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

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Agenda

- HW1
  - Iterative K-means clustering
  - Binary Classification with Spark MLib
  - Hadoop
- Spark MLlib

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
  - Load data into Spark Dataframe
  - Modeling and Evaluation
- Monitoring Hadoop metrics
  - Installing Hadoop in Pseudo Distributed Mode
  - Monitoring hadoop metrics through HTTP API

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

```
1: procedure ITERATIVE k-MEANS
2:     Select k points as initial centroids of the k clusters.
3:     for iterations := 1 to MAX_ITER do
4:         for each point p in the dataset do
5:             Assign point p to the cluster with the closest centroid
6:         end for
7:         for each cluster c do
8:             Recompute the centroid of c as the mean of all the data points assigned to c
9:         end for
10:    end for
11: end procedure
```

Iterative K-means in Spark

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

Algorithm 1 Iterative k-Means Algorithm

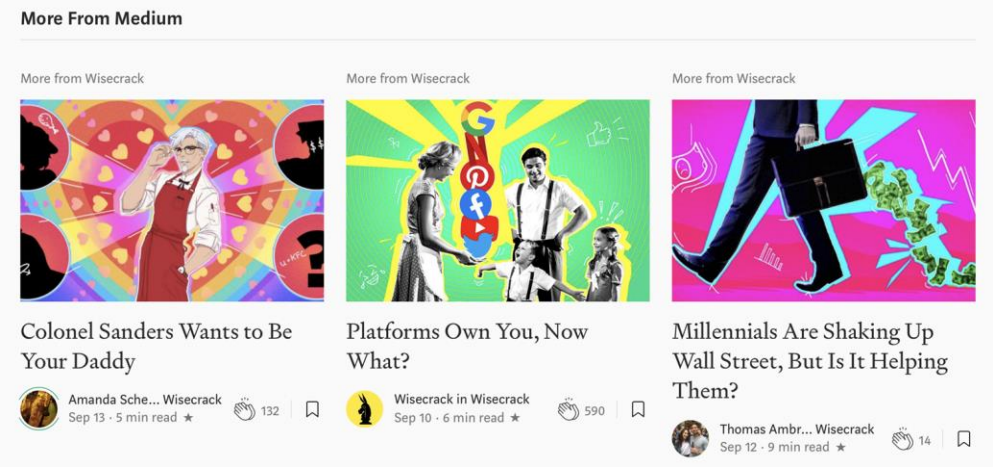
```
1: procedure ITERATIVE k-MEANS
2:     Select k points as initial centroids of the k clusters.
3:     for iterations := 1 to MAX_ITER do
4:         for each point p in the dataset do
5:             Assign point p to the cluster with the closest centroid
6:         end for
7:         for each cluster c do
8:             Recompute the centroid of c as the mean of all the data points assigned to c
9:         end for
10:    end for
11: end procedure
```

```
# 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
```

Document clustering



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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)
```

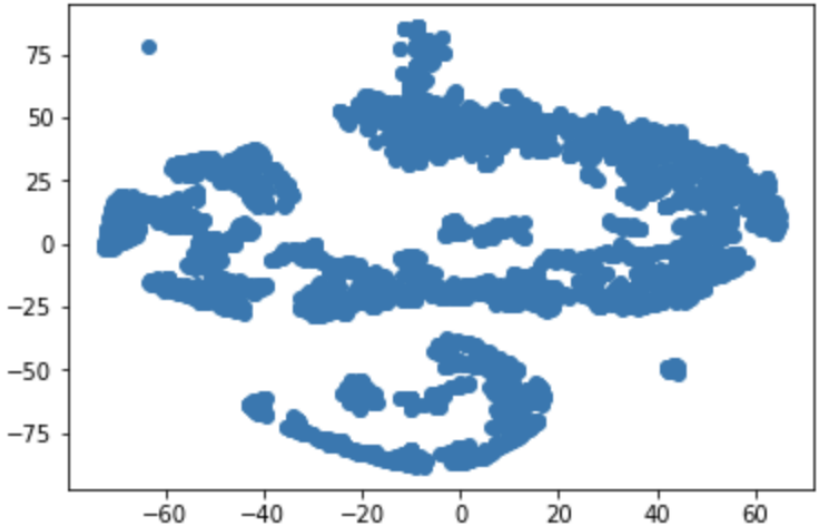
```
data_embedded = TSNE(n_components=2).fit_transform(data_np)
```

```
data_embedded.shape
```

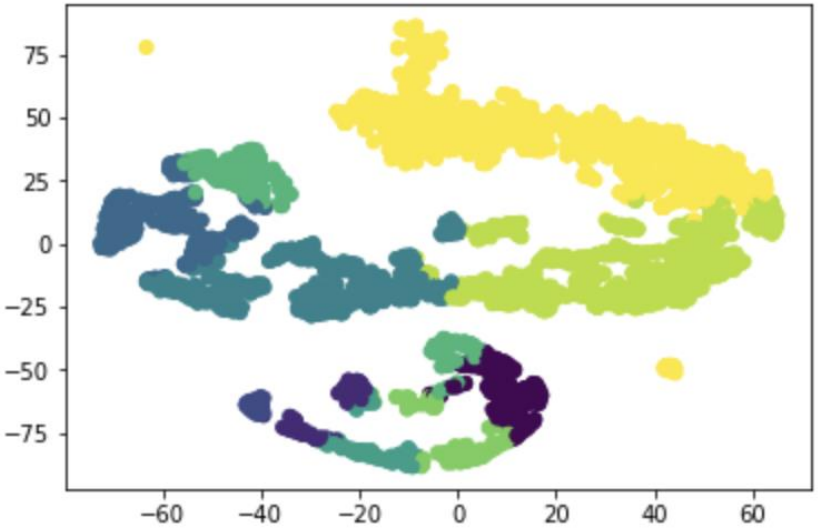
```
(4601, 2)
```

