Project Solution Lab 2:

Problem: Predicting Airplane Delays

The multi-fold goals of this notebook are:

- Process and create a dataset from downloaded ZIP files
- Exploratory data analysis (EDA)
- Establish a baseline model
- Move from a simple model to an ensemble model
- Hyperparameter optimization
- Check feature importance

Introduction to business scenario

You work for a travel booking website that is working to improve the customer experience for flights that were delayed. The company wants to create a feature to let customers know if the flight will be delayed due to weather when the customers are booking the flight to or from the busiest airports for domestic travel in the US.

You are tasked with solving part of this problem by leveraging machine learning to identify whether the flight will be delayed due to weather. You have been given access to the a dataset of on-time performance of domestic flights operated by large air carriers. You can use this data to train a machine learning model to predict if the flight is going to be delayed for the busiest airports.

About this dataset

This dataset contains scheduled and actual departure and arrival times reported by certified US air carriers that account for at least 1% of domestic scheduled passenger revenues. The data was collected by the Office of Airline Information, Bureau of Transportation Statistics (BTS). The dataset contains date, time, origin, destination, airline, distance, and delay status of flights for flights between 2013 and 2018.

Features

For more information about features in the dataset, see On-time delay dataset features (https://www.transtats.bts.gov/Fields.asp?gnoyr_VQ=FGJ).

Dataset attributions

Website: https://www.transtats.bts.gov/ (https://www.transtats.bts.gov/)

Dataset(s) used in this lab were compiled by the Office of Airline Information, Bureau of Transportation Statistics (BTS), Airline On-Time Performance Data, available at https://www.transtats.bts.gov/DatabaseInfo.asp?DB_ID=120&DB_URL=Mode_ID=1&Mode_Desc=Aviation&Subject_ID2=0 (https://www.transtats.bts.gov/DatabaseInfo.asp?DB_ID=120&DB_URL=Mode_ID=1&Mode_Desc=Aviation&Subject_ID2=0).

Step 1: Problem formulation and data collection

Start this project off by writing a few sentences below that summarize the business problem and the business goal you're trying to achieve in this scenario. Include a business metric you would like your team to aspire toward. With that information defined, clearly write out the machine learning problem statement. Finally, add a comment or two about the type of machine learning this represents.

Project presentation: Include a summary of these details in your project presentations.

1. Determine if and why ML is an appropriate solution to deploy.

Write your answer here

2. Formulate the business problem, success metrics, and desired ML output.

Write your answer here

3. Identify the type of ML problem you’re dealing with.

Write your answer here

4. Analyze the appropriateness of the data you’re working with.

Write your answer here

Setup

Now that we have decided where to focus our energy, let's set things up so you can start working on solving the problem.

Note: This notebook was created and tested on an `ml.m4.xlarge` notebook instance.

In [1]:
```
import os
from pathlib2 import Path
from zipfile import ZipFile
import time

import pandas as pd
import numpy as np
import subprocess

import matplotlib.pyplot as plt
import seaborn as sns

sns.set()

import warnings
warnings.filterwarnings('ignore')

%matplotlib inline
```

Step 2: Data preprocessing and visualization

In this data preprocessing phase, you should take the opportunity to explore and visualize your data to better understand it. First, import the necessary libraries and read the data into a Pandas dataframe. After that, explore your data. Look for the shape of the dataset and explore your columns and the types of columns you're working with (numerical, categorical). Consider performing basic statistics on the features to get a sense of feature means and ranges. Take a close look at your target column and determine its distribution.

Specific questions to consider

1. What can you deduce from the basic statistics you ran on the features?
2. What can you deduce from the distributions of the target classes?
3. Is there anything else you deduced from exploring the data?

Project presentation: Include a summary of your answers to these and other similar questions in your project presentations.

Start by bringing in the dataset from an Amazon S3 public bucket to this notebook environment.

In [2]:
```
# Check whether the file is already in the desired path or if it needs to be d
ownloaded

base_path = '/home/ec2-user/SageMaker/project/data/FlightDelays/'
csv_base_path = '/home/ec2-user/SageMaker/project/data/csvFlightDelays/'
file_path = 'On_Time_Reporting_Carrier_On_Time_Performance_1987_present_2014_
1.zip'

if not os.path.isfile(base_path + file_path):
    subprocess.run(['mkdir', '-p', base_path])
    subprocess.run(['mkdir', '-p', csv_base_path])
    subprocess.run(['aws', 's3', 'cp',
                    's3://aws-tc-largeobjects/ILT-TF-200-MLDWTS/flight_delay_p
roject/csvFlightData-5/',
                    base_path,'--recursive'])
else:
    print('File already downloaded!')
```

In [3]:
```
zip_files = [str(file) for file in list(Path(base_path).iterdir()) if '.zip' i
n str(file)]
len(zip_files)
```

Out[3]: 60

Extract CSV files from ZIP files

In [4]:
```
def zip2csv(zipFile_name , file_path = '/home/ec2-user/SageMaker/project/data/
csvFlightDelays'):
    """
    Extract csv from zip files
    zipFile_name: name of the zip file
    file_path : name of the folder to store csv
    """
    try:
        with ZipFile(zipFile_name, 'r') as z:
            print(f'Extracting {zipFile_name} ')
            z.extractall(path=file_path)
    except:
        print(f'zip2csv failed for {zipFile_name}')

for file in zip_files:
    zip2csv(file)

print("Files Extracted")
```

```
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2014_1.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2014_3.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2016_9.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2017_12.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_11.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2017_6.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2014_7.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2017_11.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2017_10.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_4.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_2.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2016_12.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2014_4.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_7.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2018_9.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_3.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2016_2.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2016_3.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2014_10.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2018_10.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2017_1.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2016_6.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_8.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2018_3.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_6.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2016_1.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2014_2.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
```

```
ng_Carrier_On_Time_Performance_1987_present_2016_5.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2014_5.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_9.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2018_5.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2016_7.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2016_4.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2018_12.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2018_4.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2018_7.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2017_5.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2017_7.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2014_12.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2018_8.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
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Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2014_9.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2017_3.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2016_8.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_1.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2018_1.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
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ng_Carrier_On_Time_Performance_1987_present_2014_8.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
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```
ng_Carrier_On_Time_Performance_1987_present_2016_11.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2018_11.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_10.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2014_6.zip
Extracting /home/ec2-user/SageMaker/project/data/FlightDelays/On_Time_Reporti
ng_Carrier_On_Time_Performance_1987_present_2015_12.zip
Files Extracted
```

In [5]:
```
csv_files = [str(file) for file in list(Path(csv_base_path).iterdir()) if '.cs
v' in str(file)]
len(csv_files)
```

Out[5]:
```
60
```

Before loading the CSV file, read the HTML file from the extracted folder. This HTML file includes the background and more information on the features included in the dataset.

In [6]:
```
from IPython.display import IFrame, HTML

IFrame(src="./data/csvFlightDelays/readme.html", width=1000, height=600)
```

Out[6]:

Load sample CSV

Before combining all the CSV files, get a sense of the data from a single CSV file. Using Pandas, read the `On_Time_Reporting_Carrier_On_Time_Performance_(1987_present)_2018_9.csv` file first. You can use the Python built-in `read_csv` function (documentation (https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.read_csv.html)).

In [7]:
```
df_temp = pd.read_csv(f"{csv_base_path}On_Time_Reporting_Carrier_On_Time_Performance_(1987_present)_2018_9.csv")
```

Question: Print the row and column length in the dataset, and print the column names.

Hint: Use the `<dataframe>.shape` function to view the rows and columns of a dataframe and `<dataframe>.columns` to view the column names.

In [8]:
```
df_shape = df_temp.shape
print(f'Rows and columns in one csv file is {df_shape}')
```

```
Rows and columns in one csv file is (585749, 110)
```

Question: Print the first 10 rows of the dataset.

Hint: Use the built-in Pandas function `head(x)` to print `x` number of rows.

In [9]:
```
df_temp.head(10)
```

Out[9]:

	Year	Quarter	Month	DayofMonth	DayOfWeek	FlightDate	Reporting_Airline	DOT_ID_Reporti
0	2018	3	9	3	1	2018-09-03	9E	
1	2018	3	9	9	7	2018-09-09	9E	
2	2018	3	9	10	1	2018-09-10	9E	
3	2018	3	9	13	4	2018-09-13	9E	
4	2018	3	9	14	5	2018-09-14	9E	
5	2018	3	9	16	7	2018-09-16	9E	
6	2018	3	9	17	1	2018-09-17	9E	
7	2018	3	9	20	4	2018-09-20	9E	
8	2018	3	9	21	5	2018-09-21	9E	
9	2018	3	9	23	7	2018-09-23	9E	

10 rows × 110 columns

Question: Print all the columns in the dataset. Use `<dataframe>.columns` to view the column names.

In [10]:
```
print(f'The column names are :')
print('#########')
for col in df_temp.columns:
    print(col)
```

```
The column names are :
#########
Year
Quarter
Month
DayofMonth
DayOfWeek
FlightDate
Reporting_Airline
DOT_ID_Reporting_Airline
IATA_CODE_Reporting_Airline
Tail_Number
Flight_Number_Reporting_Airline
OriginAirportID
OriginAirportSeqID
OriginCityMarketID
Origin
OriginCityName
OriginState
OriginStateFips
OriginStateName
OriginWac
DestAirportID
DestAirportSeqID
DestCityMarketID
Dest
DestCityName
DestState
DestStateFips
DestStateName
DestWac
CRSDepTime
DepTime
DepDelay
DepDelayMinutes
DepDel15
DepartureDelayGroups
DepTimeBlk
TaxiOut
WheelsOff
WheelsOn
TaxiIn
CRSArrTime
ArrTime
ArrDelay
ArrDelayMinutes
ArrDel15
ArrivalDelayGroups
ArrTimeBlk
Cancelled
CancellationCode
Diverted
CRSElapsedTime
ActualElapsedTime
AirTime
```

```
Flights
Distance
DistanceGroup
CarrierDelay
WeatherDelay
NASDelay
SecurityDelay
LateAircraftDelay
FirstDepTime
TotalAddGTime
LongestAddGTime
DivAirportLandings
DivReachedDest
DivActualElapsedTime
DivArrDelay
DivDistance
Div1Airport
Div1AirportID
Div1AirportSeqID
Div1WheelsOn
Div1TotalGTime
Div1LongestGTime
Div1WheelsOff
Div1TailNum
Div2Airport
Div2AirportID
Div2AirportSeqID
Div2WheelsOn
Div2TotalGTime
Div2LongestGTime
Div2WheelsOff
Div2TailNum
Div3Airport
Div3AirportID
Div3AirportSeqID
Div3WheelsOn
Div3TotalGTime
Div3LongestGTime
Div3WheelsOff
Div3TailNum
Div4Airport
Div4AirportID
Div4AirportSeqID
Div4WheelsOn
Div4TotalGTime
Div4LongestGTime
Div4WheelsOff
Div4TailNum
Div5Airport
Div5AirportID
Div5AirportSeqID
Div5WheelsOn
Div5TotalGTime
Div5LongestGTime
Div5WheelsOff
```

```
Div5TailNum
Unnamed: 109
```

Question: Print all the columns in the dataset that contain the word 'Del'. This will help you see how many columns have delay data in them.

Hint: You can use a Python list comprehension to include values that pass certain `if` statement criteria.

For example: `[x for x in [1,2,3,4,5] if x > 2]`

Hint: You can use the `in` keyword (documentation (https://www.w3schools.com/python/ref_keyword_in.asp)) to check if the value is in a list or not.

For example: `5 in [1,2,3,4,5]`

In [11]:
```
[col for col in df_temp.columns if 'Del' in col]
```

Out[11]:
```
['DepDelay',
 'DepDelayMinutes',
 'DepDel15',
 'DepartureDelayGroups',
 'ArrDelay',
 'ArrDelayMinutes',
 'ArrDel15',
 'ArrivalDelayGroups',
 'CarrierDelay',
 'WeatherDelay',
 'NASDelay',
 'SecurityDelay',
 'LateAircraftDelay',
 'DivArrDelay']
```

Here are some more questions to help you find out more about your dataset.

Questions

1. How many rows and columns does the dataset have?
2. How many years are included in the dataset?
3. What is the date range for the dataset?
4. Which airlines are included in the dataset?
5. Which origin and destination airports are covered?

In [12]:
```
print("The #rows and #columns are ", df_temp.shape[0] , " and ", df_temp.shape
[1])
print("The years in this dataset are: ", list(df_temp.Year.unique()))
print("The months covered in this dataset are: ", sorted(list(df_temp.Month.un
ique())))
print("The date range for data is :" , min(df_temp.FlightDate), " to ", max(df
_temp.FlightDate))
print("The airlines covered in this dataset are: ", list(df_temp.Reporting_Air
line.unique()))
print("The Origin airports covered are: ", list(df_temp.Origin.unique()))
print("The Destination airports covered are: ", list(df_temp.Dest.unique()))
```

```
The #rows and #columns are  585749  and  110
The years in this dataset are:  [2018]
The months covered in this dataset are:  [9]
The date range for data is : 2018-09-01  to  2018-09-30
The airlines covered in this dataset are:  ['9E', 'B6', 'WN', 'YV', 'YX', 'E
V', 'AA', 'AS', 'DL', 'HA', 'UA', 'F9', 'G4', 'MQ', 'NK', 'OH', 'OO']
The Origin airports covered are:  ['DFW', 'LGA', 'MSN', 'MSP', 'ATL', 'BDL',
'VLD', 'JFK', 'RDU', 'CHS', 'DTW', 'GRB', 'PVD', 'SHV', 'FNT', 'PIT', 'RIC',
'RST', 'RSW', 'CVG', 'LIT', 'ORD', 'JAX', 'TRI', 'BOS', 'CWA', 'DCA', 'CHO',
'AVP', 'IND', 'GRR', 'BTR', 'MEM', 'TUL', 'CLE', 'STL', 'BTV', 'OMA', 'MGM',
'TVC', 'SAV', 'GSP', 'EWR', 'OAJ', 'BNA', 'MCI', 'TLH', 'ROC', 'LEX', 'PWM',
'BUF', 'AGS', 'CLT', 'GSO', 'BWI', 'SAT', 'PHL', 'TYS', 'ACK', 'DSM', 'GNV',
'AVL', 'BGR', 'MHT', 'ILM', 'MOT', 'IAH', 'SBN', 'SYR', 'ORF', 'MKE', 'XNA',
'MSY', 'PBI', 'ABE', 'HPN', 'EVV', 'ALB', 'LNK', 'AUS', 'PHF', 'CHA', 'GTR',
'BMI', 'BQK', 'CID', 'CAK', 'ATW', 'ABY', 'CAE', 'SRQ', 'MLI', 'BHM', 'IAD',
'CSG', 'CMH', 'MCO', 'MBS', 'FLL', 'SDF', 'TPA', 'MVY', 'LAS', 'LGB', 'SFO',
'SAN', 'LAX', 'RNO', 'PDX', 'ANC', 'ABQ', 'SLC', 'DEN', 'PHX', 'OAK', 'SMF',
'SJU', 'SEA', 'HOU', 'STX', 'BUR', 'SWF', 'SJC', 'DAB', 'BQN', 'PSE', 'ORH',
'HYA', 'STT', 'ONT', 'HRL', 'ICT', 'ISP', 'LBB', 'MAF', 'MDW', 'OKC', 'PNS',
'SNA', 'TUS', 'AMA', 'BOI', 'CRP', 'DAL', 'ECP', 'ELP', 'GEG', 'LFT', 'MFE',
'MDT', 'JAN', 'COS', 'MOB', 'VPS', 'MTJ', 'DRO', 'GPT', 'BFL', 'MRY', 'SBA',
'PSP', 'FSD', 'BRO', 'RAP', 'COU', 'STS', 'PIA', 'FAT', 'SBP', 'FSM', 'HSV',
'BIS', 'DAY', 'BZN', 'MIA', 'EYW', 'MYR', 'HHH', 'GJT', 'FAR', 'SGF', 'HOB',
'CLL', 'LRD', 'AEX', 'ERI', 'MLU', 'LCH', 'ROA', 'LAW', 'MHK', 'GRK', 'SAF',
'GRI', 'JLN', 'ROW', 'FWA', 'CRW', 'LAN', 'OGG', 'HNL', 'KOA', 'EGE', 'LIH',
'MLB', 'JAC', 'FAI', 'RDM', 'ADQ', 'BET', 'BRW', 'SCC', 'KTN', 'YAK', 'CDV',
'JNU', 'SIT', 'PSG', 'WRG', 'OME', 'OTZ', 'ADK', 'FCA', 'FAY', 'PSC', 'BIL',
'MSO', 'ITO', 'PPG', 'MFR', 'EUG', 'GUM', 'SPN', 'DLH', 'TTN', 'BKG', 'SFB',
'PIE', 'PGD', 'AZA', 'SMX', 'RFD', 'SCK', 'OWB', 'HTS', 'BLV', 'IAG', 'USA',
'GFK', 'BLI', 'ELM', 'PBG', 'LCK', 'GTF', 'OGD', 'IDA', 'PVU', 'TOL', 'PSM',
'CKB', 'HGR', 'SPI', 'STC', 'ACT', 'TYR', 'ABI', 'AZO', 'CMI', 'BPT', 'GCK',
'MQT', 'ALO', 'TXK', 'SPS', 'SWO', 'DBQ', 'SUX', 'SJT', 'GGG', 'LSE', 'LBE',
'ACY', 'LYH', 'PGV', 'HVN', 'EWN', 'DHN', 'PIH', 'IMT', 'WYS', 'CPR', 'SCE',
'HLN', 'SUN', 'ISN', 'CMX', 'EAU', 'LWB', 'SHD', 'LBF', 'HYS', 'SLN', 'EAR',
'VEL', 'CNY', 'GCC', 'RKS', 'PUB', 'LBL', 'MKG', 'PAH', 'CGI', 'UIN', 'BFF',
'DVL', 'JMS', 'LAR', 'SGU', 'PRC', 'ASE', 'RDD', 'ACV', 'OTH', 'COD', 'LWS',
'ABR', 'APN', 'ESC', 'PLN', 'BJI', 'BRD', 'BTM', 'CDC', 'CIU', 'EKO', 'TWF',
'HIB', 'BGM', 'RHI', 'ITH', 'INL', 'FLG', 'YUM', 'MEI', 'PIB', 'HDN']
The Destination airports covered are:  ['CVG', 'PWM', 'RDU', 'MSP', 'MSN', 'S
HV', 'CLT', 'PIT', 'RIC', 'IAH', 'ATL', 'JFK', 'DCA', 'DTW', 'LGA', 'TYS', 'P
VD', 'FNT', 'LIT', 'BUF', 'ORD', 'TRI', 'IND', 'BGR', 'AVP', 'BWI', 'LEX', 'B
DL', 'GRR', 'CWA', 'TUL', 'MEM', 'AGS', 'EWR', 'MGM', 'PHL', 'SYR', 'OMA', 'S
TL', 'TVC', 'ORF', 'CLE', 'ABY', 'BOS', 'OAJ', 'TLH', 'BTR', 'SAT', 'JAX', 'B
NA', 'CHO', 'VLD', 'ROC', 'DFW', 'GNV', 'ACK', 'PBI', 'CHS', 'GRB', 'MOT', 'M
KE', 'DSM', 'ILM', 'GSO', 'MCI', 'SBN', 'BTV', 'MVY', 'XNA', 'RST', 'EVV', 'H
PN', 'RSW', 'MDT', 'ROA', 'GSP', 'MCO', 'CSG', 'SAV', 'PHF', 'ALB', 'CHA', 'A
BE', 'BMI', 'MSY', 'IAD', 'GTR', 'CID', 'CAK', 'ATW', 'AUS', 'BQK', 'MLI', 'C
AE', 'CMH', 'AVL', 'MBS', 'FLL', 'SDF', 'TPA', 'LNK', 'SRQ', 'MHT', 'BHM', 'L
AS', 'SFO', 'SAN', 'RNO', 'LGB', 'ANC', 'PDX', 'SJU', 'ABQ', 'SLC', 'DEN', 'L
AX', 'PHX', 'OAK', 'SMF', 'SEA', 'STX', 'BUR', 'DAB', 'SJC', 'SWF', 'HOU', 'B
QN', 'PSE', 'ORH', 'HYA', 'STT', 'ONT', 'DAL', 'ECP', 'ELP', 'HRL', 'MAF', 'M
DW', 'OKC', 'PNS', 'SNA', 'AMA', 'BOI', 'GEG', 'ICT', 'LBB', 'TUS', 'ISP', 'C
RP', 'MFE', 'LFT', 'VPS', 'JAN', 'COS', 'MOB', 'DRO', 'GPT', 'BFL', 'COU', 'S
BP', 'MTJ', 'SBA', 'PSP', 'FSD', 'FSM', 'BRO', 'PIA', 'STS', 'FAT', 'RAP', 'M
RY', 'HSV', 'BIS', 'DAY', 'BZN', 'MIA', 'EYW', 'MYR', 'HHH', 'GJT', 'FAR', 'M
```

```
LU', 'LRD', 'CLL', 'LCH', 'FWA', 'GRK', 'SGF', 'HOB', 'LAW', 'MHK', 'SAF', 'J
LN', 'ROW', 'GRI', 'AEX', 'CRW', 'LAN', 'ERI', 'HNL', 'KOA', 'OGG', 'EGE', 'L
IH', 'JAC', 'MLB', 'RDM', 'BET', 'ADQ', 'BRW', 'SCC', 'FAI', 'JNU', 'CDV', 'Y
AK', 'SIT', 'KTN', 'WRG', 'PSG', 'OME', 'OTZ', 'ADK', 'FCA', 'BIL', 'PSC', 'F
AY', 'MSO', 'ITO', 'PPG', 'MFR', 'DLH', 'EUG', 'GUM', 'SPN', 'TTN', 'BKG', 'A
ZA', 'SFB', 'LCK', 'BLI', 'SCK', 'PIE', 'RFD', 'PVU', 'PBG', 'BLV', 'PGD', 'S
PI', 'USA', 'TOL', 'IDA', 'ELM', 'HTS', 'HGR', 'SMX', 'OGD', 'GFK', 'STC', 'G
TF', 'IAG', 'CKB', 'OWB', 'PSM', 'ABI', 'TYR', 'ALO', 'SUX', 'AZO', 'ACT', 'C
MI', 'BPT', 'TXK', 'SWO', 'SPS', 'DBQ', 'SJT', 'GGG', 'LSE', 'MQT', 'GCK', 'L
BE', 'ACY', 'LYH', 'PGV', 'HVN', 'EWN', 'DHN', 'PIH', 'WYS', 'SCE', 'IMT', 'H
LN', 'ASE', 'SUN', 'ISN', 'EAR', 'SGU', 'VEL', 'SHD', 'LWB', 'MKG', 'SLN', 'H
YS', 'BFF', 'PUB', 'LBL', 'CMX', 'EAU', 'PAH', 'UIN', 'RKS', 'CGI', 'CNY', 'J
MS', 'DVL', 'LAR', 'GCC', 'LBF', 'PRC', 'RDD', 'ACV', 'OTH', 'COD', 'LWS', 'A
BR', 'APN', 'PLN', 'BJI', 'CPR', 'BRD', 'BTM', 'CDC', 'CIU', 'ESC', 'EKO', 'I
TH', 'HIB', 'BGM', 'TWF', 'RHI', 'INL', 'FLG', 'YUM', 'MEI', 'PIB', 'HDN']
```

