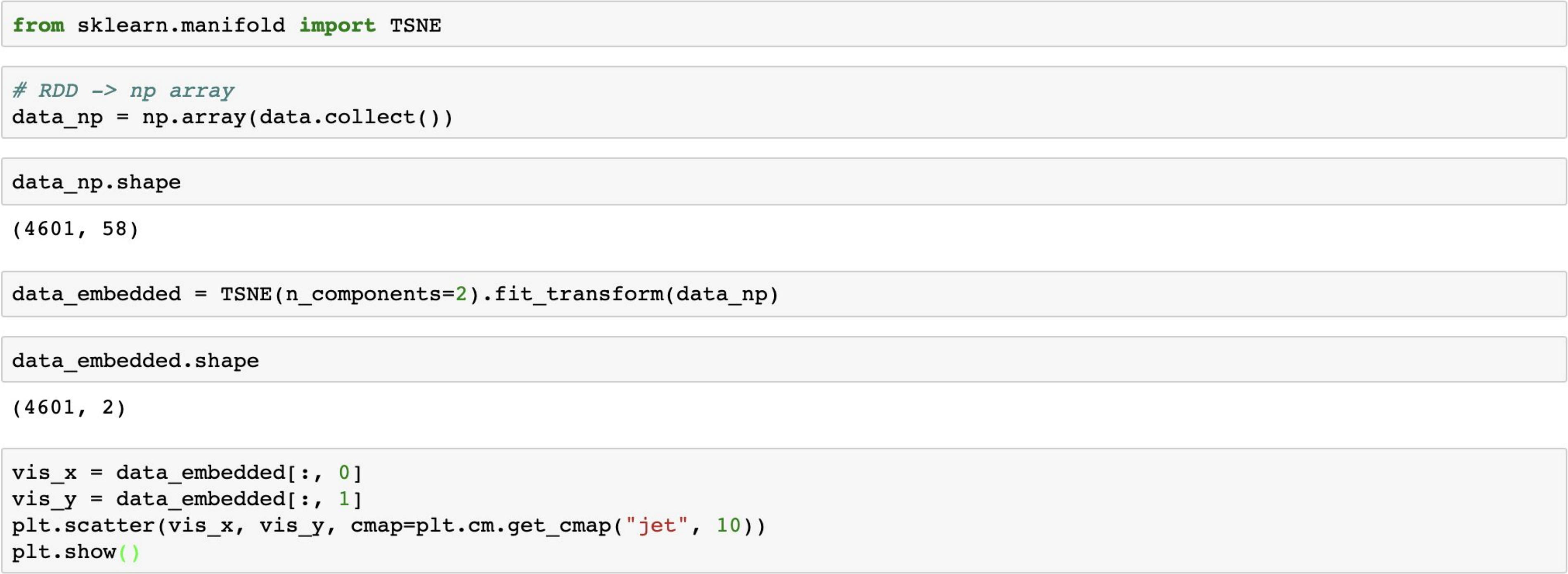
```python
# iterative k-means
for _ in range(MAX_ITER):
    # Transform each point to a combo of point, closest centroid, count
    # point -> (closest_centroid, (point, 1))

    # Re-compute cluster center

    # For each cluster center (key), aggregate its value by summing up points and count
    # Average the points for each centroid: divide sum of points by count
```

[Hint] Spark operations you might need: *map, reduceByKey, collect, keys*

Plot the result with t-SNE



```
from sklearn.manifold import TSNE
```

```
# RDD -> np array
data_np = np.array(data.collect())
```

```
data_np.shape
```

```
(4601, 58)
```

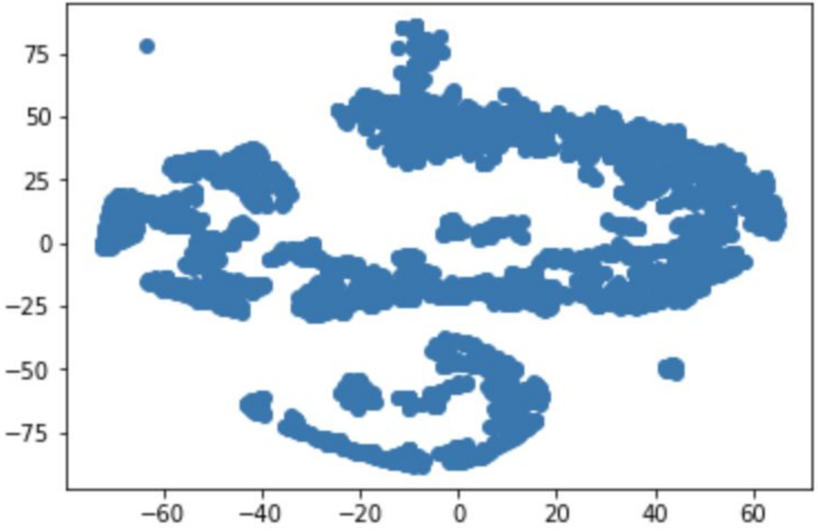
```
data_embedded = TSNE(n_components=2).fit_transform(data_np)
```

```
data_embedded.shape
```