```
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

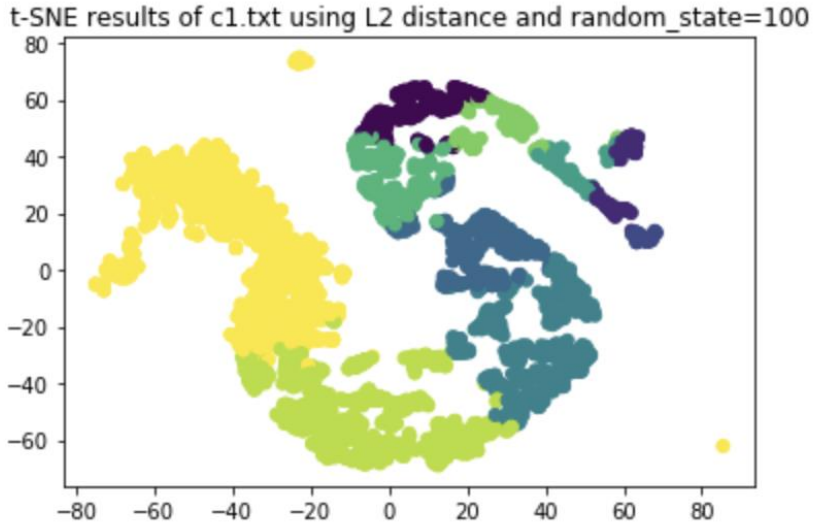


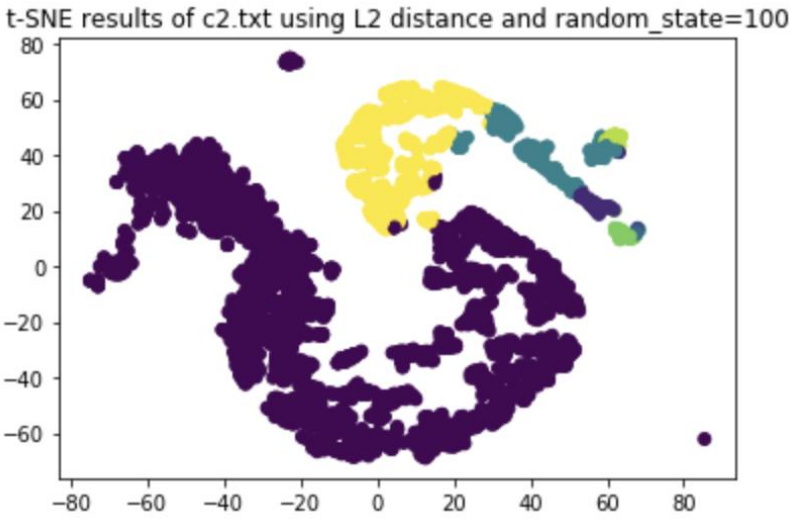
Before clustering



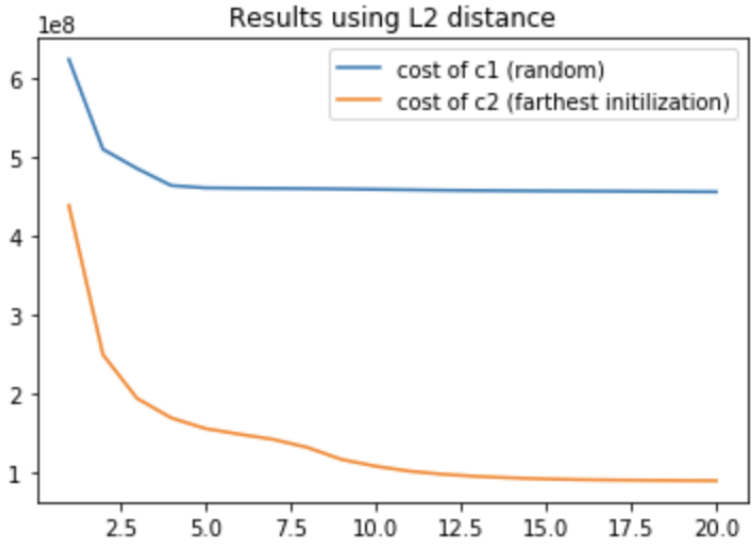
After clustering

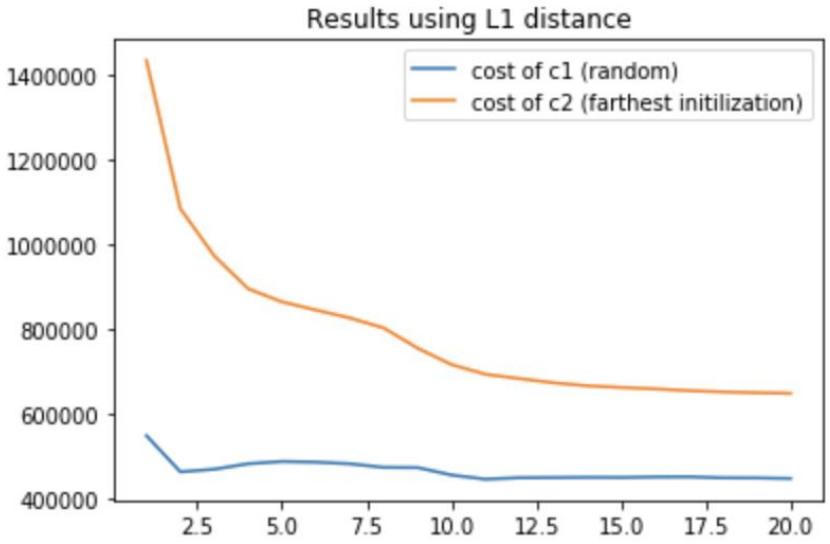
Plot the result with t-SNE (set random state)