Question: What is the count of all the origin and destination airports?

Hint: You can use the Pandas `values_count` function (documentation (https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.Series.value_counts.html)) to find out the values for each airport using the columns `Origin` and `Dest` .

In [13]:
```
counts = pd.DataFrame({'Origin':df_temp['Origin'].value_counts(), 'Destinatio
n':df_temp['Dest'].value_counts()})
counts
```

Out[13]:

	Origin	Destination
ABE	303	303
ABI	169	169
ABQ	2077	2076
ABR	60	60
ABY	79	79
...	...	...
WRG	60	60
WYS	52	52
XNA	1004	1004
YAK	60	60
YUM	96	96

346 rows × 2 columns

Question: Print the top 15 origin and destination airports based on number of flights in the dataset.

Hint: You can use the Pandas `sort_values` function (documentation (https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.DataFrame.sort_values.html)).

In [14]:
```
counts.sort_values(by=['Origin'],ascending=False).head(15)
```

Out[14]:

	Origin	Destination
ATL	31525	31521
ORD	28257	28250
DFW	22802	22795
DEN	19807	19807
CLT	19655	19654
LAX	17875	17873
SFO	14332	14348
IAH	14210	14203
LGA	13850	13850
MSP	13349	13347
LAS	13318	13322
PHX	13126	13128
DTW	12725	12724
BOS	12223	12227
SEA	11872	11877

Question: Given all the information about a flight trip, can you predict if it would be delayed?

Answer: The column **ArrDel15** is an indicator variable that takes the value 1 when the delay is more than 15 minutes, 0 otherwise.

You could use this as a target column for the classification problem.

Now, assume you are traveling from San Francisco to Los Angeles on a work trip. You want to have an ideas if your flight will be delayed, given a set of features, so that you can manage your reservations in Los Angeles better. How many features from this dataset would you know before your flight?

Columns such as `DepDelay`, `ArrDelay`, `CarrierDelay`, `WeatherDelay`, `NASDelay`, `SecurityDelay`, `LateAircraftDelay`, and `DivArrDelay` contain information about a delay. But this delay could have occured at the origin or destination. If there were a sudden weather delay 10 minutes before landing, this data would not be helpful in managing your Los Angeles reservations.

So to simplify the problem statement, consider the following columns to predict an arrival delay:

`Year`, `Quarter`, `Month`, `DayofMonth`, `DayOfWeek`, `FlightDate`, `Reporting_Airline`, `Origin`, `OriginState`, `Dest`, `DestState`, `CRSDepTime`, `DepDelayMinutes`, `DepartureDelayGroups`, `Cancelled`, `Diverted`, `Distance`, `DistanceGroup`, `ArrDelay`, `ArrDelayMinutes`, `ArrDel15`, `AirTime`

You will also filter the source and destination airports to be:

- Top airports: ATL, ORD, DFW, DEN, CLT, LAX, IAH, PHX, SFO
- Top 5 airlines: UA, OO, WN, AA, DL

This should help in reducing the size of data across the CSV files to be combined.

Combine all CSV files

Hint:
First, create an empy dataframe that you will use to copy your individual dataframes from each file. Then, for each file in the `csv_files` list:

1. Read the CSV file into a dataframe
2. Filter the columns based on the `filter_cols` variable

```
columns = ['col1', 'col2']
df_filter = df[columns]
```

1. Keep only the subset_vals in each of the subset_cols. Use the `isin` Pandas function (documentation (https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.DataFrame.isin.html)) to check if the `val` is in the dataframe column and then choose the rows that include it.

```
df_eg[df_eg['col1'].isin('5')]
```

1. Concatenate the dataframe with the empty dataframe

In [15]:
```
def combine_csv(csv_files, filter_cols, subset_cols, subset_vals, file_name =
'data/combined_files.csv'):
    """
    Combine csv files into one Data Frame
    csv_files: list of csv file paths
    filter_cols: list of columns to filter
    subset_cols: list of columns to subset rows
    subset_vals: list of list of values to subset rows
    """

    df = pd.DataFrame()

    for file in csv_files:
        df_temp = pd.read_csv(file)
        df_temp = df_temp[filter_cols]
        for col, val in zip(subset_cols,subset_vals):
            df_temp = df_temp[df_temp[col].isin(val)]

        df = pd.concat([df, df_temp], axis=0)


    df.to_csv(file_name, index=False)
    print(f'Combined csv stored at {file_name}')
```

In [16]:
```
#cols is the list of columns to predict Arrival Delay
cols = ['Year','Quarter','Month','DayofMonth','DayOfWeek','FlightDate',
        'Reporting_Airline','Origin','OriginState','Dest','DestState',
        'CRSDepTime','Cancelled','Diverted','Distance','DistanceGroup',
        'ArrDelay','ArrDelayMinutes','ArrDel15','AirTime']

subset_cols = ['Origin', 'Dest', 'Reporting_Airline']

# subset_vals is a list collection of the top origin and destination airports
 and top 5 airlines
subset_vals = [['ATL', 'ORD', 'DFW', 'DEN', 'CLT', 'LAX', 'IAH', 'PHX', 'SFO'
],
               ['ATL', 'ORD', 'DFW', 'DEN', 'CLT', 'LAX', 'IAH', 'PHX', 'SFO'
],
               ['UA', 'OO', 'WN', 'AA', 'DL']]
```

Use the function above to merge all the different files into a single file that you can read easily.

Note: This will take 5-7 minutes to complete.

In [17]:
```
start = time.time()
combine_csv(csv_files, cols, subset_cols, subset_vals)
print(f'csv\'s merged in {round((time.time() - start)/60,2)} minutes')
```

```
Combined csv stored at data/combined_files.csv
csv's merged in 4.31 minutes
```

Load dataset

Load the combined dataset.

In [18]:
```
data = pd.read_csv('/home/ec2-user/SageMaker/project/data/combined_files.csv')
```

Print the first 5 records.

In [19]:
```
data.head(5)
```

Out[19]:

	Year	Quarter	Month	DayofMonth	DayOfWeek	FlightDate	Reporting_Airline	Origin	OriginS
0	2017	4	10	1	7	2017-10-01	OO	ATL	
1	2017	4	10	1	7	2017-10-01	OO	ORD	
2	2017	4	10	1	7	2017-10-01	OO	LAX	
3	2017	4	10	1	7	2017-10-01	OO	PHX	
4	2017	4	10	1	7	2017-10-01	OO	PHX	

Here are some more questions to help you find out more about your dataset.

Questions

1. How many rows and columns does the dataset have?
2. How many years are included in the dataset?
3. What is the date range for the dataset?
4. Which airlines are included in the dataset?
5. Which origin and destination airports are covered?

In [20]:
```
print("The #rows and #columns are ", data.shape[0] , " and ", data.shape[1])
print("The years in this dataset are: ", list(data.Year.unique()))
print("The months covered in this dataset are: ", sorted(list(data.Month.uniqu
e())))
print("The date range for data is :" , min(data.FlightDate), " to ", max(data.
FlightDate))
print("The airlines covered in this dataset are: ", list(data.Reporting_Airlin
e.unique()))
print("The Origin airports covered are: ", list(data.Origin.unique()))
print("The Destination airports covered are: ", list(data.Dest.unique()))
```

```
The #rows and #columns are  1658130  and  20
The years in this dataset are:  [2017, 2014, 2018, 2015, 2016]
The months covered in this dataset are:  [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11,
12]
The date range for data is :  2014-01-01  to  2018-12-31
The airlines covered in this dataset are:  ['OO', 'WN', 'UA', 'DL', 'AA']
The Origin airports covered are:  ['ATL', 'ORD', 'LAX', 'PHX', 'IAH', 'DEN',
'SFO', 'DFW', 'CLT']
The Destination airports covered are:  ['ORD', 'ATL', 'PHX', 'LAX', 'IAH', 'D
EN', 'SFO', 'DFW', 'CLT']
```

Let's define our **target column : is_delay** (1 - if arrival time delayed more than 15 minutes, 0 - otherwise). Use the `rename` method to rename the column from `ArrDel15` to `is_delay` .

Hint: You can use the Pandas `rename` function (documentation (https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.DataFrame.rename.html)).

For example:

```
df.rename(columns={'col1':'column1'}, inplace=True)
```

In [21]:
```
# Rename ArrDel15 to is_delay
data.rename(columns={'ArrDel15':'is_delay'}, inplace=True)
```

Look for nulls across columns. You can use the `isnull()` function (documentation (https://pandas.pydata.org/pandas-docs/version/0.17.0/generated/pandas.isnull.html)).

Hint: `isnull()` detects whether the particular value is null or not and gives you a boolean (True or False) in its place. Use the `sum(axis=0)` function to sum up the number of columns.

In [22]:
```
data.isnull().sum(axis = 0)
```

Out[22]:
```
Year                     0
Quarter                  0
Month                    0
DayofMonth               0
DayOfWeek                0
FlightDate               0
Reporting_Airline        0
Origin                   0
OriginState              0
Dest                     0
DestState                0
CRSDepTime               0
Cancelled                0
Diverted                 0
Distance                 0
DistanceGroup            0
ArrDelay             22540
ArrDelayMinutes      22540
is_delay             22540
AirTime              22540
dtype: int64
```

The arrival delay details and airtime are missing for 22540 out of 1658130 rows, which is 1.3%. You can either remove or impute these rows. The documentation does not mention anything about missing rows.

Hint: Use the `~` operator to choose the values that aren't null from the `isnull()` output.

For example:

```
null_eg = df_eg[~df_eg['column_name'].isnull()]
```

In [23]:
```
### Remove null columns
data = data[~data.is_delay.isnull()]
data.isnull().sum(axis = 0)
```

Out[23]:
```
Year                0
Quarter             0
Month               0
DayofMonth          0
DayOfWeek           0
FlightDate          0
Reporting_Airline   0
Origin              0
OriginState         0
Dest                0
DestState           0
CRSDepTime          0
Cancelled           0
Diverted            0
Distance            0
DistanceGroup       0
ArrDelay            0
ArrDelayMinutes     0
is_delay            0
AirTime             0
dtype: int64
```

Get the hour of the day in 24-hour time format from CRSDepTime.

In [24]:
```
data['DepHourofDay'] = (data['CRSDepTime']//100)
```

The ML problem statement

- Given a set of features, can you predict if a flight is going to be delayed more than 15 minutes?
- Because the target variable takes only 0/1 value, you could use a classification algorithm.

Before jumping to modeling, it is always a good practice to look at feature distribution, correlations, etc.

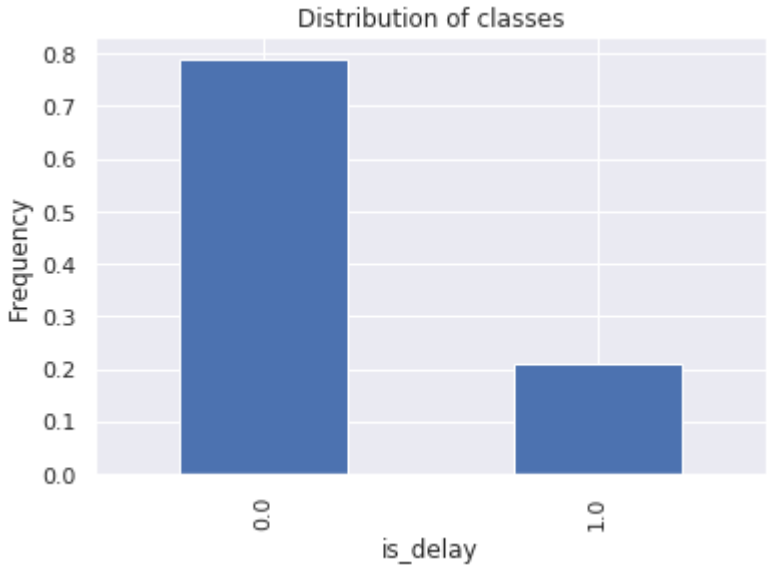
- This will give an idea of any non-linearity/patterns in the data.
  - Linear models: Add power/exponential/interaction features
  - Try a non-linear model
- Data imbalance
  - Choose metrics that will not give biased model performance (accuracy. vs AUC)
  - Use weighted/custom loss functions
- Missing data
  - Do imputation based on simple statistics - mean, median, mode (numerical variables) frequent class (categorical variables)
  - Clustering based imputation (KNNs to predict column value)
  - Drop column

Data exploration

Check class delay vs. no delay

Hint: Use a `groupby` plot (documentation (https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.DataFrame.groupby.html)) with a `bar` plot (documentation (https://matplotlib.org/tutorials/introductory/pyplot.html)) to plot the frequency vs. distribution of the class.

In [25]:
```
(data.groupby('is_delay').size()/len(data) ).plot(kind='bar')
plt.ylabel('Frequency')
plt.title('Distribution of classes')
plt.show()
```



Question: What can you deduce from the bar plot about the ratio of delay vs. no delay?

Answer: 80% of flights arrive on time, but 20% do not. This is clear class imbalance.