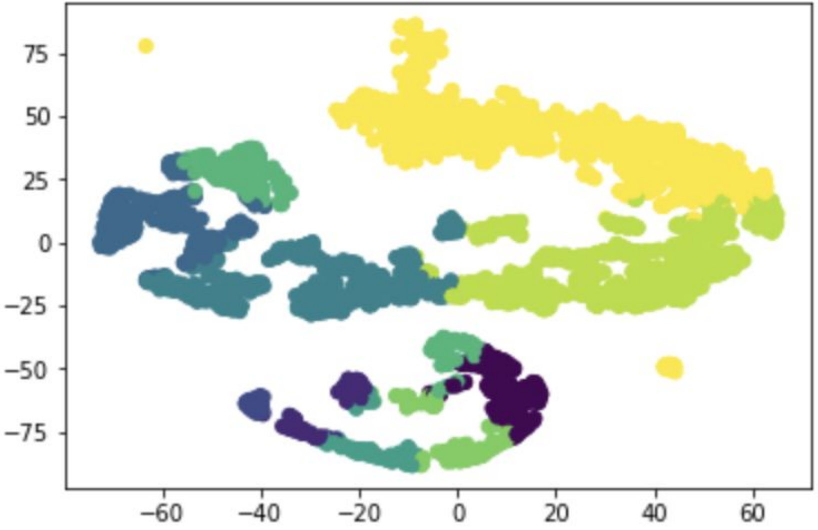
```
(4601, 2)
```

```
vis_x = data_embedded[:, 0]
vis_y = data_embedded[:, 1]
plt.scatter(vis_x, vis_y, cmap=plt.cm.get_cmap("jet", 10))
plt.show()
```