Plot the cost of each iteration





Spark MLlib

- Spark's scalable machine learning library
- Tools:
  - ML Algorithms: classification, regression, clustering, and collaborative filtering
  - Featurization: feature extraction, transformation, dimensionality reduction, and selection
  - 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
```

HW1 Part 2 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

Index of /ml/

- Parent Directory
- Index
- adult.data
- adult.names
- adult.test
- old.adult.names

Apache/2.4.6 (CentOS) Open

HW1 Part 2 Binary classification with Spark MLlib

- Workflow
  - Data loading: load data into Dataframe

    Spark Dataframe Guide: https://spark.apache.org/docs/latest/sql-getting-started.html

```
#============================
data.show(3)
```

```
+---+----------------+--------+----------+----+------------------+------------------+-------------+------+-----+------+----+----+--------
------+------+
|_c0|             _c1|     _c2|       _c3| _c4|               _c5|               _c6|          _c7|   _c8|  _c9|  _c10|_c11|_c12|
_c13|  _c14|
+---+----------------+--------+----------+----+------------------+------------------+-------------+------+-----+------+----+----+--------
------+------+
| 39|       State-gov| 77516.0| Bachelors|13.0|     Never-married|      Adm-clerical| Not-in-family| White| Male|2174.0| 0.0|40.0| United-
States| <=50K|
| 50| Self-emp-not-inc| 83311.0| Bachelors|13.0| Married-civ-spouse|   Exec-managerial|       Husband| White| Male|   0.0| 0.0|13.0| United-
States| <=50K|
| 38|         Private|215646.0|   HS-grad| 9.0|          Divorced| Handlers-cleaners| Not-in-family| White| Male|   0.0| 0.0|40.0| United-
States| <=50K|
+---+----------------+--------+----------+----+------------------+------------------+-------------+------+-----+------+----+----+--------
------+------+
only showing top 3 rows
```

HW1 Part 2 Binary classification with Spark MLlib

- Workflow
  - Data preprocessing: Convert the categorical variables into numeric variables with ML Pipelines and Feature Transformers

```
dataset = df
```

```
root
 |-- age: integer (nullable = true)
 |-- workclass: string (nullable = true)
 |-- fnlwgt: double (nullable = true)
 |-- education: string (nullable = true)
 |-- education_num: double (nullable = true)
 |-- marital_status: string (nullable = true)
 |-- occupation: string (nullable = true)
 |-- relationship: string (nullable = true)
 |-- race: string (nullable = true)
 |-- sex: string (nullable = true)
 |-- capital_gain: double (nullable = true)
 |-- capital_loss: double (nullable = true)
 |-- hours_per_week: double (nullable = true)
 |-- native_country: string (nullable = true)
 |-- income: string (nullable = true)
```

```
+---+----------------+-------+---------+-------------+------------------+----------------+------------+-----+------------+------------+--------------+--------------+------+
|age|       workclass| fnlwgt|education|education_num|     marital_status|      occupation|relationship| race|         sex|capital_gain|capital_loss|hours_per_week|native_country|income|
+---+----------------+-------+---------+-------------+------------------+----------------+------------+-----+------------+------------+------------+--------------+--------------+------+
| 39|       State-gov|77516.0|Bachelors|         13.0|     Never-married|    Adm-clerical|Not-in-family|White|        Male|      2174.0|         0.0|          40.0| United-States| <=50K|
| 50|Self-emp-not-inc|83311.0|Bachelors|         13.0|Married-civ-spouse|Exec-managerial|     Husband|White|        Male|         0.0|         0.0|          13.0| United-States| <=50K|
+---+----------------+-------+---------+-------------+------------------+----------------+------------+-----+------------+------------+------------+--------------+--------------+------+
only showing top 2 rows
```