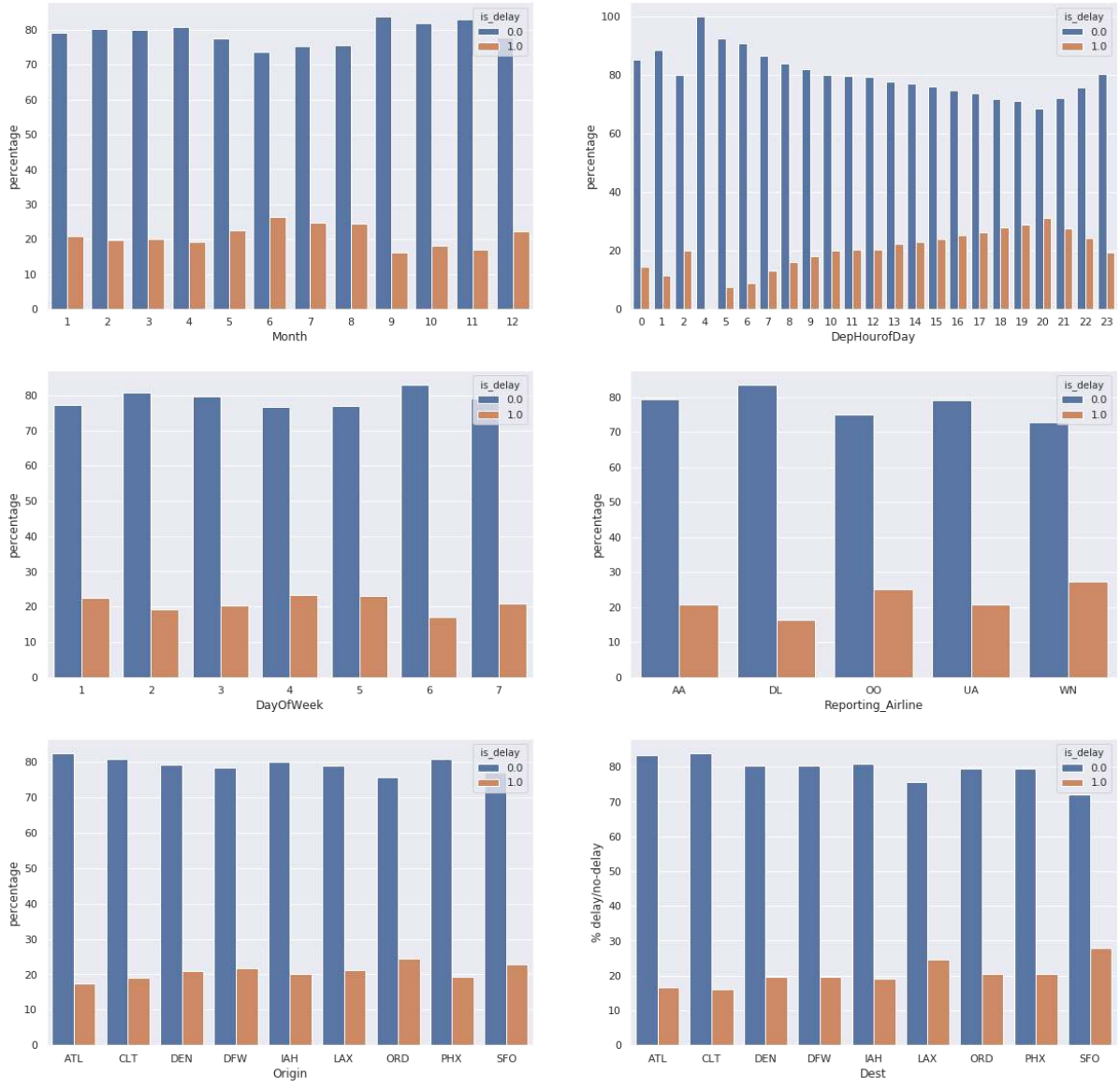
Questions:

- Which months have the most delays?
- What time of the day has the most delays?
- What day of the week has the most delays?
- Which airline has the most delays?
- Which origin and destination airports have the most delays?
- Is flight distance a factor in the delays?

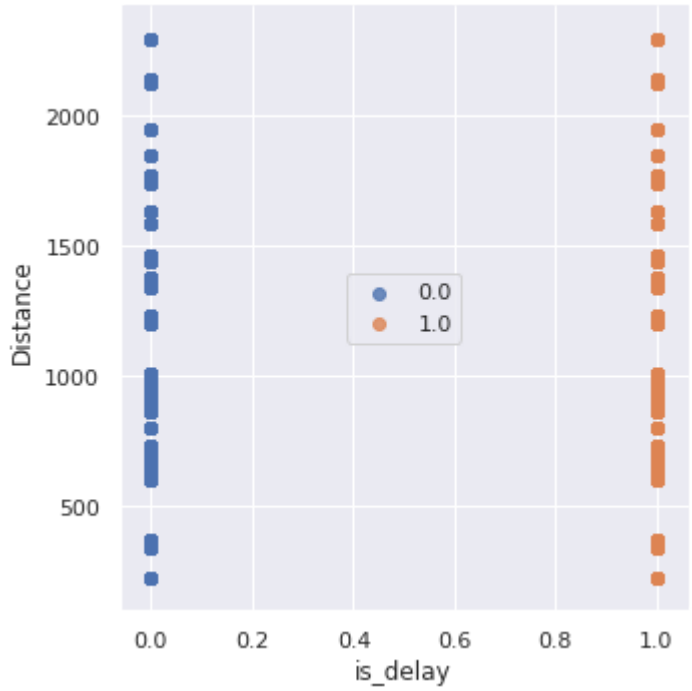
In [26]:
```
viz_columns = ['Month', 'DepHourofDay', 'DayOfWeek', 'Reporting_Airline', 'Origin', 'Dest']
fig, axes = plt.subplots(3, 2, figsize=(20,20), squeeze=False)
# fig.autofmt_xdate(rotation=90)

for idx, column in enumerate(viz_columns):
    ax = axes[idx//2, idx%2]
    temp = data.groupby(column)['is_delay'].value_counts(normalize=True).rename('percentage').\
    mul(100).reset_index().sort_values(column)
    sns.barplot(x=column, y="percentage", hue="is_delay", data=temp, ax=ax)
    plt.ylabel('% delay/no-delay')


plt.show()
```



In [27]:
```
sns.lmplot( x="is_delay", y="Distance", data=data, fit_reg=False, hue='is_dela
y', legend=False)
plt.legend(loc='center')
plt.xlabel('is_delay')
plt.ylabel('Distance')
plt.show()
```



Answers

- We see that the % delay is high in May, June, July, and August (Months 5-8).
- % delays are higher at night than during the day. There are no flights departing at 3AM!
- Sunday(1), Wednesday(4), Saturday(7) have relatively higher delays than other days.
- Airline WN has the highest % delays compared to others.
- Delays seem to occur in both short and long distance flight journeys.
- Flights with SFO as a destination have higher delays than others.

Even though some of the variables are encoded in numbers, it is important to consider them as categorical variables because we don't see a quantitative relation between them and the target variable.

Features

Look at all the columns and what their specific types are.

In [28]:
```
data.columns
```

Out[28]:
```
Index(['Year', 'Quarter', 'Month', 'DayofMonth', 'DayOfWeek', 'FlightDate',
       'Reporting_Airline', 'Origin', 'OriginState', 'Dest', 'DestState',
       'CRSDepTime', 'Cancelled', 'Diverted', 'Distance', 'DistanceGroup',
       'ArrDelay', 'ArrDelayMinutes', 'is_delay', 'AirTime', 'DepHourofDay'],
      dtype='object')
```

Filtering the required columns:

- Date is redundant, because you have Year, Quarter, Month, DayofMonth, and DayOfWeek to describe the date.
- Use Origin and Dest codes instead of OriginState and DestState.
- Because you are just classifying whether the flight is delayed or not, you don't need TotalDelayMinutes, DepDelayMinutes, and ArrDelayMinutes.

Treat DepHourofDay as a categorical variable because it doesn't have any quantitative relation with the target.

- If you had to do a one-hot encoding of it, it would result in 23 more columns.
- Other alternatives to handling categorical variables include hash encoding, regularized mean encoding, and bucketizing the values, among others.
- Just split into buckets here.

Hint: To change a column type to category, use the `astype` function (documentation (https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.DataFrame.astype.html)).

In [29]:
```
data_orig = data.copy()
data = data[[ 'Quarter', 'Month', 'DayofMonth', 'DayOfWeek',
       'Reporting_Airline', 'Origin', 'Dest','Distance','DepHourofDay', 'is_de
lay']]
categorical_columns  = ['Quarter', 'Month', 'DayofMonth', 'DayOfWeek',
       'Reporting_Airline', 'Origin', 'Dest', 'DepHourofDay', 'is_delay']
for c in categorical_columns:
    data[c] = data[c].astype('category')
```

To use one-hot encoding, use the Pandas `get_dummies` function for the categorical columns that you selected above. Then, you can concatenate those generated features to your original dataset using the Pandas `concat` function. For encoding categorical variables, you can also use *dummy encoding* by using a keyword `drop_first=True`. For more information on dummy encoding, see https://en.wikiversity.org/wiki/Dummy_variable_(statistics (https://en.wikiversity.org/wiki/Dummy_variable_(statistics)).

For example:

```
pd.get_dummies(df[['column1','columns2']], drop_first=True)
```

In [30]:
```
categorical_columns.remove('is_delay')
data_dummies = pd.get_dummies(data[categorical_columns], drop_first=True)
data = pd.concat([data, data_dummies], axis = 1)
data.drop(categorical_columns,axis=1, inplace=True)
```

Check the length of the dataset and the new columnms.

In [31]:
```
len(data)
```

Out[31]:
```
1635590
```

In [32]:
```
data.columns
```

Out[32]:
```
Index(['Distance', 'is_delay', 'Quarter_2', 'Quarter_3', 'Quarter_4',
       'Month_2', 'Month_3', 'Month_4', 'Month_5', 'Month_6', 'Month_7',
       'Month_8', 'Month_9', 'Month_10', 'Month_11', 'Month_12',
       'DayofMonth_2', 'DayofMonth_3', 'DayofMonth_4', 'DayofMonth_5',
       'DayofMonth_6', 'DayofMonth_7', 'DayofMonth_8', 'DayofMonth_9',
       'DayofMonth_10', 'DayofMonth_11', 'DayofMonth_12', 'DayofMonth_13',
       'DayofMonth_14', 'DayofMonth_15', 'DayofMonth_16', 'DayofMonth_17',
       'DayofMonth_18', 'DayofMonth_19', 'DayofMonth_20', 'DayofMonth_21',
       'DayofMonth_22', 'DayofMonth_23', 'DayofMonth_24', 'DayofMonth_25',
       'DayofMonth_26', 'DayofMonth_27', 'DayofMonth_28', 'DayofMonth_29',
       'DayofMonth_30', 'DayofMonth_31', 'DayOfWeek_2', 'DayOfWeek_3',
       'DayOfWeek_4', 'DayOfWeek_5', 'DayOfWeek_6', 'DayOfWeek_7',
       'Reporting_Airline_DL', 'Reporting_Airline_OO', 'Reporting_Airline_U
A',
       'Reporting_Airline_WN', 'Origin_CLT', 'Origin_DEN', 'Origin_DFW',
       'Origin_IAH', 'Origin_LAX', 'Origin_ORD', 'Origin_PHX', 'Origin_SFO',
       'Dest_CLT', 'Dest_DEN', 'Dest_DFW', 'Dest_IAH', 'Dest_LAX', 'Dest_OR
D',
       'Dest_PHX', 'Dest_SFO', 'DepHourofDay_1', 'DepHourofDay_2',
       'DepHourofDay_4', 'DepHourofDay_5', 'DepHourofDay_6', 'DepHourofDay_
7',
       'DepHourofDay_8', 'DepHourofDay_9', 'DepHourofDay_10',
       'DepHourofDay_11', 'DepHourofDay_12', 'DepHourofDay_13',
       'DepHourofDay_14', 'DepHourofDay_15', 'DepHourofDay_16',
       'DepHourofDay_17', 'DepHourofDay_18', 'DepHourofDay_19',
       'DepHourofDay_20', 'DepHourofDay_21', 'DepHourofDay_22',
       'DepHourofDay_23'],
      dtype='object')
```

Now you are ready to do model training. Before splitting the data, rename the column `is_delay` to `target` .

Hint: You can use the Pandas `rename` function (documentation (https://pandas.pydata.org/pandas-docs/stable/reference/api/pandas.DataFrame.rename.html)).

In [33]:
```
data.rename(columns = {'is_delay':'target'}, inplace=True )
```

Project Solution Lab 3:

Step 3: Model training and evaluation

There are some preliminary steps that you must include when converting the dataset from a dataframe to a format that a machine learning algorithm can use. For Amazon SageMaker, here are the steps you need to take:

1. Split the data into `train_data`, `validation_data`, and `test_data` using `sklearn.model_selection.train_test_split`.
2. Convert the dataset to an appropriate file format that the Amazon SageMaker training job can use. This can be either a CSV file or record protobuf. For more information, see Common Data Formats for Training (https://docs.aws.amazon.com/sagemaker/latest/dg/cdf-training.html).
3. Upload the data to your Amazon S3 bucket. If you have not created one before, see Create a Bucket (https://docs.aws.amazon.com/AmazonS3/latest/gsg/CreatingABucket.html).

Use the following cells to complete these steps. Insert and delete cells where needed.

Project presentation: Take note of the key decisions you've made in this phase in your project presentation.

Train test split

In [34]:
```
from sklearn.model_selection import train_test_split

def create_training_sets(data):
    """
    Convert data frame to train, validation and test
    params:
        data: The dataframe with the dataset to be split
    Returns:
        train_features: Training feature dataset
        test_features: Test feature dataset
        train_labels: Labels for the training dataset
        test_labels: Labels for the test dataset
        val_features: Validation feature dataset
        val_labels: Labels for the validation dataset
    """
    # Extract the target variable from the dataframe and convert the type to f
loat32
    ys = np.array(data["target"]).astype("float32")

    # Drop all the unwanted columns including the target column
    drop_list = ["target"]

    # Drop the columns from the drop_list and convert the data into a NumPy ar
ray of type float32
    xs = np.array(data.drop(drop_list, axis=1)).astype("float32")

    np.random.seed(0)

    # Use the sklearn function train_test_split to split the dataset in the ra
tio train 80% and test 20%
    train_features, test_features, train_labels, test_labels = train_test_spli
t(
    xs, ys, test_size=0.2)

    # Use the sklearn function again to split the temp dataset into 50% valida
tion and 50% test
    val_features, test_features, val_labels, test_labels = train_test_split(
    test_features, test_labels, test_size=0.5)

    return train_features, test_features, train_labels, test_labels, val_featu
res, val_labels
```

In [35]:
```
train_features, test_features, train_labels, test_labels, val_features, val_la
bels = create_training_sets(data)

print(f"Length of train_features is: {train_features.shape}")
print(f"Length of train_labels is: {train_labels.shape}")
print(f"Length of val_features is: {val_features.shape}")
print(f"Length of val_labels is: {val_labels.shape}")
print(f"Length of test_features is: {test_features.shape}")
print(f"Length of test_labels is: {test_labels.shape}")
```

```
Length of train_features is: (1308472, 93)
Length of train_labels is: (1308472,)
Length of val_features is: (163559, 93)
Length of val_labels is: (163559,)
Length of test_features is: (163559, 93)
Length of test_labels is: (163559,)
```

Answer

```
Length of train_features is: (1308472, 94)
Length of train_labels is: (1308472,)
Length of val_features is: (163559, 94)
Length of val_labels is: (163559,)
Length of test_features is: (163559, 94)
Length of test_labels is: (163559,)
```

Baseline classification model

In [36]:
```
import sagemaker
from sagemaker.predictor import CSVSerializer
from sagemaker.amazon.amazon_estimator import RecordSet
import boto3

# Instantiate the LinearLearner estimator object
num_classes = len(pd.unique(train_labels))

classifier_estimator = sagemaker.LinearLearner(role=sagemaker.get_execution_ro
le(),
                                               instance_count=1,
                                               instance_type='ml.m4.xlarge',
                                               predictor_type='binary_classifi
er',
                                              binary_classifier_model_selectio
n_criteria = 'cross_entropy_loss')
```

Linear learner accepts training data in protobuf or CSV content types, and accepts inference requests in protobuf, CSV, or JSON content types. Training data has features and ground-truth labels, while the data in an inference request has only features.

In a production pipeline, it is recommended to convert the data to the Amazon SageMaker protobuf format and store it in Amazon S3. However, to get up and running quickly, AWS provides the convenient method `record_set` for converting and uploading when the dataset is small enough to fit in local memory. It accepts NumPy arrays like the ones you already have, so let's use it here. The `RecordSet` object will keep track of the temporary Amazon S3 location of your data. Use the `estimator.record_set` function to create train, validation, and test records. Then, use the `estimator.fit` function to start your training job.