Plot the result with t-SNE

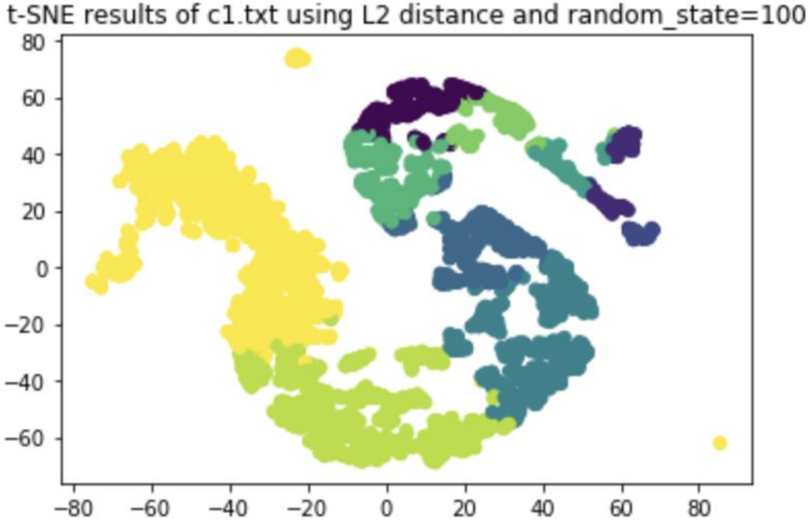


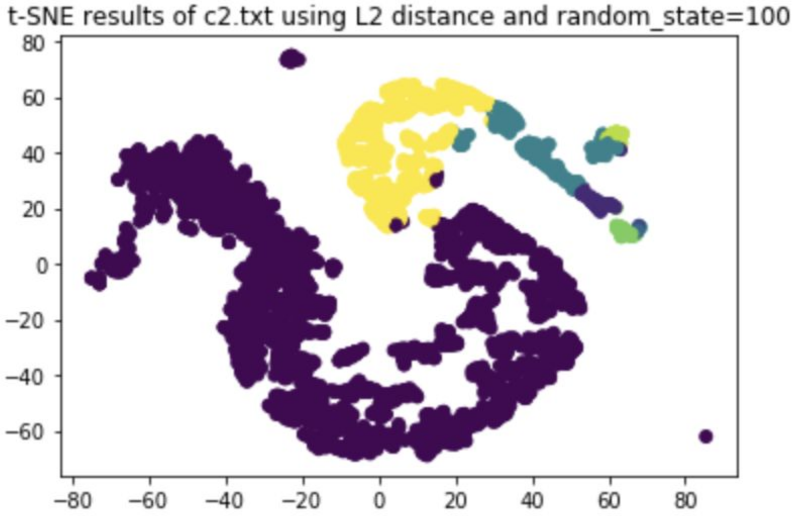
Before clustering



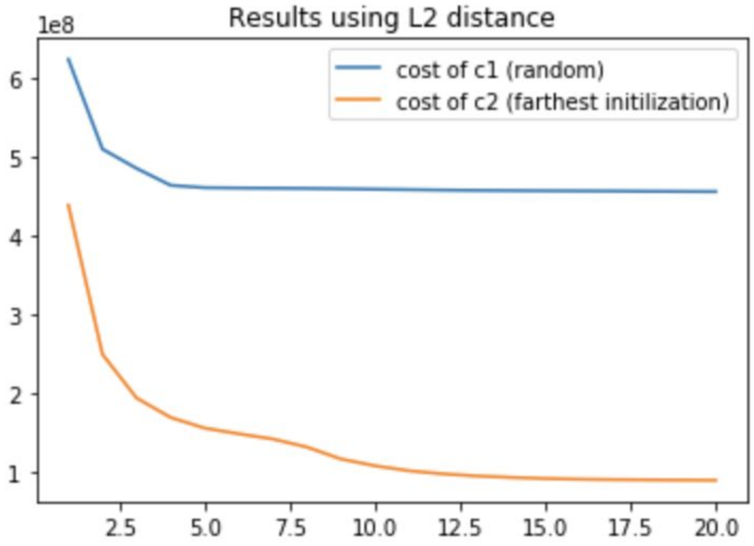
After clustering

Plot the result with t-SNE (set random state)

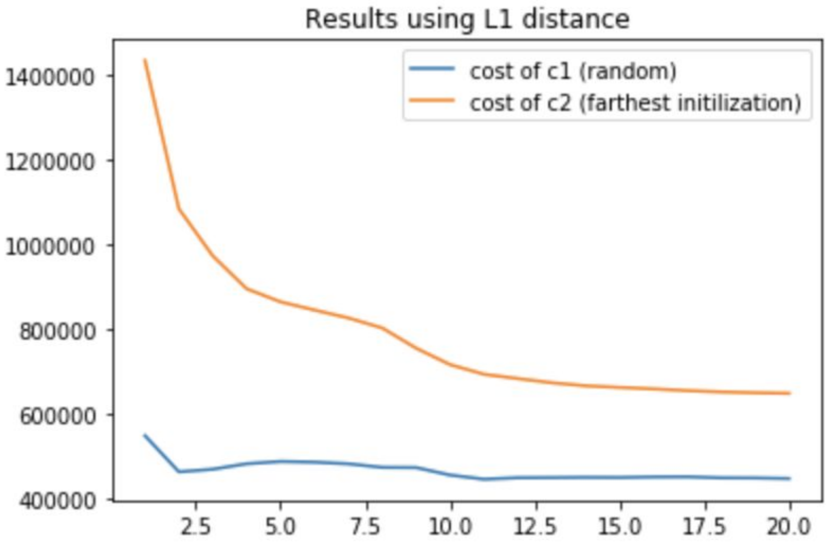

t-SNE results of c1.txt using L2 distance and random_state=100


t-SNE results of c2.txt using L2 distance and random_state=100

Plot the cost of each iteration



Results using L2 distance



Results using L1 distance

Binary classification with Spark MLlib

- Adult dataset from UCI Machine Learning Repository
- Given information of a person, predict if the person could earn > 50k per year
- Workflow
    - Data loading: load data into Dataframe
    - Data preprocessing: Convert the categorical variables into numeric variables with ML Pipelines and Feature Transformers
    - Modelling: Conduct classification with Logistic Regression model
    - Evaluation

References

- https://spark.apache.org/docs/latest/sql-getting-started.html
- https://www.analyticsvidhya.com/blog/2016/10/spark-dataframe-and-operations/
- https://spark.apache.org/docs/latest/ml-guide.html
- https://spark.apache.org/docs/latest/ml-pipeline.html
- https://spark.apache.org/docs/latest/ml-features.html
- https://spark.apache.org/docs/latest/ml-classification-regression.html
- https://towardsdatascience.com/machine-learning-with-pyspark-and-mllib-solving-a-binary-classification-problem-96396065d2aa