```
In [43]: preppedDataDF.take(3)
```

```
Out[43]: [Row(age=39, workclass=' State-gov', fnlwgt=77516.0, education=' Bachelors', education_num=13.0, marital_status=' Never-married', occupation=' Adm-clerical', relationship=' Not-in-family', race=' White', sex=' Male', capital_gain=2174.0, capital_loss=0.0, hours_per_week=40.0, native_country=' United-States', income=' <=50K', workclassIndex=4.0, workclassclassVec=SparseVector(8, {4: 1.0}), educationIndex=2.0, educationclassVec=SparseVector(15, {2: 1.0}), marital_statusIndex=1.0, marital_statusclassVec=SparseVector(6, {1: 1.0}), occupationIndex=3.0, occupationclassVec=SparseVector(14, {3: 1.0}), relationshipIndex=1.0, relationshipclassVec=SparseVector(5, {1: 1.0}), raceIndex=0.0, raceclassVec=SparseVector(4, {0: 1.0}), sexIndex=0.0, sexclassVec=SparseVector(1, {0: 1.0}), native_countryIndex=0.0, native_countryclassVec=SparseVector(41, {0: 1.0}), label=0.0, features=SparseVector(100, {4: 1.0, 10: 1.0, 24: 1.0, 32: 1.0, 44: 1.0, 48: 1.0, 52: 1.0, 53: 1.0, 94: 39.0, 95: 77516.0, 96: 13.0, 97: 2174.0, 99: 40.0})),
 Row(age=50, workclass=' Self-emp-not-inc', fnlwgt=83311.0, education=' Bachelors', education_num=13.0, marital_status=' Married-civ-spouse', occupation=' Exec-managerial', relationship=' Husband', race=' White', sex=' Male', capital_gain=0.0, capital_loss=0.0, hours_per_week=13.0, native_country=' United-States', income=' <=50K', workclassIndex=1.0, workclassclassVec=SparseVector(8, {1: 1.0}), educationIndex=2.0, educationclassVec=SparseVector(15, {2: 1.0}), marital_statusIndex=0.0, marital_statusclassVec=SparseVector(6, {0: 1.0}), occupationIndex=2.0, occupationclassVec=SparseVector(14, {2: 1.0}), relationshipIndex=0.0, relationshipclassVec=SparseVector(5, {0: 1.0}), raceIndex=0.0, raceclassVec=SparseVector(4, {0: 1.0}), sexIndex=0.0, sexclassVec=SparseVector(1, {0: 1.0}), native_countryIndex=0.0, native_countryclassVec=SparseVector(41, {0: 1.0}), label=0.0, features=SparseVector(100, {1: 1.0, 10: 1.0, 23: 1.0, 31: 1.0, 43: 1.0, 48: 1.0, 52: 1.0, 53: 1.0, 94: 50.0, 95: 83311.0, 96: 13.0, 99: 13.0})),
 Row(age=38, workclass=' Private', fnlwgt=215646.0, education=' HS-grad', education_num=9.0, marital_status=' Divorced', occupation=' Handlers-cleaners', relationship=' Not-in-family', race=' White', sex=' Male', capital_gain=0.0, capital_loss=0.0, hours_per_week=40.0, native_country=' United-States', income=' <=50K', workclassIndex=0.0, workclassclassVec=SparseVector(8, {0: 1.0}), educationIndex=0.0, educationclassVec=SparseVector(15, {0: 1.0}), marital_statusIndex=2.0, marital_statusclassVec=SparseVector(6, {2: 1.0}), occupationIndex=9.0, occupationclassVec=SparseVector(14, {9: 1.0}), relationshipIndex=1.0, relationshipclassVec=SparseVector(5, {1: 1.0}), raceIndex=0.0, raceclassVec=SparseVector(4, {0: 1.0}), sexIndex=0.0, sexclassVec=SparseVector(1, {0: 1.0}), native_countryIndex=0.0, native_countryclassVec=SparseVector(41, {0: 1.0}), label=0.0, features=SparseVector(100, {0: 1.0, 8: 1.0, 25: 1.0, 38: 1.0, 44: 1.0, 48: 1.0, 52: 1.0, 53: 1.0, 94: 38.0, 95: 215646.0, 96: 9.0, 99: 40.0}))]
```

HW1 Part 2 Binary classification with Spark MLlib

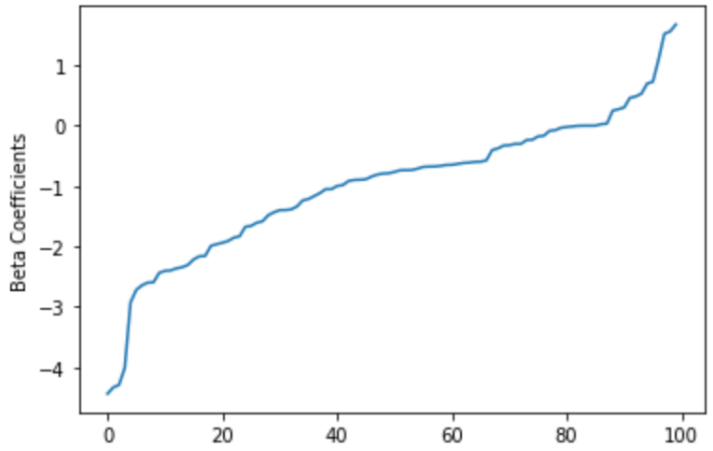
- Workflow
  - Modelling:
    Logistic Regression
    KNN
    Random Forest
    Naive Bayes
    Decision Tree
    Gradient Boosting Trees
    Multi-layer perceptron
    Linear Support Vector Machine
    One-vs-Rest

https://spark.apache.org/docs/latest/ml-classification-regression.html

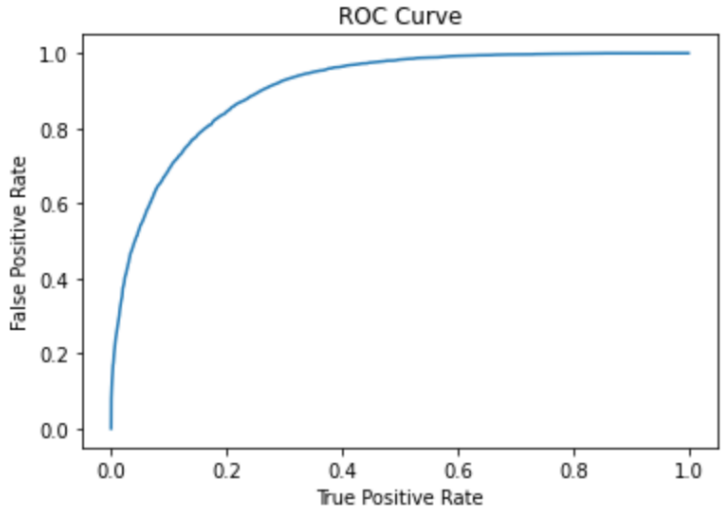
HW1 Part 2 Binary classification with Spark MLlib

- Workflow
  - Evaluation (Logistic Regression)

```
plt.ylabel('Beta Coefficients')
plt.show()
```




```
print('Training set areaUnderROC: ' + str(trainingSummary.areaUnderROC))
```

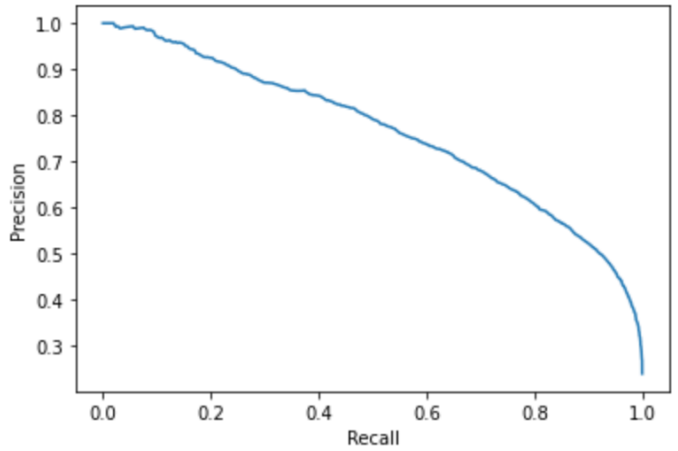


ROC: Receiver operating characteristic - Wikipedia

HW1 Part 2 Binary classification with Spark MLlib

- Workflow
  - Evaluation (Logistic Regression)