In [37]:
```
### Create train, val, test record
train_records = classifier_estimator.record_set(train_features, train_labels,
channel='train')
val_records = classifier_estimator.record_set(val_features, val_labels, channe
l='validation')
test_records = classifier_estimator.record_set(test_features, test_labels, cha
nnel='test')

### Fit the classifier
classifier_estimator.fit([train_records, val_records, test_records])
```

```
Defaulting to the only supported framework/algorithm version: 1. Ignoring fra
mework/algorithm version: 1.
Defaulting to the only supported framework/algorithm version: 1. Ignoring fra
mework/algorithm version: 1.
```

```
2020-11-12 13:42:38 Starting - Starting the training job...
2020-11-12 13:42:58 Starting - Launching requested ML instances.........
2020-11-12 13:44:10 Starting - Preparing the instances for training......
2020-11-12 13:45:26 Downloading - Downloading input data...
2020-11-12 13:46:08 Training - Downloading the training image...
2020-11-12 13:46:28 Training - Training image download completed. Training in
progress.Docker entrypoint called with argument(s): train
Running default environment configuration script
[11/12/2020 13:46:32 INFO 140191812458304] Reading default configuration from
/opt/amazon/lib/python2.7/site-packages/algorithm/resources/default-input.jso
n: {u'loss_insensitivity': u'0.01', u'epochs': u'15', u'feature_dim': u'aut
o', u'init_bias': u'0.0', u'lr_scheduler_factor': u'auto', u'num_calibration_
samples': u'10000000', u'accuracy_top_k': u'3', u'_num_kv_servers': u'auto',
 u'use_bias': u'true', u'num_point_for_scaler': u'10000', u'_log_level': u'in
fo', u'quantile': u'0.5', u'bias_lr_mult': u'auto', u'lr_scheduler_step': u'a
uto', u'init_method': u'uniform', u'init_sigma': u'0.01', u'lr_scheduler_mini
mum_lr': u'auto', u'target_recall': u'0.8', u'num_models': u'auto', u'early_s
topping_patience': u'3', u'momentum': u'auto', u'unbias_label': u'auto', u'w
d': u'auto', u'optimizer': u'auto', u'_tuning_objective_metric': u'', u'early
_stopping_tolerance': u'0.001', u'learning_rate': u'auto', u'_kvstore': u'aut
o', u'normalize_data': u'true', u'binary_classifier_model_selection_criteri
a': u'accuracy', u'use_lr_scheduler': u'true', u'target_precision': u'0.8',
 u'unbias_data': u'auto', u'init_scale': u'0.07', u'bias_wd_mult': u'auto',
 u'f_beta': u'1.0', u'mini_batch_size': u'1000', u'huber_delta': u'1.0', u'nu
m_classes': u'1', u'beta_1': u'auto', u'loss': u'auto', u'beta_2': u'auto',
 u'_enable_profiler': u'false', u'normalize_label': u'auto', u'_num_gpus':
 u'auto', u'balance_multiclass_weights': u'false', u'positive_example_weight_
mult': u'1.0', u'l1': u'auto', u'margin': u'1.0'}
[11/12/2020 13:46:32 INFO 140191812458304] Merging with provided configuratio
n from /opt/ml/input/config/hyperparameters.json: {u'feature_dim': u'93', u'm
ini_batch_size': u'1000', u'predictor_type': u'binary_classifier', u'binary_c
lassifier_model_selection_criteria': u'cross_entropy_loss'}
[11/12/2020 13:46:32 INFO 140191812458304] Final configuration: {u'loss_insen
sitivity': u'0.01', u'epochs': u'15', u'feature_dim': u'93', u'init_bias':
 u'0.0', u'lr_scheduler_factor': u'auto', u'num_calibration_samples': u'10000
000', u'accuracy_top_k': u'3', u'_num_kv_servers': u'auto', u'use_bias': u'tr
ue', u'num_point_for_scaler': u'10000', u'_log_level': u'info', u'quantile':
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e': u'0.001', u'learning_rate': u'auto', u'_kvstore': u'auto', u'normalize_da
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l': u'auto', u'_num_gpus': u'auto', u'balance_multiclass_weights': u'false',
 u'positive_example_weight_mult': u'1.0', u'l1': u'auto', u'margin': u'1.0'}
[11/12/2020 13:46:32 WARNING 140191812458304] Loggers have already been setu
p.
Process 1 is a worker.
[11/12/2020 13:46:32 INFO 140191812458304] Using default worker.
```

```
[11/12/2020 13:46:32 INFO 140191812458304] Checkpoint loading and saving are
 disabled.
[2020-11-12 13:46:32.986] [tensorio] [warning] TensorIO is already initialize
d; ignoring the initialization routine.
[2020-11-12 13:46:33.001] [tensorio] [warning] TensorIO is already initialize
d; ignoring the initialization routine.
[2020-11-12 13:46:33.066] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/train", "epoch": 0, "duration": 93, "num_examples": 1, "num_
bytes": 420000}
[11/12/2020 13:46:33 INFO 140191812458304] Create Store: local
[2020-11-12 13:46:33.286] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/train", "epoch": 1, "duration": 219, "num_examples": 11, "nu
m_bytes": 4620000}
[11/12/2020 13:46:33 INFO 140191812458304] Scaler algorithm parameters
 <algorithm.scaler.ScalerAlgorithmStable object at 0x7f808fa2bf10>
[11/12/2020 13:46:33 INFO 140191812458304] Scaling model computed with parame
ters:
 {'stdev_weight':
[5.38944458e+02 4.30678546e-01 4.41381633e-01 4.34885800e-01
 2.60583669e-01 2.78204143e-01 2.70729452e-01 2.73114115e-01
 2.79152125e-01 2.95462012e-01 2.84874916e-01 2.70305485e-01
 2.80364066e-01 2.73114145e-01 2.80498236e-01 1.75515771e-01
 1.71336770e-01 1.76241562e-01 1.85609370e-01 1.76241547e-01
 1.75515771e-01 1.68569982e-01 1.80055961e-01 1.73563421e-01
 1.80291310e-01 1.84239119e-01 1.74298480e-01 1.87418282e-01
 1.71585813e-01 1.81462720e-01 1.82857007e-01 1.77203983e-01
 1.73563436e-01 1.75999999e-01 1.70336545e-01 1.84009612e-01
 1.81229129e-01 1.78873971e-01 1.84239134e-01 1.81695953e-01
 1.82393610e-01 1.75030008e-01 1.76963925e-01 1.70085460e-01
 1.31292105e-01 3.52100879e-01 3.56357127e-01 3.58137488e-01
 3.58668089e-01 3.19350779e-01 3.47081333e-01 3.71672094e-01
 2.38159344e-01 4.61135209e-01 3.08881938e-01 2.37318337e-01
 3.19460273e-01 3.33278239e-01 2.72555709e-01 3.59460950e-01
 3.33785892e-01 2.97560334e-01 3.29374015e-01 2.38494679e-01
 3.14244658e-01 3.27495664e-01 2.70022362e-01 3.55909199e-01
 3.40261221e-01 2.99149632e-01 3.37995946e-01 4.85597514e-02
 1.00000000e+00 1.00000000e+00 1.62877053e-01 2.31320769e-01
 2.54840404e-01 2.58938968e-01 2.50964314e-01 2.41320595e-01
 2.37991467e-01 2.44104028e-01 2.32536137e-01 2.41979301e-01
 2.34771982e-01 2.39663541e-01 2.41650209e-01 2.22027034e-01
 2.21475884e-01 1.88091412e-01 1.52198195e-01 1.75515801e-01
 1.03875324e-01]
<NDArray 93 @cpu(0)>, 'stdev_label': None, 'mean_label': None, 'mean_weight':
[1.00651935e+03 2.46000037e-01 2.65090942e-01 2.53272712e-01
 7.32727498e-02 8.45454708e-02 7.96363726e-02 8.11818242e-02
 8.51818249e-02 9.66363698e-02 8.90908986e-02 7.93636292e-02
 8.60000104e-02 8.11818168e-02 8.60909149e-02 3.18181813e-02
 3.02727297e-02 3.20909098e-02 3.57272737e-02 3.20909098e-02
 3.18181850e-02 2.92727333e-02 3.35454568e-02 3.10909115e-02
 3.36363614e-02 3.51818204e-02 3.13636363e-02 3.64545435e-02
 3.03636417e-02 3.40909101e-02 3.46363671e-02 3.24545503e-02
 3.10909115e-02 3.20000015e-02 2.99090892e-02 3.50909121e-02
 3.40000056e-02 3.30909118e-02 3.51818204e-02 3.41818184e-02
 3.44545431e-02 3.16363685e-02 3.23636420e-02 2.98181865e-02
 1.75454561e-02 1.44999996e-01 1.49272755e-01 1.51090920e-01
 1.51636377e-01 1.15272738e-01 1.40090927e-01 1.65545464e-01
```

```
 6.03636429e-02 3.06727320e-01 1.06818192e-01 5.99090979e-02
 1.15363650e-01 1.27272740e-01 8.08181837e-02 1.52454555e-01
 1.27727285e-01 9.81818363e-02 1.23818196e-01 6.05454557e-02
 1.11090913e-01 1.22181833e-01 7.91818276e-02 1.48818195e-01
 1.33636355e-01 9.93636400e-02 1.31545454e-01 2.36363616e-03
 0.00000000e+00 0.00000000e+00 2.72727292e-02 5.67272753e-02
 6.98181912e-02 7.22727329e-02 6.75454587e-02 6.20909147e-02
 6.02727346e-02 6.36363700e-02 5.73636405e-02 6.24545515e-02
 5.85454553e-02 6.11818247e-02 6.22727349e-02 5.20000048e-02
 5.17272837e-02 3.67272757e-02 2.37272773e-02 3.18181813e-02
 1.09090926e-02]
<NDArray 93 @cpu(0)>}
[11/12/2020 13:46:33 INFO 140191812458304] nvidia-smi took: 0.025178194046 se
cs to identify 0 gpus
[11/12/2020 13:46:33 INFO 140191812458304] Number of GPUs being used: 0
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1, "max": 0, "sum": 0.0, "min": 0}, "Number of Records Since Last Reset": {"c
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12000, "sum": 12000.0, "min": 12000}, "Max Records Seen Between Resets": {"co
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sions": {"Host": "algo-1", "Meta": "init_train_data_iter", "Operation": "trai
ning", "Algorithm": "Linear Learner"}, "StartTime": 1605188793.43635}

[2020-11-12 13:47:19.085] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/train", "epoch": 3, "duration": 45648, "num_examples": 1309,
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```
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poch": 0}, "StartTime": 1605188839.085689}

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5185332668199452}}, "EndTime": 1605188839.08579, "Dimensions": {"model": 7,
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st": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoc
h": 0}, "StartTime": 1605188839.085901}

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[11/12/2020 13:47:19 INFO 140191812458304] #quality_metric: host=algo-1, epoch=0, train binary_classification_cross_entropy_objective <loss>=0.4946966112
[2020-11-12 13:47:19.109] [tensorio] [info] epoch_stats={"data_pipeline": "/o

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1, "num_bytes": 420000}
[2020-11-12 13:47:23.442] [tensorio] [info] epoch_stats={"data_pipeline": "/o
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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[11/12/2020 13:47:23 INFO 140191812458304] #quality_metric: host=algo-1, epoc
h=0, validation binary_classification_cross_entropy_objective <loss>=0.492167
102953
[11/12/2020 13:47:23 INFO 140191812458304] #early_stopping_criteria_metric: h
ost=algo-1, epoch=0, criteria=binary_classification_cross_entropy_objective,
 value=0.492167102953
[11/12/2020 13:47:23 INFO 140191812458304] Epoch 0: Loss improved. Updating b
est model
[11/12/2020 13:47:23 INFO 140191812458304] Saving model for epoch: 0
[11/12/2020 13:47:23 INFO 140191812458304] Saved checkpoint to "/tmp/tmpY2TD4
o/mx-mod-0000.params"
[11/12/2020 13:47:23 INFO 140191812458304] #progress_metric: host=algo-1, com
pleted 6 % of epochs
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[11/12/2020 13:47:23 INFO 140191812458304] #throughput_metric: host=algo-1, t
rain throughput=26155.9404221 records/second

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[2020-11-12 13:48:08.829] [tensorio] [info] epoch_stats={"data_pipeline": "/o
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[2020-11-12 13:48:13.087] [tensorio] [info] epoch_stats={"data_pipeline": "/opt/ml/input/data/validation", "epoch": 5, "duration": 4236, "num_examples": 164, "num_bytes": 68694780}
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[11/12/2020 13:48:13 INFO 140191812458304] #quality_metric: host=algo-1, epoc
h=1, validation binary_classification_cross_entropy_objective <loss>=0.492005
111202
[11/12/2020 13:48:13 INFO 140191812458304] #early_stopping_criteria_metric: h
ost=algo-1, epoch=1, criteria=binary_classification_cross_entropy_objective,
 value=0.492005111202
[11/12/2020 13:48:13 INFO 140191812458304] Saving model for epoch: 1
[11/12/2020 13:48:13 INFO 140191812458304] Saved checkpoint to "/tmp/tmpzoYKJ
V/mx-mod-0000.params"
[11/12/2020 13:48:13 INFO 140191812458304] #progress_metric: host=algo-1, com
pleted 13 % of epochs
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[11/12/2020 13:48:13 INFO 140191812458304] #throughput_metric: host=algo-1, t
rain throughput=26358.8260648 records/second
[2020-11-12 13:48:58.524] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/train", "epoch": 7, "duration": 45417, "num_examples": 1309,
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[11/12/2020 13:48:58 INFO 140191812458304] #quality_metric: host=algo-1, epoch=2, train binary_classification_cross_entropy_objective <loss>=0.492311689884

[2020-11-12 13:49:02.594] [tensorio] [info] epoch_stats={"data_pipeline": "/opt/ml/input/data/validation", "epoch": 8, "duration": 4036, "num_examples": 164, "num_bytes": 68694780}
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objective": {"count": 1, "max": 0.5118858319630167, "sum": 0.5118858319630167, "min": 0.5118858319630167}}, "EndTime": 1605188942.604184, "Dimensions": {"model": 7, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 2}, "StartTime": 1605188942.604166}

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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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[11/12/2020 13:49:02 INFO 140191812458304] #quality_metric: host=algo-1, epoc
h=2, validation binary_classification_cross_entropy_objective <loss>=0.492010
343032
[11/12/2020 13:49:02 INFO 140191812458304] #early_stopping_criteria_metric: h
ost=algo-1, epoch=2, criteria=binary_classification_cross_entropy_objective,
 value=0.492010343032
[11/12/2020 13:49:02 INFO 140191812458304] Saving model for epoch: 2
[11/12/2020 13:49:02 INFO 140191812458304] Saved checkpoint to "/tmp/tmplO02R
4/mx-mod-0000.params"
[11/12/2020 13:49:02 INFO 140191812458304] #progress_metric: host=algo-1, com
pleted 20 % of epochs
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ar Learner", "epoch": 2}, "StartTime": 1605188893.107237}

[11/12/2020 13:49:02 INFO 140191812458304] #throughput_metric: host=algo-1, t
rain throughput=26431.0844858 records/second
[2020-11-12 13:49:47.411] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/train", "epoch": 9, "duration": 44791, "num_examples": 1309,
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":

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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective": {"count": 1, "max": 0.49226496933869995, "sum": 0.49226496933869995, "min": 0.49226496933869995}}, "EndTime": 1605188987.411452, "Dimensions": {"model": 2, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 3}, "StartTime": 1605188987.411434}

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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective": {"count": 1, "max": 0.5153238309574418, "sum": 0.5153238309574418, "min": 0.5153238309574418}}, "EndTime": 1605188987.413039, "Dimensions": {"model": 29, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 3}, "StartTime": 1605188987.413019}

#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective": {"count": 1, "max": 0.5140407354372357, "sum": 0.5140407354372357, "min": 0.5140407354372357}}, "EndTime": 1605188987.41312, "Dimensions": {"model": 30, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 3}, "StartTime": 1605188987.4131}

#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective": {"count": 1, "max": 0.5153238404300234, "sum": 0.5153238404300234, "min": 0.5153238404300234}}, "EndTime": 1605188987.4132, "Dimensions": {"model": 31, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 3}, "StartTime": 1605188987.413181}

[11/12/2020 13:49:47 INFO 140191812458304] #quality_metric: host=algo-1, epoch=3, train binary_classification_cross_entropy_objective <loss>=0.492243028273
[2020-11-12 13:49:51.334] [tensorio] [info] epoch_stats={"data_pipeline": "/opt/ml/input/data/validation", "epoch": 11, "duration": 3901, "num_examples": 164, "num_bytes": 68694780}
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objective": {"count": 1, "max": 0.49200832418790535, "sum": 0.49200832418790535, "min": 0.49200832418790535}}, "EndTime": 1605188991.341257, "Dimensions": {"model": 2, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 3}, "StartTime": 1605188991.341246}

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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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[11/12/2020 13:49:51 INFO 140191812458304] #quality_metric: host=algo-1, epoc
h=3, validation binary_classification_cross_entropy_objective <loss>=0.492001
351711

```
[11/12/2020 13:49:51 INFO 140191812458304] #early_stopping_criteria_metric: h
ost=algo-1, epoch=3, criteria=binary_classification_cross_entropy_objective,
 value=0.491995013435
[11/12/2020 13:49:51 INFO 140191812458304] Saving model for epoch: 3
[11/12/2020 13:49:51 INFO 140191812458304] Saved checkpoint to "/tmp/tmp3wE55
5/mx-mod-0000.params"
[11/12/2020 13:49:51 INFO 140191812458304] #progress_metric: host=algo-1, com
pleted 26 % of epochs
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[11/12/2020 13:49:51 INFO 140191812458304] #throughput_metric: host=algo-1, t
rain throughput=26851.5417478 records/second
[2020-11-12 13:50:37.610] [tensorio] [info] epoch_stats={"data_pipeline": "/o
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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h": 4}, "StartTime": 1605189037.61297}

[11/12/2020 13:50:37 INFO 140191812458304] #quality_metric: host=algo-1, epoc
h=4, train binary_classification_cross_entropy_objective <loss>=0.49221655217
4
[2020-11-12 13:50:41.604] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/validation", "epoch": 14, "duration": 3970, "num_examples":
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti

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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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r", "epoch": 4}, "StartTime": 1605189041.612422}

#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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er", "epoch": 4}, "StartTime": 1605189041.612931}

#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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n": 0.5088721209739299}}, "EndTime": 1605189041.613284, "Dimensions": {"mode
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er", "epoch": 4}, "StartTime": 1605189041.613273}

#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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er", "epoch": 4}, "StartTime": 1605189041.613361}

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l": 24, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learn
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
ve": {"count": 1, "max": 0.513782313073534, "sum": 0.513782313073534, "min":
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
ve": {"count": 1, "max": 0.513785153636324, "sum": 0.513785153636324, "min":
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
ve": {"count": 1, "max": 0.5140526647192656, "sum": 0.5140526647192656, "mi
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er", "epoch": 4}, "StartTime": 1605189041.613808}

[11/12/2020 13:50:41 INFO 140191812458304] #quality_metric: host=algo-1, epoc
h=4, validation binary_classification_cross_entropy_objective <loss>=0.491997
897098
[11/12/2020 13:50:41 INFO 140191812458304] #early_stopping_criteria_metric: h
ost=algo-1, epoch=4, criteria=binary_classification_cross_entropy_objective,
 value=0.491995177816
[11/12/2020 13:50:41 INFO 140191812458304] Saving model for epoch: 4
[11/12/2020 13:50:41 INFO 140191812458304] Saved checkpoint to "/tmp/tmpMOIlX
m/mx-mod-0000.params"
[11/12/2020 13:50:41 INFO 140191812458304] Early stop condition met. Stopping
training.
[11/12/2020 13:50:41 INFO 140191812458304] #progress_metric: host=algo-1, com
pleted 100 % epochs
#metrics {"Metrics": {"Max Batches Seen Between Resets": {"count": 1, "max":
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ount": 1, "max": 1309, "sum": 1309.0, "min": 1309}, "Number of Records Since
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ar Learner", "epoch": 4}, "StartTime": 1605188991.35923}

[11/12/2020 13:50:41 INFO 140191812458304] #throughput_metric: host=algo-1, t
rain throughput=26033.673248 records/second
[11/12/2020 13:50:41 WARNING 140191812458304] wait_for_all_workers will not s
ync workers since the kv store is not running distributed
[11/12/2020 13:50:41 WARNING 140191812458304] wait_for_all_workers will not s
ync workers since the kv store is not running distributed
[2020-11-12 13:50:45.644] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/validation", "epoch": 17, "duration": 4006, "num_examples":

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 164, "num_bytes": 68694780}
[11/12/2020 13:50:45 INFO 140191812458304] #early_stopping_criteria_metric: h
ost=algo-1, epoch=4, criteria=binary_classification_cross_entropy_objective,
 value=0.491995177816
[2020-11-12 13:50:46.402] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/validation", "epoch": 19, "duration": 747, "num_examples": 1
64, "num_bytes": 68694780}
[11/12/2020 13:50:46 INFO 140191812458304] #validation_score (algo-1) : ('bin
ary_classification_cross_entropy_objective', 0.4921671029530294)
[11/12/2020 13:50:46 INFO 140191812458304] #validation_score (algo-1) : ('bin
ary_classification_accuracy', 0.7901919185125856)
[11/12/2020 13:50:46 INFO 140191812458304] #validation_score (algo-1) : ('bin
ary_f_1.000', 0.00734741105004339)
[11/12/2020 13:50:46 INFO 140191812458304] #validation_score (algo-1) : ('pre
cision', 0.5291666666666667)
[11/12/2020 13:50:46 INFO 140191812458304] #validation_score (algo-1) : ('rec
all', 0.003699388290125255)
[11/12/2020 13:50:46 INFO 140191812458304] #validation_score (algo-1) : ('roc
_auc_score', 0.6443875838932415)
[11/12/2020 13:50:46 INFO 140191812458304] #quality_metric: host=algo-1, vali
dation binary_classification_cross_entropy_objective <loss>=0.492167102953
[11/12/2020 13:50:46 INFO 140191812458304] #quality_metric: host=algo-1, vali
dation binary_classification_accuracy <score>=0.790191918513
[11/12/2020 13:50:46 INFO 140191812458304] #quality_metric: host=algo-1, vali
dation binary_f_1.000 <score>=0.00734741105004
[11/12/2020 13:50:46 INFO 140191812458304] #quality_metric: host=algo-1, vali
dation precision <score>=0.529166666667
[11/12/2020 13:50:46 INFO 140191812458304] #quality_metric: host=algo-1, vali
dation recall <score>=0.00369938829013
[11/12/2020 13:50:46 INFO 140191812458304] #quality_metric: host=algo-1, vali
dation roc_auc_score <score>=0.644387583893
[11/12/2020 13:50:46 INFO 140191812458304] Best model found for hyperparamete
rs: {"lr_scheduler_step": 10, "wd": 0.0001, "optimizer": "adam", "lr_schedule
r_factor": 0.99, "l1": 0.0, "learning_rate": 0.005, "lr_scheduler_minimum_l
r": 1e-05}
[11/12/2020 13:50:46 INFO 140191812458304] Saved checkpoint to "/tmp/tmpUkRog
H/mx-mod-0000.params"
[2020-11-12 13:50:46.479] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/test", "epoch": 0, "duration": 253477, "num_examples": 1, "n
um_bytes": 420000}
[2020-11-12 13:50:47.081] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/test", "epoch": 1, "duration": 601, "num_examples": 164, "nu
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ta_iter", "Operation": "training", "Algorithm": "Linear Learner"}, "StartTim
e": 1605189046.478757}