```
plt.ylabel('Precision')
plt.xlabel('Recall')
plt.show()
```




```
print("Accuracy: %s\nFPR: %s\nTPR: %s\nF-measure: %s\nPrecision: %s\nRecall: %s"
      % (accuracy, falsePositiveRate, truePositiveRate, fMeasure, precision, recall))
```

```
Accuracy: 0.8526629292221444
FPR: 0.3172889625959339
TPR: 0.8526629292221444
F-measure: 0.8475083896808702
Precision: 0.8464035949642436
Recall: 0.8526629292221444
```

```
evaluator.evaluate(predictions)
```

Out[54]: 0.8993574699928725

In [55]:
```
# accuracy
correct = float(predictions.filter(predi
total = float(predictions.count())
print(correct, total, correct/total)
```

8218.0 9729.0 0.8446911296124987

Hadoop installation

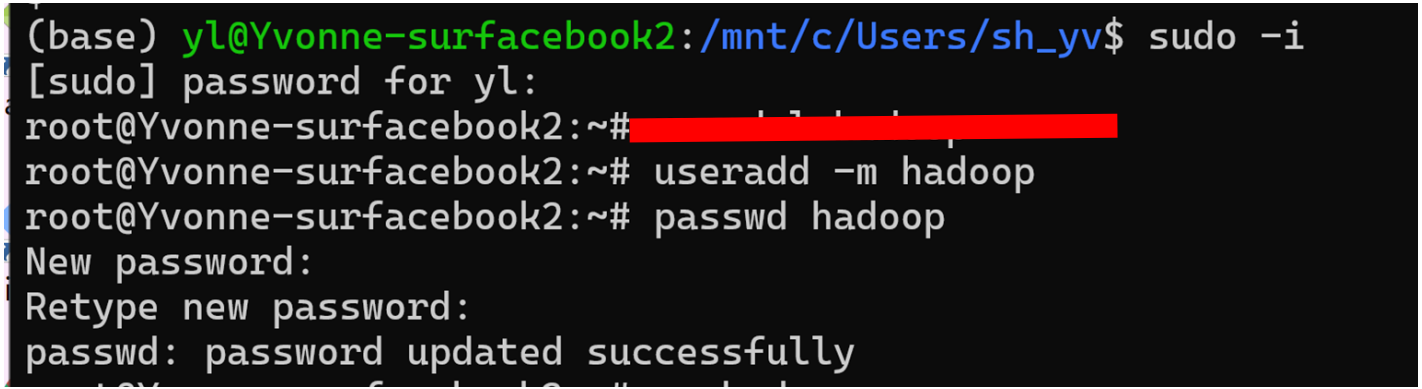
Step 1: Pre-installation Setup

- Before the installation, learn how to login & exit the root account
  - Login: sudo -i
  - Exit: exit (or use ctrl+D)

```
(base) yl@Yvonne-surfacebook2:/mnt/c/Users/sh_yv$ sudo -i
[sudo] password for yl:
root@Yvonne-surfacebook2:~# exit
logout
(base) yl@Yvonne-surfacebook2:/mnt/c/Users/sh_yv$
```

Create a user

- Open the **root** using the command “sudo -i”.
- Create a user from the root account using the command “useradd -m username”.
- Set the password using the command “passwd username”
- Now you can open the new user account.
  - If you’re under root account, use the command “su username”
  - Otherwise, use “su - username”



- Create a user
  - Add user to sudo group

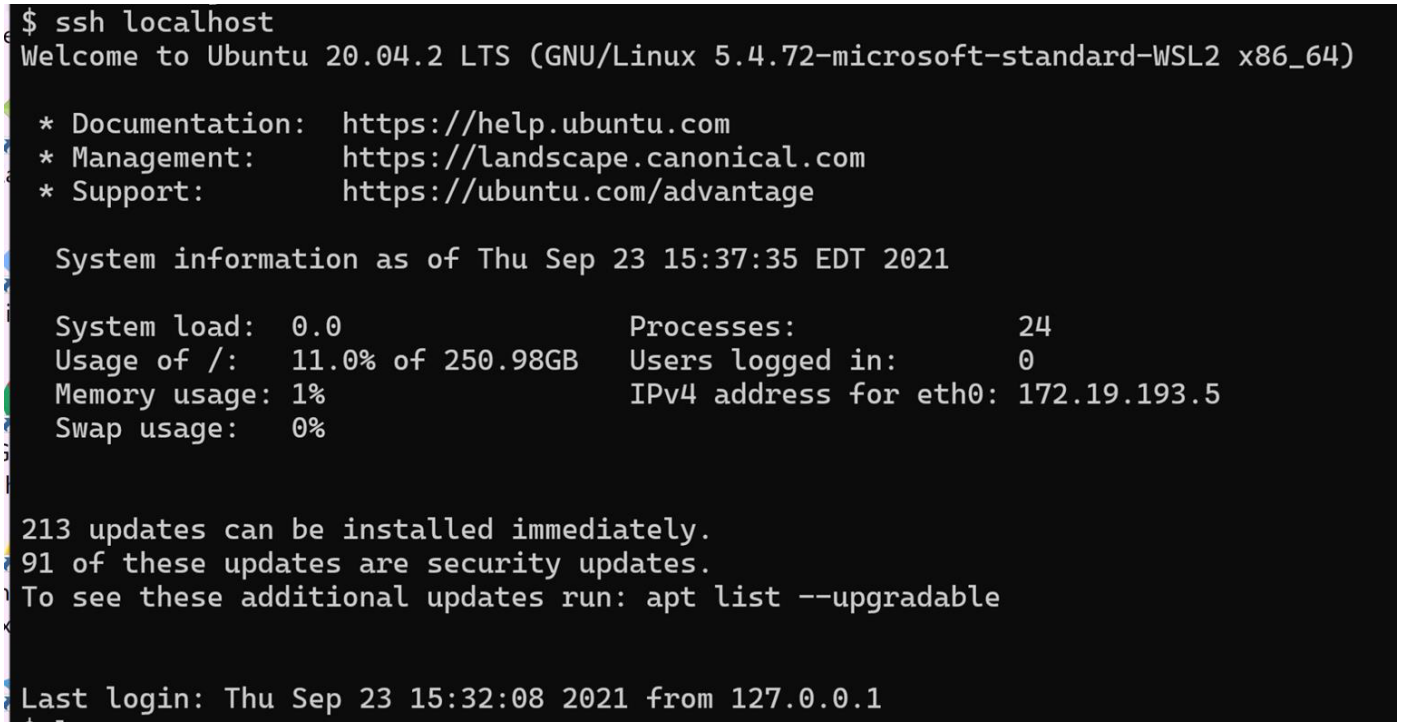
```
root@Yvonne-surfacebook2:~# adduser hadoop sudo
Adding user `hadoop' to group `sudo' ...
Adding user hadoop to group sudo
Done.
```

SSH Setup and Key Generation

- Open the account you created, using
  - su hadoop
- Generate generating a key value pair using SSH, using
  - ssh-keygen -t rsa (press “enter” directly where you’re asked to enter)
- Copy the public keys from id_rsa.pub to authorized_keys, using
  - cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys
- Provide the owner with read and write permissions to authorized_keys file respectively
  - chmod 0600 ~/.ssh/authorized_keys
- Test SSH setup
  - ssh localhost

```
root@Yvonne-surfacebook2:~# su hadoop
$ ssh-keygen -t rsa
Generating public/private rsa key pair.
Enter file in which to save the key (/home/hadoop/.ssh/id_rsa):
Created directory '/home/hadoop/.ssh'.
Enter passphrase (empty for no passphrase):
Enter same passphrase again:
Your identification has been saved in /home/hadoop/.ssh/id_rsa
Your public key has been saved in /home/hadoop/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:gl3ZvwdeOON6gVncTWlUyc22YoKFP4HsuhfhVmIMRJY hadoop@Yvonne-surfacebook2
The key's randomart image is:
+---[RSA 3072]----+
|      o+o o   oo*|
|      .E * o   ==|
|        * =....+.|
|     o . B *o+...|
|    . o S ++X o  |
|       o +oo.*   |
|        o . +..  |
|       . . ...   |
|        . ..     |
+----[SHA256]-----+
$ cat ~/.ssh/id_rsa.pub >> ~/.ssh/authorized_keys
$ chmod 0600 ~/.ssh/authorized_keys
```

- Test ssh setup. Use “logout” command to log out



SSH Setup (for Debugging)

- If ssh localhost doesn’t work

```
$ ssh localhost
ssh: connect to host localhost port 22: Connection refused
```

- Try reinstall some packages:
  - sudo apt-get remove openssh-client openssh-server
  - sudo apt-get install openssh-client openssh-server
- If still doesn’t work, check the following
  - sudo service ssh start
  - ssh localhost

Installing Java

- Verify the existence of Java in your system
  - java -version
  - If you've installed Java, it will give you the following output, and you can skip the java installing steps, continuing to the next section.

```
java version "1.7.0_71"
Java(TM) SE Runtime Environment (build 1.7.0_71-b13)
Java HotSpot(TM) Client VM (build 25.0-b02, mixed mode)
```

- If you did not install Java, you need to follow the next steps to install Java.

Installing Java

- Install java
  - sudo apt-get install openjdk-8-jre openjdk-8-jdk
- Then check Java version to see if you have installed java
  - java -version
- If that doesn’t work, try:
  - sudo add-apt-repository ppa:openjdk-r/ppa
  - sudo apt-get update
  - sudo apt-get install openjdk-8-jdk

Installing Java

- Then check Java version to see if you have installed java
  - java -version
- To find where you have installed java
  - dirname $(dirname $(readlink -f $(which javac)))

```
(base) yl@Yvonne-surfacebook2:/usr/bin$ dirname $(dirname $(readlink -f $(which javac)))
/usr/lib/jvm/java-8-openjdk-amd64
```

- Set up PATH and JAVA_HOME variables
  - export JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64 (the path from last step)
  - export PATH=$PATH:$JAVA_HOME/bin
- Now apply all the changes into the current running system.
  - exec bash

Step 2: Downloading Hadoop

- Change to root and change directory
  - sudo -i
  - cd /usr/local/
- Download and extract Hadoop
  - wget http://apache.claz.org/hadoop/common/hadoop-3.3.4/hadoop-3.3.4.tar.gz
  - tar xzf hadoop-3.3.4.tar.gz
  - mv hadoop-3.3.4 hadoop
- Change owner
  - sudo chown -R hadoop:hadoop ./hadoop
- Set Hadoop environment variables
  - su hadoop
  - export HADOOP_HOME=/usr/local/hadoop
  - export PATH=$PATH:/usr/local/hadoop/bin
  - exec bash

Test the Hadoop setup

- Type the following command
  - hadoop version
  - If everything is fine, you'll see the following