[11/12/2020 13:50:47 INFO 140191812458304] #test_score (algo-1) : ('binary_cl
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assification_cross_entropy_objective', 0.49027497597895914)
[11/12/2020 13:50:47 INFO 140191812458304] #test_score (algo-1) : ('binary_cl
assification_accuracy', 0.7916776209196681)
[11/12/2020 13:50:47 INFO 140191812458304] #test_score (algo-1) : ('binary_f_
1.000', 0.00763069753895442)
[11/12/2020 13:50:47 INFO 140191812458304] #test_score (algo-1) : ('precisio
n', 0.5282258064516129)
[11/12/2020 13:50:47 INFO 140191812458304] #test_score (algo-1) : ('recall',
 0.003843107342975328)
[11/12/2020 13:50:47 INFO 140191812458304] #test_score (algo-1) : ('roc_auc_s
core', 0.6440386992312175)
[11/12/2020 13:50:47 INFO 140191812458304] #quality_metric: host=algo-1, test
binary_classification_cross_entropy_objective <loss>=0.490274975979
[11/12/2020 13:50:47 INFO 140191812458304] #quality_metric: host=algo-1, test
binary_classification_accuracy <score>=0.79167762092
[11/12/2020 13:50:47 INFO 140191812458304] #quality_metric: host=algo-1, test
binary_f_1.000 <score>=0.00763069753895
[11/12/2020 13:50:47 INFO 140191812458304] #quality_metric: host=algo-1, test
precision <score>=0.528225806452
[11/12/2020 13:50:47 INFO 140191812458304] #quality_metric: host=algo-1, test
recall <score>=0.00384310734298
[11/12/2020 13:50:47 INFO 140191812458304] #quality_metric: host=algo-1, test
roc_auc_score <score>=0.644038699231
#metrics {"Metrics": {"totaltime": {"count": 1, "max": 254428.26414108276, "s
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34521484375}, "setuptime": {"count": 1, "max": 33.599138259887695, "sum": 33.
599138259887695, "min": 33.599138259887695}, "update.time": {"count": 5, "ma
x": 50257.895946502686, "sum": 248143.807888031, "min": 48727.07295417786},
 "epochs": {"count": 1, "max": 15, "sum": 15.0, "min": 15}}, "EndTime": 16051
89047.150254, "Dimensions": {"Host": "algo-1", "Operation": "training", "Algo
rithm": "Linear Learner"}, "StartTime": 1605188792.972044}


2020-11-12 13:51:40 Uploading - Uploading generated training model
2020-11-12 13:51:40 Completed - Training job completed
Training seconds: 374
Billable seconds: 374
```

Model evaluation

In this section, you'll evaluate your trained model. First, use the `estimator.deploy` function with `initial_instance_count= 1` and `instance_type= 'ml.m4.xlarge'` to deploy your model on Amazon SageMaker.

In [38]:
```
### Deloy an endpoint for batch prediction
classifier_predictor = classifier_estimator.deploy(initial_instance_count=1, i
nstance_type='ml.m4.xlarge')
```

```
Defaulting to the only supported framework/algorithm version: 1. Ignoring fra
mework/algorithm version: 1.

---------------!
```

Once your endpoint is 'InService', evaluate how your model performs on the test set. Use the `predict_batches` function to predict the metrics on your test set.

In [39]:
```
from sklearn.metrics import roc_auc_score
from sklearn.metrics import precision_recall_fscore_support

def predict_batches(predictor, features, labels):
    """
    Return evaluation results
    predictor : Predictor object of model
    features: Input features to model
    label: Ground truth target values
    """
    prediction_batches = [predictor.predict(batch) for batch in np.array_split
(features, 100)]

    # Parse protobuf responses to extract predicted labels
    extract_label = lambda x: x.label['predicted_label'].float32_tensor.values
    preds = np.concatenate([np.array([extract_label(x) for x in batch]) for ba
tch in prediction_batches])
    preds = preds.reshape((-1,))

    # Calculate accuracy
    accuracy = (preds == labels).sum() / labels.shape[0]
    print(f'Accuracy: {accuracy}')

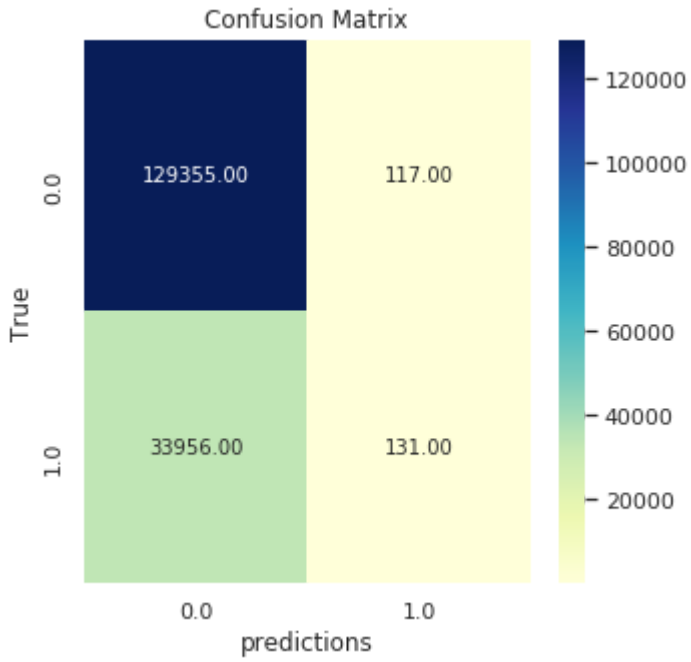
    auc = roc_auc_score(labels, preds)
    print(f'AUC      : {auc}')

    precision, recall, f1_score, _ = precision_recall_fscore_support(labels, p
reds, average = 'binary')
    print(f'Precision: {precision}')
    print(f'Recall: {recall}')
    print(f'F1_score: {f1_score}')

    confusion_matrix = pd.crosstab(index=labels, columns=np.round(preds), rown
ames=['True'], colnames=['predictions']).astype(int)
    plt.figure(figsize = (5,5))
    sns.heatmap(confusion_matrix, annot=True, fmt='.2f', cmap="YlGnBu").set_ti
tle('Confusion Matrix')
```

In [40]:
```
predict_batches(classifier_predictor, test_features, test_labels)
```

```
Accuracy: 0.7916776209196681
AUC     : 0.5014697185256647
Precision: 0.5282258064516129
Recall: 0.003843107342975328
F1_score: 0.007630697538954419
```



Key questions to consider:

1. How does your model's performance on the test set compare to the training set? What can you deduce from this comparison?
2. Are there obvious differences between the outcomes of metrics like accuracy, precision, and recall? If so, why might you be seeing those differences?
3. Given your business situation and goals, which metric(s) is most important for you to consider here? Why?
4. Is the outcome for the metric(s) you consider most important sufficient for what you need from a business standpoint? If not, what are some things you might change in your next iteration (in the feature engineering section, which is coming up next)?

Use the cells below to answer these and other questions. Insert and delete cells where needed.

Project presentation: Record answers to these and other similar questions you might answer in this section in your project presentations. Record key details and decisions you've made in your project presentations.

Question: What can you summarize from the confusion matrix?

Case of class imbalance

- When dealing with imbalanced classes, it is important to weigh in between which metric you can optimize to solve a given problem at hand.
- You can choose precision or recall, depending on whether only correct positive predictions matter or all positive predictions are of most importance.
- You can also balance between precision and recall with custom weights with F1-beta score.
- AUC measures the area under the TPR vs. FPR curve. It is the power of the model to discriminate between a positive and negative prediction.
- An AUC of 0.5 means the model predictions are as good as random prediction.
- Note that AUC is independent of threshold online precision or recall, making it easier to compare models.

For the classifier above, we see that:

- Accuracy ~ 80% and AUC ~0.5, meaning the model does not have enough predictive power and is as good as a random choice.
- High false negatives resulted in a low recall value.

To improve classifier performance, you can:

- Add more features
- Optimize for a different metric/loss
- Try non-linear models
- Do ensemble modeling

For more information about customizing linear learner, see Train Faster, More Flexible Models with Amazon SageMaker Linear Learner (https://aws.amazon.com/blogs/machine-learning/train-faster-more-flexible-models-with-amazon-sagemaker-linear-learner/).

Project Solution Lab 4:

Iteration II

Step 4: Feature engineering

You've now gone through one iteration of training and evaluating your model. Given that the outcome you reached for your model the first time probably wasn't sufficient for solving your business problem, what are some things you could change about your data to possibly improve model performance?

Key questions to consider:

1. How might the balance of your two main classes (delay and no delay) impact model performance?
2. Do you have any features that are correlated?
3. Are there feature reduction techniques you could perform at this stage that might have a positive impact on model performance?
4. Can you think of adding some more data/datasets?
5. After performing some feature engineering, how does your model performance compare to the first iteration?

Use the cells below to perform specific feature engineering techniques (per the questions above) that you think could improve your model performance. Insert and delete cells where needed.

Project presentation: Record key decisions and methods you use in this section in your project presentations, as well as any new performance metrics you obtain after evaluating your model again.

Before you start, think about why the precision and recall are around 80% while the accuracy is 99%.

Add more features

1. Holidays
2. Weather

Because the list of holidays from 2014 to 2018 is known, you can create an indicator variable **is_holiday** to mark these. The hypothesis is that airplane delays could be higher during holidays compared to the rest of the days. Add a boolean variable `is_holiday` that includes the holidays for the years 2014-2018.

In [41]:
```
# Source: http://www.calendarpedia.com/holidays/federal-holidays-2014.html

holidays_14 = ['2014-01-01',  '2014-01-20', '2014-02-17', '2014-05-26', '2014-
07-04', '2014-09-01', '2014-10-13', '2014-11-11', '2014-11-27', '2014-12-25' ]
holidays_15 = ['2015-01-01',  '2015-01-19', '2015-02-16', '2015-05-25', '2015-
06-03', '2015-07-04', '2015-09-07', '2015-10-12', '2015-11-11', '2015-11-26',
'2015-12-25']
holidays_16 = ['2016-01-01',  '2016-01-18', '2016-02-15', '2016-05-30', '2016-
07-04', '2016-09-05', '2016-10-10', '2016-11-11', '2016-11-24', '2016-12-25',
'2016-12-26']
holidays_17 = ['2017-01-02', '2017-01-16', '2017-02-20', '2017-05-29' , '2017-
07-04', '2017-09-04' ,'2017-10-09', '2017-11-10', '2017-11-23', '2017-12-25']
holidays_18 = ['2018-01-01', '2018-01-15', '2018-02-19', '2018-05-28' , '2018-
07-04', '2018-09-03' ,'2018-10-08', '2018-11-12','2018-11-22', '2018-12-25']
# holidays_19 = ['2019-01-01', '2019-01-21', '2019-02-18', '2019-05-27' , '201
9-07-04', '2019-09-02' ,'2019-10-14', '2019-11-11','2019-11-28', '2019-12-25']
holidays = holidays_14+ holidays_15+ holidays_16 + holidays_17+ holidays_18

### Add indicator variable for holidays
data_orig['is_holiday'] = data_orig.FlightDate.isin(holidays).astype(int)
```

Weather data was fetched from [https://www.ncei.noaa.gov/access/services/data/v1?dataset=daily-summaries&stations=USW00023174,USW00012960,USW00003017,USW00094846,USW00013874,USW00023201-01&endDate=2018-12-31 (https://www.ncei.noaa.gov/access/services/data/v1?dataset=daily-summaries&stations=USW00023174,USW00012960,USW00003017,USW00094846,USW00013874,USW00023201-01&endDate=2018-12-31)](https://www.ncei.noaa.gov/access/services/data/v1?dataset=daily-summaries&stations=USW00023174,USW00012960,USW00003017,USW00094846,USW00013874,USW00023201-01&endDate=2018-12-31).

This dataset has information on wind speed, precipitation, snow, and temperature for cities by their airport codes.

Question: Could bad weather due to rains, heavy winds, or snow lead to airplane delay? Let's check!

In [42]:
```
%%bash
aws s3 cp s3://aws-tc-largeobjects/ILT-TF-200-MLDWTS/flight_delay_project/dail
y-summaries.csv /home/ec2-user/SageMaker/project/data/
#wget 'https://www.ncei.noaa.gov/access/services/data/v1?dataset=daily-summari
es&stations=USW00023174,USW00012960,USW00003017,USW00094846,USW00013874,USW000
23234,USW00003927,USW00023183,USW00013881&dataTypes=AWND,PRCP,SNOW,SNWD,TAVG,T
MIN,TMAX&startDate=2014-01-01&endDate=2018-12-31' -O /home/ec2-user/SageMaker/
project/data/daily-summaries.csv
```

```
Completed 256.0 KiB/1.2 MiB (2.8 MiB/s) with 1 file(s) remaining
Completed 512.0 KiB/1.2 MiB (5.4 MiB/s) with 1 file(s) remaining
Completed 768.0 KiB/1.2 MiB (8.0 MiB/s) with 1 file(s) remaining
Completed 1.0 MiB/1.2 MiB (10.5 MiB/s) with 1 file(s) remaining
Completed 1.2 MiB/1.2 MiB (12.8 MiB/s) with 1 file(s) remaining
download: s3://aws-tc-largeobjects/ILT-TF-200-MLDWTS/flight_delay_project/dai
ly-summaries.csv to data/daily-summaries.csv
```

Import weather data prepared for the airport codes in our dataset. Use the stations and airports below for the analysis, and create a new column called `airport` that maps the weather station to the airport name.

In [43]:
```
weather = pd.read_csv('/home/ec2-user/SageMaker/project/data/daily-summaries.csv')
station = ['USW00023174','USW00012960','USW00003017','USW00094846','USW00013874','USW00023234','USW00003927','USW00023183','USW00013881']
airports = ['LAX', 'IAH', 'DEN', 'ORD', 'ATL', 'SFO', 'DFW', 'PHX', 'CLT']

### Map weather stations to airport code
station_map = {s:a for s,a in zip(station, airports)}
weather['airport'] = weather['STATION'].map(station_map)
```

Create another column called `MONTH` from the `DATE` column.

In [44]:
```
weather['MONTH'] = weather['DATE'].apply(lambda x: x.split('-')[1])
weather.head()
```

Out[44]:

	STATION	DATE	AWND	PRCP	SNOW	SNWD	TAVG	TMAX	TMIN	airport	MONTH
0	USW00023174	2014-01-01	16	0	NaN	NaN	131.0	178.0	78.0	LAX	01
1	USW00023174	2014-01-02	22	0	NaN	NaN	159.0	256.0	100.0	LAX	01
2	USW00023174	2014-01-03	17	0	NaN	NaN	140.0	178.0	83.0	LAX	01
3	USW00023174	2014-01-04	18	0	NaN	NaN	136.0	183.0	100.0	LAX	01
4	USW00023174	2014-01-05	18	0	NaN	NaN	151.0	244.0	83.0	LAX	01

Analyze and handle the `SNOW` and `SNWD` columns for missing values using `fillna()`. Use the `isna()` function to check the missing values for all the columns.

In [45]:
```
weather.SNOW.fillna(0, inplace=True)
weather.SNWD.fillna(0, inplace=True)
weather.isna().sum()
```

Out[45]:
```
STATION     0
DATE        0
AWND        0
PRCP        0
SNOW        0
SNWD        0
TAVG       62
TMAX       20
TMIN       20
airport     0
MONTH       0
dtype: int64
```

Question: Print the index of the rows that have missing values for TAVG, TMAX, TMIN.

Hint: Use the `isna()` function to find the rows that are missing, and then use the list on the idx variable to get the index.

In [46]:
```
idx = np.array([i for i in range(len(weather))])
TAVG_idx = idx[weather.TAVG.isna()]
TMAX_idx = idx[weather.TMAX.isna()]
TMIN_idx = idx[weather.TMIN.isna()]
TAVG_idx
```

Out[46]:
```
array([ 3956,  3957,  3958,  3959,  3960,  3961,  3962,  3963,  3964,
        3965,  3966,  3967,  3968,  3969,  3970,  3971,  3972,  3973,
        3974,  3975,  3976,  3977,  3978,  3979,  3980,  3981,  3982,
        3983,  3984,  3985,  4017,  4018,  4019,  4020,  4021,  4022,
        4023,  4024,  4025,  4026,  4027,  4028,  4029,  4030,  4031,
        4032,  4033,  4034,  4035,  4036,  4037,  4038,  4039,  4040,
        4041,  4042,  4043,  4044,  4045,  4046,  4047, 13420])
```

You can replace the missing TAVG, TMAX, and TMIN with the average value for a particular station/airport. Because the consecutive rows of TAVG_idx are missing, replacing with a previous value would not be possible. Instead, replace it with the mean. Use the `groupby` function to aggregate the variables with a mean value.

In [47]:
```
weather_impute = weather.groupby(['MONTH','STATION']).agg({'TAVG':'mean','TMA
X':'mean', 'TMIN':'mean' }).reset_index()
weather_impute.head(2)
```

Out[47]:

	MONTH	STATION	TAVG	TMAX	TMIN
0	01	USW00003017	-2.741935	74.000000	-69.858065
1	01	USW00003927	79.529032	143.767742	20.696774

In [48]:
```
weather.head()
```

Out[48]:

	STATION	DATE	AWND	PRCP	SNOW	SNWD	TAVG	TMAX	TMIN	airport	MONTH
0	USW00023174	2014-01-01	16	0	0.0	0.0	131.0	178.0	78.0	LAX	01
1	USW00023174	2014-01-02	22	0	0.0	0.0	159.0	256.0	100.0	LAX	01
2	USW00023174	2014-01-03	17	0	0.0	0.0	140.0	178.0	83.0	LAX	01
3	USW00023174	2014-01-04	18	0	0.0	0.0	136.0	183.0	100.0	LAX	01
4	USW00023174	2014-01-05	18	0	0.0	0.0	151.0	244.0	83.0	LAX	01

In [49]:
```
weather_impute
```

Out[49]:

	MONTH	STATION	TAVG	TMAX	TMIN
0	01	USW00003017	-2.741935	74.000000	-69.858065
1	01	USW00003927	79.529032	143.767742	20.696774
2	01	USW00012960	110.535484	170.438710	52.425806
3	01	USW00013874	59.070968	114.600000	8.161290
4	01	USW00013881	48.929032	106.529032	-15.645161
...	...	...	...	...	...
103	12	USW00013881	87.670968	138.870968	31.625806
104	12	USW00023174	147.922581	195.032258	102.038710
105	12	USW00023183	135.806452	198.206452	78.787097
106	12	USW00023234	115.025806	147.032258	80.361290
107	12	USW00094846	-2.735484	29.522581	-36.703226

108 rows × 5 columns

Merge the mean data with the weather data.

In [50]:
```
weather = pd.merge(weather, weather_impute,  how='left', left_on=['MONTH','STA
TION'], right_on = ['MONTH','STATION'])\
.rename(columns = {'TAVG_y':'TAVG_AVG',
                   'TMAX_y':'TMAX_AVG',
                   'TMIN_y':'TMIN_AVG',
                   'TAVG_x':'TAVG',
                   'TMAX_x':'TMAX',
                   'TMIN_x':'TMIN'})
```

Check for missing values again.

In [51]:
```
weather.TAVG[TAVG_idx] = weather.TAVG_AVG[TAVG_idx]
weather.TMAX[TMAX_idx] = weather.TMAX_AVG[TMAX_idx]
weather.TMIN[TMIN_idx] = weather.TMIN_AVG[TMIN_idx]
weather.isna().sum()
```

Out[51]:
```
STATION     0
DATE        0
AWND        0
PRCP        0
SNOW        0
SNWD        0
TAVG        0
TMAX        0
TMIN        0
airport     0
MONTH       0
TAVG_AVG    0
TMAX_AVG    0
TMIN_AVG    0
dtype: int64
```

Drop `STATION,MONTH,TAVG_AVG,TMAX_AVG,TMIN_AVG,TMAX,TMIN,SNWD` from the dataset.

In [52]:
```
weather.drop(columns=['STATION','MONTH','TAVG_AVG', 'TMAX_AVG', 'TMIN_AVG', 'TMAX' ,'TMIN', 'SNWD'],inplace=True)
```

Add the origin and destination weather conditions to the dataset.

In [53]:
```
### Add origin weather conditions
data_orig = pd.merge(data_orig, weather,  how='left', left_on=['FlightDate','Origin'], right_on = ['DATE','airport'])\
.rename(columns = {'AWND':'AWND_O','PRCP':'PRCP_O', 'TAVG':'TAVG_O', 'SNOW': 'SNOW_O'})\
.drop(columns=['DATE','airport'])