```
$ hadoop version
Hadoop 3.3.1
Source code repository https://github.com/apache/hadoop.git -r a3b9c37a397ad4188041dd80621bdeefc46885f2
Compiled by ubuntu on 2021-06-15T05:13Z
Compiled with protoc 3.7.1
From source with checksum 88a4ddb2299aca054416d6b7f81ca55
This command was run using /usr/local/hadoop/share/hadoop/common/hadoop-common-3.3.1.jar
```

- Now you have successfully set up the Hadoop's standalone mode

Installing Hadoop in Pseudo Distributed Mode

- Set the Hadoop environment variables
  - export HADOOP_HOME=/usr/local/hadoop
  - export HADOOP_MAPRED_HOME=$HADOOP_HOME
  - export HADOOP_COMMON_HOME=$HADOOP_HOME

  - export HADOOP_HDFS_HOME=$HADOOP_HOME
  - export YARN_HOME=$HADOOP_HOME
  - export HADOOP_COMMON_LIB_NATIVE_DIR=$HADOOP_HOME/lib/native
  - export PATH=$PATH:$HADOOP_HOME/sbin:$HADOOP_HOME/bin
  - export HADOOP_INSTALL=$HADOOP_HOME
  - exec bash

Hadoop configuration

- Find the Hadoop configuration files
  - cd $HADOOP_HOME/etc/hadoop
  - vim hadoop-env.sh (Add the location of java to this file, namely the following line)
  - JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64

```
###

#
# When building Hadoop, one can add the class paths to the commands
# via this special env var:
# export HADOOP_ENABLE_BUILD_PATHS="true"

#
# To prevent accidents, shell commands be (superficially) locked
# to only allow certain users to execute certain subcommands.
# It uses the format of (command)_(subcommand)_USER.
#
# For example, to limit who can execute the namenode command,
# export HDFS_NAMENODE_USER=hdfs


###
# Registry DNS specific parameters
###
# For privileged registry DNS, user to run as after dropping privileges
# This will replace the hadoop.id.str Java property in secure mode.
# export HADOOP_REGISTRYDNS_SECURE_USER=yarn

# Supplemental options for privileged registry DNS
# By default, Hadoop uses jsvc which needs to know to launch a
# server jvm.
# export HADOOP_REGISTRYDNS_SECURE_EXTRA_OPTS="-jvm server"
JAVA_HOME=/usr/lib/jvm/java-8-openjdk-amd64
"hadoop-env.sh" 431L, 16698C
```

- Some files that you need to edit to configure Hadoop
  - Open the core-site.xml and add the following properties in between <configuration>, </configuration> tags.

```
<configuration>
   <property>
      <name>fs.default.name</name>
      <value>hdfs://localhost:9000</value>
   </property>
</configuration>
```

- Some files that you need to edit to configure Hadoop
  - Open the hdfs-site.xml and add the following properties in between <configuration>, </configuration> tags.

```
<configuration>
   <property>
      <name>dfs.replication</name>
      <value>1</value>
   </property>

   <property>
      <name>dfs.name.dir</name>
      <value>file:///home/hadoop/hadoopinfra/hdfs/namenode </value>
   </property>

   <property>
      <name>dfs.data.dir</name>
      <value>file:///home/hadoop/hadoopinfra/hdfs/datanode </value>
   </property>
</configuration>
```

- Some files that you need to edit to configure Hadoop
  - Open the yarn-site.xml and add the following properties in between <configuration>, </configuration> tags.

```
<configuration>
   <property>
      <name>yarn.nodemanager.aux-services</name>
      <value>mapreduce_shuffle</value>
   </property>
</configuration>
```

- Some files that you need to edit to configure Hadoop
  - Open the mapred-site.xml and add the following properties in between <configuration>, </configuration> tags.

```
<configuration>
   <property>
      <name>mapreduce.framework.name</name>
      <value>yarn</value>
   </property>
</configuration>
```

Verify Hadoop installation

- Set up the namenode
  - cd ~
  - hdfs namenode -format

```
10/24/14 21:30:55 INFO namenode.NameNode: STARTUP_MSG:
/************************************************************
STARTUP_MSG: Starting NameNode
STARTUP_MSG:   host = localhost/192.168.1.11
STARTUP_MSG:   args = [-format]
STARTUP_MSG:   version = 2.4.1
...
...
10/24/14 21:30:56 INFO common.Storage: Storage directory
/home/hadoop/hadoopinfra/hdfs/namenode has been successfully formatted.
10/24/14 21:30:56 INFO namenode.NNStorageRetentionManager: Going to
retain 1 images with txid >= 0
10/24/14 21:30:56 INFO util.ExitUtil: Exiting with status 0
10/24/14 21:30:56 INFO namenode.NameNode: SHUTDOWN_MSG:
/************************************************************
SHUTDOWN_MSG: Shutting down NameNode at localhost/192.168.1.11
************************************************************/
```

- Verify Hadoop installation
  - Verify Hadoop dfs
    - Start-dfs.sh

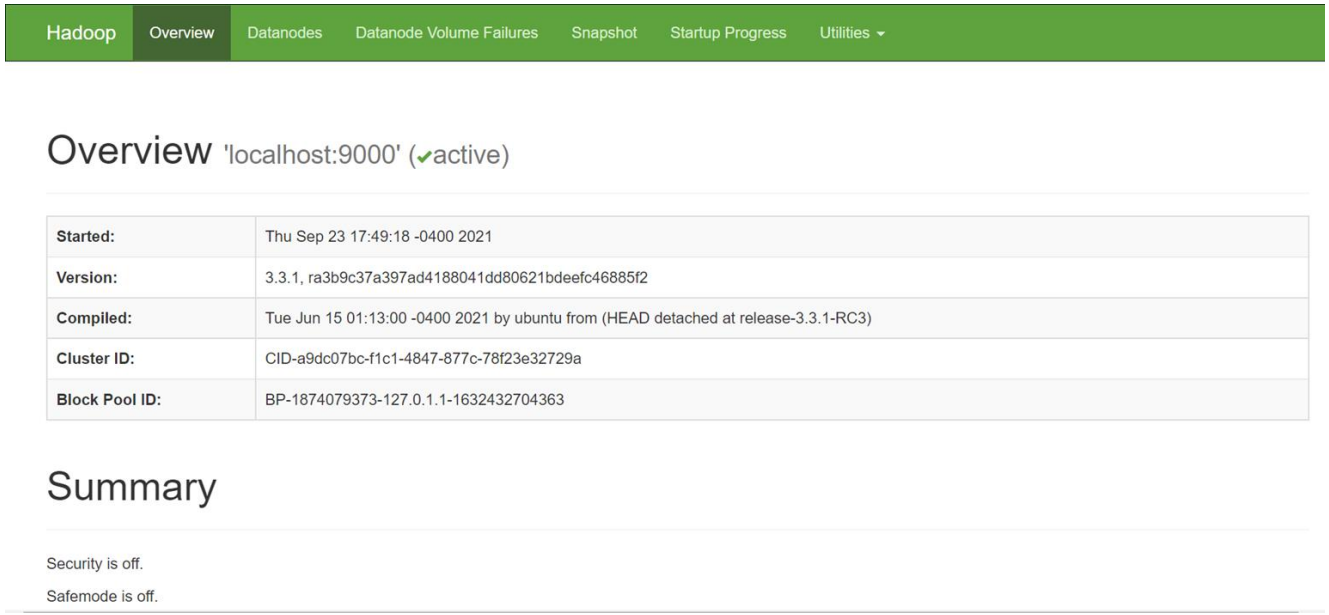
```
hadoop@Yvonne-surfacebook2:/usr/local/hadoop/etc/hadoop$ start-dfs.sh
Starting namenodes on [localhost]
Starting datanodes
Starting secondary namenodes [Yvonne-surfacebook2]
```

  - Verify yarn script
    - start-yarn.sh

```
hadoop@Yvonne-surfacebook2:~$ start-yarn.sh
Starting resourcemanager
Starting nodemanagers
```

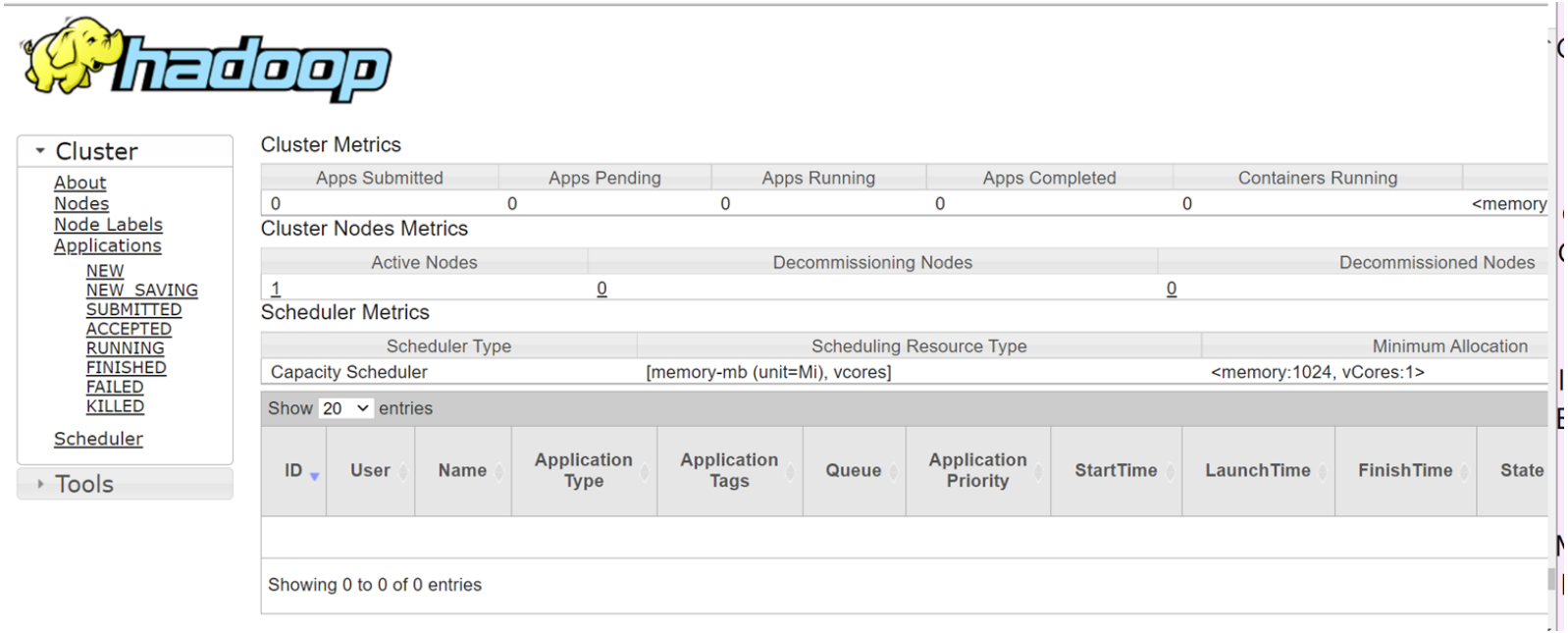
Access Hadoop on Browser

- Use the following url to get Hadoop services on browser.
  - http://localhost:9870/



Access Hadoop on Browser

- Access all applications of cluster
  - http://localhost:8088/



References

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- https://www.analyticsvidhya.com/blog/2016/10/spark-dataframe-and-operations/
- https://spark.apache.org/docs/latest/ml-guide.html
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