### Add destination weather conditions
data_orig = pd.merge(data_orig, weather,  how='left', left_on=['FlightDate','Dest'], right_on = ['DATE','airport'])\
.rename(columns = {'AWND':'AWND_D','PRCP':'PRCP_D', 'TAVG':'TAVG_D', 'SNOW': 'SNOW_D'})\
.drop(columns=['DATE','airport'])
```

Note: It is always a good practice to check nulls/NAs after joins.

In [54]:
```
sum(data.isna().any())
```

Out[54]:
```
0
```

In [55]:
```
data_orig.columns
```

Out[55]:
```
Index(['Year', 'Quarter', 'Month', 'DayofMonth', 'DayOfWeek', 'FlightDate',
       'Reporting_Airline', 'Origin', 'OriginState', 'Dest', 'DestState',
       'CRSDepTime', 'Cancelled', 'Diverted', 'Distance', 'DistanceGroup',
       'ArrDelay', 'ArrDelayMinutes', 'is_delay', 'AirTime', 'DepHourofDay',
       'is_holiday', 'AWND_O', 'PRCP_O', 'SNOW_O', 'TAVG_O', 'AWND_D',
       'PRCP_D', 'SNOW_D', 'TAVG_D'],
      dtype='object')
```

Convert the categorical data into numerical data using one-hot encoding.

In [56]:
```
data = data_orig.copy()
data = data[['Year', 'Quarter', 'Month', 'DayofMonth', 'DayOfWeek',
       'Reporting_Airline', 'Origin', 'Dest','Distance','DepHourofDay', 'is_de
lay', 'is_holiday', 'AWND_O', 'PRCP_O',
       'TAVG_O', 'AWND_D', 'PRCP_D', 'TAVG_D', 'SNOW_O', 'SNOW_D']]


categorical_columns  = ['Year', 'Quarter', 'Month', 'DayofMonth', 'DayOfWeek',
       'Reporting_Airline', 'Origin', 'Dest', 'is_holiday','is_delay']
for c in categorical_columns:
    data[c] = data[c].astype('category')
```

In [57]:
```
data_dummies = pd.get_dummies(data[['Year', 'Quarter', 'Month', 'DayofMonth',
'DayOfWeek', 'Reporting_Airline', 'Origin', 'Dest', 'is_holiday']], drop_first
=True)
data = pd.concat([data, data_dummies], axis = 1)
categorical_columns.remove('is_delay')
data.drop(categorical_columns,axis=1, inplace=True)
```

Check the new columns.

In [58]:
```
data.columns
```

Out[58]:
```
Index(['Distance', 'DepHourofDay', 'is_delay', 'AWND_O', 'PRCP_O', 'TAVG_O',
       'AWND_D', 'PRCP_D', 'TAVG_D', 'SNOW_O', 'SNOW_D', 'Year_2015',
       'Year_2016', 'Year_2017', 'Year_2018', 'Quarter_2', 'Quarter_3',
       'Quarter_4', 'Month_2', 'Month_3', 'Month_4', 'Month_5', 'Month_6',
       'Month_7', 'Month_8', 'Month_9', 'Month_10', 'Month_11', 'Month_12',
       'DayofMonth_2', 'DayofMonth_3', 'DayofMonth_4', 'DayofMonth_5',
       'DayofMonth_6', 'DayofMonth_7', 'DayofMonth_8', 'DayofMonth_9',
       'DayofMonth_10', 'DayofMonth_11', 'DayofMonth_12', 'DayofMonth_13',
       'DayofMonth_14', 'DayofMonth_15', 'DayofMonth_16', 'DayofMonth_17',
       'DayofMonth_18', 'DayofMonth_19', 'DayofMonth_20', 'DayofMonth_21',
       'DayofMonth_22', 'DayofMonth_23', 'DayofMonth_24', 'DayofMonth_25',
       'DayofMonth_26', 'DayofMonth_27', 'DayofMonth_28', 'DayofMonth_29',
       'DayofMonth_30', 'DayofMonth_31', 'DayOfWeek_2', 'DayOfWeek_3',
       'DayOfWeek_4', 'DayOfWeek_5', 'DayOfWeek_6', 'DayOfWeek_7',
       'Reporting_Airline_DL', 'Reporting_Airline_OO', 'Reporting_Airline_U
A',
       'Reporting_Airline_WN', 'Origin_CLT', 'Origin_DEN', 'Origin_DFW',
       'Origin_IAH', 'Origin_LAX', 'Origin_ORD', 'Origin_PHX', 'Origin_SFO',
       'Dest_CLT', 'Dest_DEN', 'Dest_DFW', 'Dest_IAH', 'Dest_LAX', 'Dest_OR
D',
       'Dest_PHX', 'Dest_SFO', 'is_holiday_1'],
      dtype='object')
```

Rename the `is_delay` column to `target` again. Use the same code as before.

In [59]:
```
data.rename(columns = {'is_delay':'target'}, inplace=True )
```

Create the training sets again.

In [60]:
```
train_features, test_features, train_labels, test_labels, val_features, val_la
bels = create_training_sets(data)

print(f"Length of train_features is: {train_features.shape}")
print(f"Length of train_labels is: {train_labels.shape}")
print(f"Length of val_features is: {val_features.shape}")
print(f"Length of val_labels is: {val_labels.shape}")
print(f"Length of test_features is: {test_features.shape}")
print(f"Length of test_labels is: {test_labels.shape}")
```

```
Length of train_features is: (1308472, 85)
Length of train_labels is: (1308472,)
Length of val_features is: (163559, 85)
Length of val_labels is: (163559,)
Length of test_features is: (163559, 85)
Length of test_labels is: (163559,)
```

New baseline classifier

Now, see if these new features add any predictive power to the model.

In [61]:
```
# Instantiate the LinearLearner estimator object
num_classes = len(pd.unique(train_labels))
classifier_estimator = sagemaker.LinearLearner(role=sagemaker.get_execution_ro
le(),
                                               instance_count=1,
                                               instance_type='ml.m4.xlarge',
                                               predictor_type='binary_classifi
er',
                                              binary_classifier_model_selectio
n_criteria = 'cross_entropy_loss')
```

In [62]:
```
train_records = classifier_estimator.record_set(train_features, train_labels,
channel='train')
val_records = classifier_estimator.record_set(val_features, val_labels, channe
l='validation')
test_records = classifier_estimator.record_set(test_features, test_labels, cha
nnel='test')

classifier_estimator.fit([train_records, val_records, test_records])
```

```
Defaulting to the only supported framework/algorithm version: 1. Ignoring fra
mework/algorithm version: 1.
Defaulting to the only supported framework/algorithm version: 1. Ignoring fra
mework/algorithm version: 1.
```

```
2020-11-12 14:01:06 Starting - Starting the training job...
2020-11-12 14:01:08 Starting - Launching requested ML instances.........
2020-11-12 14:02:38 Starting - Preparing the instances for training......
2020-11-12 14:03:43 Downloading - Downloading input data...
2020-11-12 14:04:33 Training - Downloading the training image...
2020-11-12 14:04:52 Training - Training image download completed. Training in
progress.Docker entrypoint called with argument(s): train
Running default environment configuration script
[11/12/2020 14:04:56 INFO 140524350674752] Reading default configuration from
/opt/amazon/lib/python2.7/site-packages/algorithm/resources/default-input.jso
n: {u'loss_insensitivity': u'0.01', u'epochs': u'15', u'feature_dim': u'aut
o', u'init_bias': u'0.0', u'lr_scheduler_factor': u'auto', u'num_calibration_
samples': u'10000000', u'accuracy_top_k': u'3', u'_num_kv_servers': u'auto',
 u'use_bias': u'true', u'num_point_for_scaler': u'10000', u'_log_level': u'in
fo', u'quantile': u'0.5', u'bias_lr_mult': u'auto', u'lr_scheduler_step': u'a
uto', u'init_method': u'uniform', u'init_sigma': u'0.01', u'lr_scheduler_mini
mum_lr': u'auto', u'target_recall': u'0.8', u'num_models': u'auto', u'early_s
topping_patience': u'3', u'momentum': u'auto', u'unbias_label': u'auto', u'w
d': u'auto', u'optimizer': u'auto', u'_tuning_objective_metric': u'', u'early
_stopping_tolerance': u'0.001', u'learning_rate': u'auto', u'_kvstore': u'aut
o', u'normalize_data': u'true', u'binary_classifier_model_selection_criteri
a': u'accuracy', u'use_lr_scheduler': u'true', u'target_precision': u'0.8',
 u'unbias_data': u'auto', u'init_scale': u'0.07', u'bias_wd_mult': u'auto',
 u'f_beta': u'1.0', u'mini_batch_size': u'1000', u'huber_delta': u'1.0', u'nu
m_classes': u'1', u'beta_1': u'auto', u'loss': u'auto', u'beta_2': u'auto',
 u'_enable_profiler': u'false', u'normalize_label': u'auto', u'_num_gpus':
 u'auto', u'balance_multiclass_weights': u'false', u'positive_example_weight_
mult': u'1.0', u'l1': u'auto', u'margin': u'1.0'}
[11/12/2020 14:04:56 INFO 140524350674752] Merging with provided configuratio
n from /opt/ml/input/config/hyperparameters.json: {u'feature_dim': u'85', u'm
ini_batch_size': u'1000', u'predictor_type': u'binary_classifier', u'binary_c
lassifier_model_selection_criteria': u'cross_entropy_loss'}
[11/12/2020 14:04:56 INFO 140524350674752] Final configuration: {u'loss_insen
sitivity': u'0.01', u'epochs': u'15', u'feature_dim': u'85', u'init_bias':
 u'0.0', u'lr_scheduler_factor': u'auto', u'num_calibration_samples': u'10000
000', u'accuracy_top_k': u'3', u'_num_kv_servers': u'auto', u'use_bias': u'tr
ue', u'num_point_for_scaler': u'10000', u'_log_level': u'info', u'quantile':
 u'0.5', u'bias_lr_mult': u'auto', u'lr_scheduler_step': u'auto', u'init_meth
od': u'uniform', u'init_sigma': u'0.01', u'lr_scheduler_minimum_lr': u'auto',
u'target_recall': u'0.8', u'num_models': u'auto', u'early_stopping_patience':
u'3', u'momentum': u'auto', u'unbias_label': u'auto', u'wd': u'auto', u'optim
izer': u'auto', u'_tuning_objective_metric': u'', u'early_stopping_toleranc
e': u'0.001', u'learning_rate': u'auto', u'_kvstore': u'auto', u'normalize_da
ta': u'true', u'binary_classifier_model_selection_criteria': u'cross_entropy_
loss', u'use_lr_scheduler': u'true', u'target_precision': u'0.8', u'unbias_da
ta': u'auto', u'init_scale': u'0.07', u'bias_wd_mult': u'auto', u'f_beta':
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u'1', u'predictor_type': u'binary_classifier', u'beta_1': u'auto', u'loss':
 u'auto', u'beta_2': u'auto', u'_enable_profiler': u'false', u'normalize_labe
l': u'auto', u'_num_gpus': u'auto', u'balance_multiclass_weights': u'false',
 u'positive_example_weight_mult': u'1.0', u'l1': u'auto', u'margin': u'1.0'}
[11/12/2020 14:04:56 WARNING 140524350674752] Loggers have already been setu
p.
Process 1 is a worker.
[11/12/2020 14:04:56 INFO 140524350674752] Using default worker.
```

```
[11/12/2020 14:04:56 INFO 140524350674752] Checkpoint loading and saving are
 disabled.
[2020-11-12 14:04:56.832] [tensorio] [warning] TensorIO is already initialize
d; ignoring the initialization routine.
[2020-11-12 14:04:56.844] [tensorio] [warning] TensorIO is already initialize
d; ignoring the initialization routine.
[2020-11-12 14:04:56.915] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/train", "epoch": 0, "duration": 93, "num_examples": 1, "num_
bytes": 388000}
[11/12/2020 14:04:56 INFO 140524350674752] Create Store: local
[2020-11-12 14:04:57.107] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/train", "epoch": 1, "duration": 190, "num_examples": 11, "nu
m_bytes": 4268000}
[11/12/2020 14:04:57 INFO 140524350674752] Scaler algorithm parameters
 <algorithm.scaler.ScalerAlgorithmStable object at 0x7fce00710750>
[11/12/2020 14:04:57 INFO 140524350674752] Scaling model computed with parame
ters:
 {'stdev_weight':
[5.3894446e+02 4.9662480e+00 1.6503336e+01 7.7865707e+01 8.9011513e+01
 1.6113295e+01 7.1753654e+01 8.9449318e+01 7.1183734e+00 7.8497138e+00
 3.9521766e-01 4.0795398e-01 4.0872484e-01 4.0476048e-01 4.3067855e-01
 4.4138163e-01 4.3488580e-01 2.6058367e-01 2.7820414e-01 2.7072945e-01
 2.7311411e-01 2.7915213e-01 2.9546201e-01 2.8487492e-01 2.7030548e-01
 2.8036407e-01 2.7311414e-01 2.8049824e-01 1.7551577e-01 1.7133677e-01
 1.7624156e-01 1.8560937e-01 1.7624155e-01 1.7551577e-01 1.6856998e-01
 1.8005596e-01 1.7356342e-01 1.8029131e-01 1.8423912e-01 1.7429848e-01
 1.8741828e-01 1.7158581e-01 1.8146272e-01 1.8285701e-01 1.7720398e-01
 1.7356344e-01 1.7600000e-01 1.7033654e-01 1.8400961e-01 1.8122913e-01
 1.7887397e-01 1.8423913e-01 1.8169595e-01 1.8239361e-01 1.7503001e-01
 1.7696393e-01 1.7008546e-01 1.3129210e-01 3.5210088e-01 3.5635713e-01
 3.5813749e-01 3.5866809e-01 3.1935078e-01 3.4708133e-01 3.7167209e-01
 2.3815934e-01 4.6113521e-01 3.0888194e-01 2.3731834e-01 3.1946027e-01
 3.3327824e-01 2.7255571e-01 3.5946095e-01 3.3378589e-01 2.9756033e-01
 3.2937402e-01 2.3849468e-01 3.1424466e-01 3.2749566e-01 2.7002236e-01
 3.5590920e-01 3.4026122e-01 2.9914963e-01 3.3799595e-01 1.6445161e-01]
<NDArray 85 @cpu(0)>, 'stdev_label': None, 'mean_label': None, 'mean_weight':
[1.00651935e+03 1.28398180e+01 3.87498207e+01 2.03989105e+01
 1.71987762e+02 3.83867340e+01 1.91429081e+01 1.71469635e+02
 6.55636370e-01 7.13636398e-01 1.93727300e-01 2.10909098e-01
 2.12000012e-01 2.06454575e-01 2.46000037e-01 2.65090942e-01
 2.53272712e-01 7.32727498e-02 8.45454708e-02 7.96363726e-02
 8.11818242e-02 8.51818249e-02 9.66363698e-02 8.90908986e-02
 7.93636292e-02 8.60000104e-02 8.11818168e-02 8.60909149e-02
 3.18181813e-02 3.02727297e-02 3.20909098e-02 3.57272737e-02
 3.20909098e-02 3.18181850e-02 2.92727333e-02 3.35454568e-02
 3.10909115e-02 3.36363614e-02 3.51818204e-02 3.13636363e-02
 3.64545435e-02 3.03636417e-02 3.40909101e-02 3.46363671e-02
 3.24545503e-02 3.10909115e-02 3.20000015e-02 2.99090892e-02
 3.50909121e-02 3.40000056e-02 3.30909118e-02 3.51818204e-02
 3.41818184e-02 3.44545431e-02 3.16363685e-02 3.23636420e-02
 2.98181865e-02 1.75454561e-02 1.44999996e-01 1.49272755e-01
 1.51090920e-01 1.51636377e-01 1.15272738e-01 1.40090927e-01
 1.65545464e-01 6.03636429e-02 3.06727320e-01 1.06818192e-01
 5.99090979e-02 1.15363650e-01 1.27272740e-01 8.08181837e-02
 1.52454555e-01 1.27727285e-01 9.81818363e-02 1.23818196e-01
 6.05454557e-02 1.11090913e-01 1.22181833e-01 7.91818276e-02
```

```
 1.48818195e-01 1.33636355e-01 9.93636400e-02 1.31545454e-01
 2.78181862e-02]
<NDArray 85 @cpu(0)>}
[11/12/2020 14:04:57 INFO 140524350674752] nvidia-smi took: 0.0251998901367 s
ecs to identify 0 gpus
[11/12/2020 14:04:57 INFO 140524350674752] Number of GPUs being used: 0
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1, "max": 0, "sum": 0.0, "min": 0}, "Number of Records Since Last Reset": {"c
ount": 1, "max": 0, "sum": 0.0, "min": 0}, "Total Batches Seen": {"count": 1,
"max": 12, "sum": 12.0, "min": 12}, "Total Records Seen": {"count": 1, "max":
12000, "sum": 12000.0, "min": 12000}, "Max Records Seen Between Resets": {"co
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t": 1, "max": 2, "sum": 2.0, "min": 2}}, "EndTime": 1605189897.259495, "Dimen
sions": {"Host": "algo-1", "Meta": "init_train_data_iter", "Operation": "trai
ning", "Algorithm": "Linear Learner"}, "StartTime": 1605189897.259449}

[2020-11-12 14:05:41.335] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/train", "epoch": 3, "duration": 44075, "num_examples": 1309,
"num_bytes": 507687136}
#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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 "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "e
poch": 0}, "StartTime": 1605189941.335842}

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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective": {"count": 1, "max": 0.5061015803019205, "sum": 0.5061015803019205, "min": 0.5061015803019205}}, "EndTime": 1605189941.336705, "Dimensions": {"model": 17, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 0}, "StartTime": 1605189941.336697}

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[11/12/2020 14:05:41 INFO 140524350674752] #quality_metric: host=algo-1, epoc
h=0, train binary_classification_cross_entropy_objective <loss>=0.48336594176
2
[2020-11-12 14:05:41.358] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/validation", "epoch": 0, "duration": 44526, "num_examples":
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[2020-11-12 14:05:45.881] [tensorio] [info] epoch_stats={"data_pipeline": "/o
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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er", "epoch": 0}, "StartTime": 1605189945.890735}

[11/12/2020 14:05:45 INFO 140524350674752] #quality_metric: host=algo-1, epoc
h=0, validation binary_classification_cross_entropy_objective <loss>=0.480654
575311
[11/12/2020 14:05:45 INFO 140524350674752] #early_stopping_criteria_metric: h
ost=algo-1, epoch=0, criteria=binary_classification_cross_entropy_objective,
 value=0.480654575311
[11/12/2020 14:05:45 INFO 140524350674752] Epoch 0: Loss improved. Updating b
est model
[11/12/2020 14:05:45 INFO 140524350674752] Saving model for epoch: 0
[11/12/2020 14:05:45 INFO 140524350674752] Saved checkpoint to "/tmp/tmpnOrIZ
q/mx-mod-0000.params"
[11/12/2020 14:05:45 INFO 140524350674752] #progress_metric: host=algo-1, com
pleted 6 % of epochs
#metrics {"Metrics": {"Max Batches Seen Between Resets": {"count": 1, "max":
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ar Learner", "epoch": 0}, "StartTime": 1605189897.259758}

[11/12/2020 14:05:45 INFO 140524350674752] #throughput_metric: host=algo-1, t
rain throughput=26900.6004843 records/second
[2020-11-12 14:06:28.489] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/train", "epoch": 5, "duration": 42588, "num_examples": 1309,
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective":
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{"count": 1, "max": 0.4812802187251753, "sum": 0.4812802187251753, "min": 0.4812802187251753}}, "EndTime": 1605189988.490766, "Dimensions": {"model": 10, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 1}, "StartTime": 1605189988.490749}

#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective": {"count": 1, "max": 0.4821828073857392, "sum": 0.4821828073857392, "min": 0.4821828073857392}}, "EndTime": 1605189988.490836, "Dimensions": {"model": 11, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 1}, "StartTime": 1605189988.490819}

#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective": {"count": 1, "max": 0.4848318594836314, "sum": 0.4848318594836314, "min": 0.4848318594836314}}, "EndTime": 1605189988.490902, "Dimensions": {"model": 12, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 1}, "StartTime": 1605189988.490884}

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#metrics {"Metrics": {"train_binary_classification_cross_entropy_objective": {"count": 1, "max": 0.48483156602025396, "sum": 0.48483156602025396, "min": 0.48483156602025396}}, "EndTime": 1605189988.491037, "Dimensions": {"model": 14, "Host": "algo-1", "Operation": "training", "Algorithm": "Linear Learner", "epoch": 1}, "StartTime": 1605189988.491019}

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[11/12/2020 14:06:28 INFO 140524350674752] #quality_metric: host=algo-1, epoc
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7
[2020-11-12 14:06:32.481] [tensorio] [info] epoch_stats={"data_pipeline": "/o
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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[11/12/2020 14:06:32 INFO 140524350674752] #quality_metric: host=algo-1, epoc
h=1, validation binary_classification_cross_entropy_objective <loss>=0.480475
289041
[11/12/2020 14:06:32 INFO 140524350674752] #early_stopping_criteria_metric: h
ost=algo-1, epoch=1, criteria=binary_classification_cross_entropy_objective,
 value=0.480475289041
[11/12/2020 14:06:32 INFO 140524350674752] Saving model for epoch: 1

```
[11/12/2020 14:06:32 INFO 140524350674752] Saved checkpoint to "/tmp/tmpJssJH
L/mx-mod-0000.params"
[11/12/2020 14:06:32 INFO 140524350674752] #progress_metric: host=algo-1, com
pleted 13 % of epochs
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[11/12/2020 14:06:32 INFO 140524350674752] #throughput_metric: host=algo-1, t
rain throughput=28080.5903132 records/second
[2020-11-12 14:07:14.719] [tensorio] [info] epoch_stats={"data_pipeline": "/o
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[2020-11-12 14:07:18.889] [tensorio] [info] epoch_stats={"data_pipeline": "/opt/ml/input/data/validation", "epoch": 8, "duration": 4146, "num_examples": 164, "num_bytes": 63460892}
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[11/12/2020 14:07:18 INFO 140524350674752] #quality_metric: host=algo-1, epoc
h=2, validation binary_classification_cross_entropy_objective <loss>=0.480470
166736
[11/12/2020 14:07:18 INFO 140524350674752] #early_stopping_criteria_metric: h
ost=algo-1, epoch=2, criteria=binary_classification_cross_entropy_objective,
 value=0.480470166736
[11/12/2020 14:07:18 INFO 140524350674752] Saving model for epoch: 2
[11/12/2020 14:07:18 INFO 140524350674752] Saved checkpoint to "/tmp/tmpPNoYT
Q/mx-mod-0000.params"
[11/12/2020 14:07:18 INFO 140524350674752] #progress_metric: host=algo-1, com
pleted 20 % of epochs
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[11/12/2020 14:07:18 INFO 140524350674752] #throughput_metric: host=algo-1, t
rain throughput=28195.5411667 records/second
[2020-11-12 14:08:02.406] [tensorio] [info] epoch_stats={"data_pipeline": "/o
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[11/12/2020 14:08:02 INFO 140524350674752] #quality_metric: host=algo-1, epoch=3, train binary_classification_cross_entropy_objective <loss>=0.480796710793
[2020-11-12 14:08:06.446] [tensorio] [info] epoch_stats={"data_pipeline": "/opt/ml/input/data/validation", "epoch": 11, "duration": 4018, "num_examples": 164, "num_bytes": 63460892}
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[11/12/2020 14:08:06 INFO 140524350674752] #quality_metric: host=algo-1, epoc
h=3, validation binary_classification_cross_entropy_objective <loss>=0.480464
946288
[11/12/2020 14:08:06 INFO 140524350674752] #early_stopping_criteria_metric: h
ost=algo-1, epoch=3, criteria=binary_classification_cross_entropy_objective,
 value=0.480464946288
[11/12/2020 14:08:06 INFO 140524350674752] Saving model for epoch: 3
[11/12/2020 14:08:06 INFO 140524350674752] Saved checkpoint to "/tmp/tmpr8ZQF
E/mx-mod-0000.params"
[11/12/2020 14:08:06 INFO 140524350674752] #progress_metric: host=algo-1, com
pleted 26 % of epochs

#metrics {"Metrics": {"Max Batches Seen Between Resets": {"count": 1, "max":
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[11/12/2020 14:08:06 INFO 140524350674752] #throughput_metric: host=algo-1, t
rain throughput=27515.6514943 records/second
[2020-11-12 14:08:49.247] [tensorio] [info] epoch_stats={"data_pipeline": "/o
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[11/12/2020 14:08:49 INFO 140524350674752] #quality_metric: host=algo-1, epoch=4, train binary_classification_cross_entropy_objective <loss>=0.480771993375
[2020-11-12 14:08:53.198] [tensorio] [info] epoch_stats={"data_pipeline": "/opt/ml/input/data/validation", "epoch": 14, "duration": 3931, "num_examples": 164, "num_bytes": 63460892}
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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#metrics {"Metrics": {"validation_binary_classification_cross_entropy_objecti
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er", "epoch": 4}, "StartTime": 1605190133.206172}

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er", "epoch": 4}, "StartTime": 1605190133.206514}

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 "epoch": 4}, "StartTime": 1605190133.206722}

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ve": {"count": 1, "max": 0.5043878367838713, "sum": 0.5043878367838713, "mi
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er", "epoch": 4}, "StartTime": 1605190133.206923}

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ve": {"count": 1, "max": 0.513721784867435, "sum": 0.513721784867435, "min":
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 "epoch": 4}, "StartTime": 1605190133.20699}

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er", "epoch": 4}, "StartTime": 1605190133.207058}

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ve": {"count": 1, "max": 0.5137258302064952, "sum": 0.5137258302064952, "mi
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er", "epoch": 4}, "StartTime": 1605190133.207125}

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ve": {"count": 1, "max": 0.5136720112067024, "sum": 0.5136720112067024, "mi
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er", "epoch": 4}, "StartTime": 1605190133.207189}

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ve": {"count": 1, "max": 0.5136721707364702, "sum": 0.5136721707364702, "mi
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er", "epoch": 4}, "StartTime": 1605190133.207409}

[11/12/2020 14:08:53 INFO 140524350674752] #quality_metric: host=algo-1, epoc
h=4, validation binary_classification_cross_entropy_objective <loss>=0.480463
71427
[11/12/2020 14:08:53 INFO 140524350674752] #early_stopping_criteria_metric: h
ost=algo-1, epoch=4, criteria=binary_classification_cross_entropy_objective,
 value=0.48046371427
[11/12/2020 14:08:53 INFO 140524350674752] Saving model for epoch: 4
[11/12/2020 14:08:53 INFO 140524350674752] Saved checkpoint to "/tmp/tmpagbki
2/mx-mod-0000.params"
[11/12/2020 14:08:53 INFO 140524350674752] Early stop condition met. Stopping
training.
[11/12/2020 14:08:53 INFO 140524350674752] #progress_metric: host=algo-1, com
pleted 100 % epochs
#metrics {"Metrics": {"Max Batches Seen Between Resets": {"count": 1, "max":
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ount": 1, "max": 1309, "sum": 1309.0, "min": 1309}, "Number of Records Since
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ar Learner", "epoch": 4}, "StartTime": 1605190086.464043}

[11/12/2020 14:08:53 INFO 140524350674752] #throughput_metric: host=algo-1, t
rain throughput=27988.7184434 records/second
[11/12/2020 14:08:53 WARNING 140524350674752] wait_for_all_workers will not s
ync workers since the kv store is not running distributed
[11/12/2020 14:08:53 WARNING 140524350674752] wait_for_all_workers will not s
ync workers since the kv store is not running distributed
[2020-11-12 14:08:56.907] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/validation", "epoch": 17, "duration": 3675, "num_examples":
 164, "num_bytes": 63460892}
[11/12/2020 14:08:56 INFO 140524350674752] #early_stopping_criteria_metric: h
ost=algo-1, epoch=4, criteria=binary_classification_cross_entropy_objective,
 value=0.48046371427
[2020-11-12 14:08:57.631] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/validation", "epoch": 19, "duration": 712, "num_examples": 1
64, "num_bytes": 63460892}
[11/12/2020 14:08:57 INFO 140524350674752] #validation_score (algo-1) : ('bin

```
ary_classification_cross_entropy_objective', 0.48065457531135314)
[11/12/2020 14:08:57 INFO 140524350674752] #validation_score (algo-1) : ('bin
ary_classification_accuracy', 0.7932917173619306)
[11/12/2020 14:08:57 INFO 140524350674752] #validation_score (algo-1) : ('bin
ary_f_1.000', 0.10956306460533594)
[11/12/2020 14:08:57 INFO 140524350674752] #validation_score (algo-1) : ('pre
cision', 0.5715856004396812)
[11/12/2020 14:08:57 INFO 140524350674752] #validation_score (algo-1) : ('rec
all', 0.0605884066414215)
[11/12/2020 14:08:57 INFO 140524350674752] #validation_score (algo-1) : ('roc
_auc_score', 0.6770432434507268)
[11/12/2020 14:08:57 INFO 140524350674752] #quality_metric: host=algo-1, vali
dation binary_classification_cross_entropy_objective <loss>=0.480654575311
[11/12/2020 14:08:57 INFO 140524350674752] #quality_metric: host=algo-1, vali
dation binary_classification_accuracy <score>=0.793291717362
[11/12/2020 14:08:57 INFO 140524350674752] #quality_metric: host=algo-1, vali
dation binary_f_1.000 <score>=0.109563064605
[11/12/2020 14:08:57 INFO 140524350674752] #quality_metric: host=algo-1, vali
dation precision <score>=0.57158560044
[11/12/2020 14:08:57 INFO 140524350674752] #quality_metric: host=algo-1, vali
dation recall <score>=0.0605884066414
[11/12/2020 14:08:57 INFO 140524350674752] #quality_metric: host=algo-1, vali
dation roc_auc_score <score>=0.677043243451
[11/12/2020 14:08:57 INFO 140524350674752] Best model found for hyperparamete
rs: {"lr_scheduler_step": 10, "wd": 0.0001, "optimizer": "adam", "lr_schedule
r_factor": 0.99, "l1": 0.0, "learning_rate": 0.005, "lr_scheduler_minimum_l
r": 1e-05}
[11/12/2020 14:08:57 INFO 140524350674752] Saved checkpoint to "/tmp/tmpY3cWy
v/mx-mod-0000.params"
[2020-11-12 14:08:57.705] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/test", "epoch": 0, "duration": 240861, "num_examples": 1, "n
um_bytes": 388000}
[2020-11-12 14:08:58.357] [tensorio] [info] epoch_stats={"data_pipeline": "/o
pt/ml/input/data/test", "epoch": 1, "duration": 651, "num_examples": 164, "nu
m_bytes": 63460892}
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ds Seen": {"count": 1, "max": 163559, "sum": 163559.0, "min": 163559}, "Max R
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n": 163559}, "Reset Count": {"count": 1, "max": 1, "sum": 1.0, "min": 1}}, "E
ndTime": 1605190138.427524, "Dimensions": {"Host": "algo-1", "Meta": "test_da
ta_iter", "Operation": "training", "Algorithm": "Linear Learner"}, "StartTim
e": 1605190137.702621}

[11/12/2020 14:08:58 INFO 140524350674752] #test_score (algo-1) : ('binary_cl
assification_cross_entropy_objective', 0.4791369917664459)
[11/12/2020 14:08:58 INFO 140524350674752] #test_score (algo-1) : ('binary_cl
assification_accuracy', 0.7948263317824149)
[11/12/2020 14:08:58 INFO 140524350674752] #test_score (algo-1) : ('binary_f_
1.000', 0.11076368646987121)
[11/12/2020 14:08:58 INFO 140524350674752] #test_score (algo-1) : ('precisio
n', 0.5724459052314435)
[11/12/2020 14:08:58 INFO 140524350674752] #test_score (algo-1) : ('recall',
```

```
 0.06131369730395752)
[11/12/2020 14:08:58 INFO 140524350674752] #test_score (algo-1) : ('roc_auc_s
core', 0.6752809152813174)
[11/12/2020 14:08:58 INFO 140524350674752] #quality_metric: host=algo-1, test
binary_classification_cross_entropy_objective <loss>=0.479136991766
[11/12/2020 14:08:58 INFO 140524350674752] #quality_metric: host=algo-1, test
binary_classification_accuracy <score>=0.794826331782
[11/12/2020 14:08:58 INFO 140524350674752] #quality_metric: host=algo-1, test
binary_f_1.000 <score>=0.11076368647
[11/12/2020 14:08:58 INFO 140524350674752] #quality_metric: host=algo-1, test
precision <score>=0.572445905231
[11/12/2020 14:08:58 INFO 140524350674752] #quality_metric: host=algo-1, test
recall <score>=0.061313697304
[11/12/2020 14:08:58 INFO 140524350674752] #quality_metric: host=algo-1, test
roc_auc_score <score>=0.675280915281
#metrics {"Metrics": {"totaltime": {"count": 1, "max": 241930.9549331665, "su
m": 241930.9549331665, "min": 241930.9549331665}, "finalize.time": {"count":
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t": 6, "max": 0.8299350738525391, "sum": 2.1452903747558594, "min": 0.2439022
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435404, "Dimensions": {"Host": "algo-1", "Operation": "training", "Algorith
m": "Linear Learner"}, "StartTime": 1605189896.821136}


2020-11-12 14:10:03 Uploading - Uploading generated training model
2020-11-12 14:10:03 Completed - Training job completed
Training seconds: 380
Billable seconds: 380
```

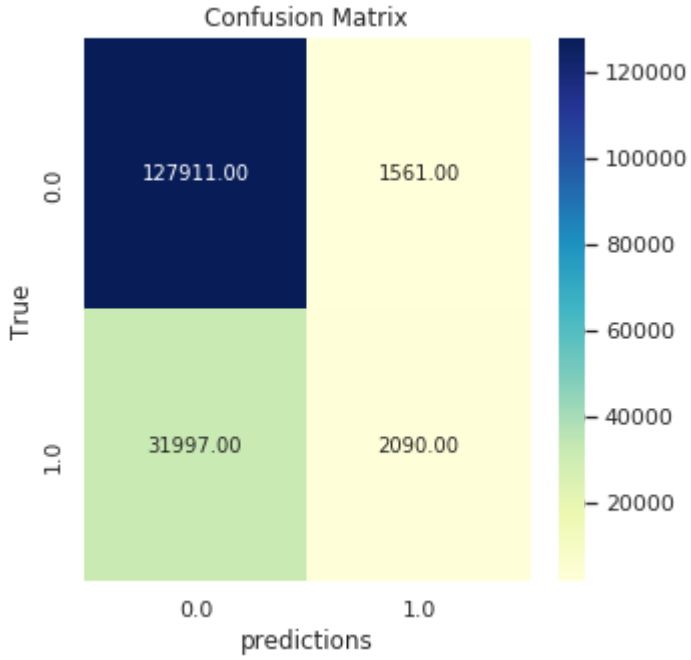
In [63]:
```
classifier_predictor = classifier_estimator.deploy(initial_instance_count=1, i
nstance_type='ml.m4.xlarge')
```

```
Defaulting to the only supported framework/algorithm version: 1. Ignoring fra
mework/algorithm version: 1.

---------------!
```

In [64]:
```
predict_batches(classifier_predictor, test_features, test_labels)
```

```
Accuracy: 0.7948263317824149
AUC     : 0.5246285182021517
Precision: 0.5724459052314435
Recall: 0.06131369730395752
F1_score: 0.11076368646987121
```



The linear model shows only a little improvement in performance. Try a tree-based ensemble model called XGBoost with Amazon SageMaker.

Try the XGBoost model

Here are the steps you need to take:

1. Use the training set variables and save them as CSV files: train.csv, validation.csv and test.csv
2. Store the bucket name in the variable. The Amazon S3 bucket name is provided to the left of the lab instructions.
   a. `bucket = <LabBucketName>`
   b. `prefix = 'sagemaker/xgboost'`
3. Use Boto3 to upload the model to the bucket.

In [65]:
```
train_data, validation_data, test_data = np.split(data.sample(frac=1, random_s
tate=1729), [int(0.7 * len(data)), int(0.9*len(data))])

pd.concat([train_data['target'], train_data.drop(['target'], axis=1)], axis=1)
.to_csv('train.csv', index=False, header=False)
pd.concat([validation_data['target'], validation_data.drop(['target'], axis=1
)], axis=1).to_csv('validation.csv', index=False, header=False)
pd.concat([test_data['target'], test_data.drop(['target'], axis=1)], axis=1).t
o_csv('test.csv', index=False, header=False)
```

Replace **<LabBucketName>** with the resource name that was provided with your lab account.

In [66]:
```
bucket = 'ml-pipeline-bucket'
prefix = 'sagemaker/xgboost'
```

In [67]:
```
### Upload data to S3
boto3.Session().resource('s3').Bucket(bucket).Object(os.path.join(prefix, 'tra
in/train.csv')).upload_file('train.csv')
boto3.Session().resource('s3').Bucket(bucket).Object(os.path.join(prefix, 'val
idation/validation.csv')).upload_file('validation.csv')
```

In [68]:
```
from sagemaker.amazon.amazon_estimator import image_uris
container = image_uris.retrieve('xgboost',boto3.Session().region_name, '0.90-
1')
```

Use the `sagemaker.inputs.TrainingInput` function to create a record_set for the training and validation datasets.

In [69]:
```
s3_input_train = sagemaker.inputs.TrainingInput(s3_data='s3://{}/{}/train'.for
mat(bucket, prefix), content_type='csv')
s3_input_validation = sagemaker.inputs.TrainingInput(s3_data='s3://{}/{}/valid
ation/'.format(bucket, prefix), content_type='csv')
```

In [70]:
```
sess = sagemaker.Session()

xgb = sagemaker.estimator.Estimator(container,
                                    role = sagemaker.get_execution_role(),
                                    instance_count=1,
                                    instance_type='ml.m4.xlarge',
                                    output_path='s3://{}/{}/output'.format(buc
ket, prefix),
                                    sagemaker_session=sess)
xgb.set_hyperparameters(max_depth=5,
                        eta=0.2,
                        gamma=4,
                        min_child_weight=6,
                        subsample=0.8,
                        silent=0,
                        objective='binary:logistic',
                        eval_metric = "auc",
                        num_round=100)

xgb.fit({'train': s3_input_train, 'validation': s3_input_validation})
```

```
2020-11-12 14:19:03 Starting - Starting the training job...
2020-11-12 14:19:05 Starting - Launching requested ML instances.........
2020-11-12 14:20:34 Starting - Preparing the instances for training...
2020-11-12 14:21:23 Downloading - Downloading input data...
2020-11-12 14:21:44 Training - Downloading the training image...
2020-11-12 14:22:13 Training - Training image download completed. Training in
progress.INFO:sagemaker-containers:Imported framework sagemaker_xgboost_conta
iner.training
INFO:sagemaker-containers:Failed to parse hyperparameter eval_metric value au
c to Json.
Returning the value itself
INFO:sagemaker-containers:Failed to parse hyperparameter objective value bina
ry:logistic to Json.
Returning the value itself
INFO:sagemaker-containers:No GPUs detected (normal if no gpus installed)
INFO:sagemaker_xgboost_container.training:Running XGBoost Sagemaker in algori
thm mode
INFO:root:Determined delimiter of CSV input is ','
INFO:root:Determined delimiter of CSV input is ','
INFO:root:Determined delimiter of CSV input is ','
[14:22:18] 1144913x85 matrix with 97317605 entries loaded from /opt/ml/input/
data/train?format=csv&label_column=0&delimiter=,
INFO:root:Determined delimiter of CSV input is ','
[14:22:19] 327118x85 matrix with 27805030 entries loaded from /opt/ml/input/d
ata/validation?format=csv&label_column=0&delimiter=,
INFO:root:Single node training.
INFO:root:Train matrix has 1144913 rows
INFO:root:Validation matrix has 327118 rows
[0]#011train-auc:0.654532#011validation-auc:0.655617
[1]#011train-auc:0.666847#011validation-auc:0.668206
[2]#011train-auc:0.669282#011validation-auc:0.670599
[3]#011train-auc:0.673045#011validation-auc:0.674019
[4]#011train-auc:0.676361#011validation-auc:0.677643
[5]#011train-auc:0.679057#011validation-auc:0.680134
[6]#011train-auc:0.679818#011validation-auc:0.680607
[7]#011train-auc:0.682762#011validation-auc:0.683342
[8]#011train-auc:0.684812#011validation-auc:0.6856
[9]#011train-auc:0.687286#011validation-auc:0.687814
[10]#011train-auc:0.688729#011validation-auc:0.689269
[11]#011train-auc:0.690798#011validation-auc:0.691097
[12]#011train-auc:0.693199#011validation-auc:0.693413
[13]#011train-auc:0.694325#011validation-auc:0.694535
[14]#011train-auc:0.696288#011validation-auc:0.696314
[15]#011train-auc:0.697802#011validation-auc:0.697719
[16]#011train-auc:0.69893#011validation-auc:0.698875
[17]#011train-auc:0.700827#011validation-auc:0.700665
[18]#011train-auc:0.702206#011validation-auc:0.701991
[19]#011train-auc:0.702929#011validation-auc:0.70264
[20]#011train-auc:0.703555#011validation-auc:0.703309
[21]#011train-auc:0.704449#011validation-auc:0.704132
[22]#011train-auc:0.705413#011validation-auc:0.704908
[23]#011train-auc:0.706434#011validation-auc:0.705783
[24]#011train-auc:0.707115#011validation-auc:0.706335
[25]#011train-auc:0.707817#011validation-auc:0.706992
[26]#011train-auc:0.708519#011validation-auc:0.707543
```

```
[27]#011train-auc:0.709232#011validation-auc:0.708181
[28]#011train-auc:0.71006#011validation-auc:0.709066
[29]#011train-auc:0.710734#011validation-auc:0.709751
[30]#011train-auc:0.711384#011validation-auc:0.710345
[31]#011train-auc:0.712961#011validation-auc:0.711901
[32]#011train-auc:0.713421#011validation-auc:0.712309
[33]#011train-auc:0.713929#011validation-auc:0.712792
[34]#011train-auc:0.714469#011validation-auc:0.713246
[35]#011train-auc:0.714872#011validation-auc:0.713622
[36]#011train-auc:0.715888#011validation-auc:0.714574
[37]#011train-auc:0.717109#011validation-auc:0.71571
[38]#011train-auc:0.717519#011validation-auc:0.716064
[39]#011train-auc:0.717893#011validation-auc:0.716382
[40]#011train-auc:0.718107#011validation-auc:0.716608
[41]#011train-auc:0.718902#011validation-auc:0.717325
[42]#011train-auc:0.719606#011validation-auc:0.717962
[43]#011train-auc:0.719881#011validation-auc:0.718164
[44]#011train-auc:0.720297#011validation-auc:0.718538
[45]#011train-auc:0.720554#011validation-auc:0.71877
[46]#011train-auc:0.720838#011validation-auc:0.718979
[47]#011train-auc:0.721514#011validation-auc:0.719607
[48]#011train-auc:0.721773#011validation-auc:0.719836
[49]#011train-auc:0.722189#011validation-auc:0.720209
[50]#011train-auc:0.722331#011validation-auc:0.720356
[51]#011train-auc:0.722814#011validation-auc:0.720822
[52]#011train-auc:0.723241#011validation-auc:0.721193
[53]#011train-auc:0.723858#011validation-auc:0.721812
[54]#011train-auc:0.724004#011validation-auc:0.721949
[55]#011train-auc:0.724407#011validation-auc:0.722214
[56]#011train-auc:0.724637#011validation-auc:0.72242
[57]#011train-auc:0.724815#011validation-auc:0.722574
[58]#011train-auc:0.725003#011validation-auc:0.722699
[59]#011train-auc:0.725205#011validation-auc:0.72284
[60]#011train-auc:0.725516#011validation-auc:0.723156
[61]#011train-auc:0.725774#011validation-auc:0.723366
[62]#011train-auc:0.726091#011validation-auc:0.723675
[63]#011train-auc:0.726742#011validation-auc:0.724259
[64]#011train-auc:0.727127#011validation-auc:0.7246
[65]#011train-auc:0.727621#011validation-auc:0.724997
[66]#011train-auc:0.728029#011validation-auc:0.72534
[67]#011train-auc:0.728189#011validation-auc:0.725461
[68]#011train-auc:0.728499#011validation-auc:0.725774
[69]#011train-auc:0.72865#011validation-auc:0.725932
[70]#011train-auc:0.72881#011validation-auc:0.726093
[71]#011train-auc:0.729102#011validation-auc:0.726353
[72]#011train-auc:0.729186#011validation-auc:0.726402
[73]#011train-auc:0.729538#011validation-auc:0.726734
[74]#011train-auc:0.729756#011validation-auc:0.726875
[75]#011train-auc:0.730012#011validation-auc:0.727106
[76]#011train-auc:0.730267#011validation-auc:0.727327
[77]#011train-auc:0.730405#011validation-auc:0.727394
[78]#011train-auc:0.730713#011validation-auc:0.727676
[79]#011train-auc:0.730878#011validation-auc:0.727784
[80]#011train-auc:0.731106#011validation-auc:0.72797
[81]#011train-auc:0.731301#011validation-auc:0.728098
[82]#011train-auc:0.731354#011validation-auc:0.728163
```

```
[83]#011train-auc:0.731538#011validation-auc:0.728315
[84]#011train-auc:0.7317#011validation-auc:0.72843
[85]#011train-auc:0.731951#011validation-auc:0.728599
[86]#011train-auc:0.732154#011validation-auc:0.728741
[87]#011train-auc:0.732471#011validation-auc:0.729066
[88]#011train-auc:0.732745#011validation-auc:0.729271
[89]#011train-auc:0.732914#011validation-auc:0.729383
[90]#011train-auc:0.733062#011validation-auc:0.729514
[91]#011train-auc:0.733332#011validation-auc:0.72975
[92]#011train-auc:0.733571#011validation-auc:0.729907
[93]#011train-auc:0.733642#011validation-auc:0.729971
[94]#011train-auc:0.733803#011validation-auc:0.730066
[95]#011train-auc:0.73401#011validation-auc:0.730228
[96]#011train-auc:0.734093#011validation-auc:0.730294
[97]#011train-auc:0.734282#011validation-auc:0.73044
[98]#011train-auc:0.734406#011validation-auc:0.730527
[99]#011train-auc:0.734639#011validation-auc:0.730709

2020-11-12 14:25:54 Uploading - Uploading generated training model
2020-11-12 14:25:54 Completed - Training job completed
Training seconds: 271
Billable seconds: 271
```

Deploy the predictor for your new model and evaluate the model on the test dataset.

In [71]:
```
from sagemaker.serializers import CSVSerializer

xgb_predictor = xgb.deploy(initial_instance_count = 1,
                           instance_type = 'ml.m4.xlarge',
                           serializer=CSVSerializer())
```

```
----------------!
```

In [72]:
```
test_data = pd.concat([test_data['target'], test_data.drop(['target'], axis=1
)], axis=1)
```

In [73]:
```
def predict(predictor , features, labels , prob_threshold = 0.5, rows=500):
    """
    Return evaluation results
    predictor : Predictor object of model
    features: Input features to model
    label: Ground truth target values
    prob_threshold : Probability cut off to separate positive and negative cla
ss
    """
    split_array = np.array_split(features, int(features.shape[0] / float(rows)
+ 1))
    predictions = ''
    for array in split_array:
        predictions = ','.join([predictions, predictor.predict(array).decode(
'utf-8')])

    preds = np.fromstring(predictions[1:], sep=',')
    preds = preds.reshape((-1,))
    predictions = np.where(preds > prob_threshold , 1, 0)
    labels = labels.reshape((-1,))


    # Calculate accuracy
    accuracy = (predictions == labels).sum() / labels.shape[0]
    print(f'Accuracy: {accuracy}')

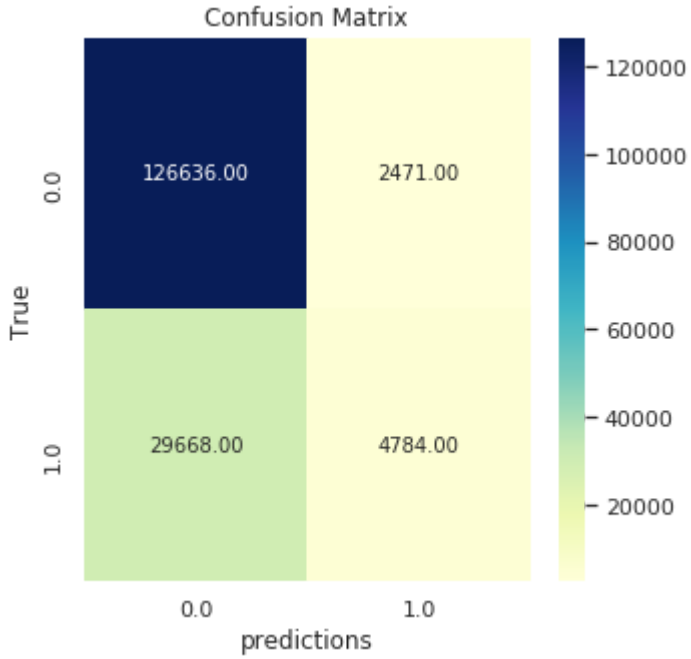
    auc = roc_auc_score(labels, preds)
    print(f'AUC      : {auc}')

    precision, recall, f1_score, _ = precision_recall_fscore_support(labels, p
redictions, average = 'binary')
    print(f'Precision: {precision}')
    print(f'Recall: {recall}')
    print(f'F1_score: {f1_score}')


    confusion_matrix = pd.crosstab(index=labels, columns=np.round(preds), rown
ames=['True'], colnames=['predictions']).astype(int)
    plt.figure(figsize = (5,5))
    sns.heatmap(confusion_matrix, annot=True, fmt='.2f', cmap="YlGnBu").set_ti
tle('Confusion Matrix')
    return list(preds)
```

In [74]:
```
predictions = predict(xgb_predictor, test_data.values[:, 1:] ,  test_data.iloc
[:, 0:1].values, prob_threshold = 0.5)
```

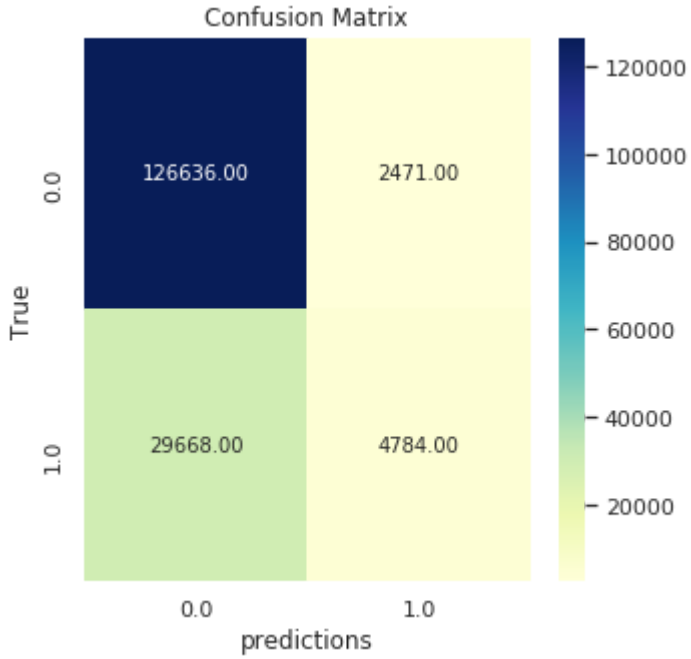
```
Accuracy: 0.8035021001595755
AUC     : 0.7310358690688304
Precision: 0.659407305306685
Recall: 0.13885986299779404
F1_score: 0.22940993118661135
```



Try different thresholds

In [75]:
```
predictions = predict(xgb_predictor, test_data.values[:, 1:] ,  test_data.iloc
[:, 0:1].values, prob_threshold = 0.8)
```

```
Accuracy: 0.791182386783974
AUC     : 0.7310358690688304
Precision: 0.8962765957446809
Recall: 0.009781725298966678
F1_score: 0.019352245319857585
```



Question: What can you conclude from how the model did on the test set?

Answer: By changing the threshold for positive class, we see that:

- AUC doesnt change.
- Precision, recall, and accuracy change. We could use a threshold based on precision-recall trade-off or use metrics like AUC to gauge model performance.

Hyperparameter optimization (HPO)

In [76]:
```
from sagemaker.tuner import IntegerParameter, CategoricalParameter, Continuous
Parameter, HyperparameterTuner

### You can spin up multiple instances to do hyperparameter optimization in pa
rallel

xgb = sagemaker.estimator.Estimator(container,
                                    role=sagemaker.get_execution_role(),
                                    instance_count= 2, # make sure you have li
mit set for these instances
                                    instance_type='ml.m4.xlarge',
                                    output_path='s3://{}/{}/output'.format(buc
ket, prefix),
                                    sagemaker_session=sess)

xgb.set_hyperparameters(eval_metric='auc',
                        objective='binary:logistic',
                        num_round=100,
                        early_stopping_rounds=50,
                        rate_drop=0.3,
                        tweedie_variance_power=1.4)
```

In [77]:
```
hyperparameter_ranges = {'eta': ContinuousParameter(0, 0.5),
                         'min_child_weight': ContinuousParameter(3, 10),
                         'alpha': ContinuousParameter(0, 2)}

objective_metric_name = 'validation:auc'

tuner = HyperparameterTuner(xgb,
                            objective_metric_name,
                            hyperparameter_ranges,
                            max_jobs=9,
                            max_parallel_jobs=3)
```

In [78]:
```
tuner.fit({'train': s3_input_train, 'validation': s3_input_validation})
```

```
.....................................................................
```

In [79]:
```
boto3.client('sagemaker').describe_hyper_parameter_tuning_job(
    HyperParameterTuningJobName=tuner.latest_tuning_job.job_name)['HyperParame
terTuningJobStatus']
```

Out[79]:
```
'Completed'
```

Wait until the training job is finished. It may take 25-30 minutes.

To monitor hyperparameter optimization jobs:

1. In the AWS Management Console, on the **Services** menu, click **Amazon SageMaker**.
2. Click **Training** > **Hyperparameter tuning jobs**.
3. You can check the status of each hyperparametertuning job, its objective metric value, and its logs.

In [80]:
```
sage_client = boto3.Session().client('sagemaker')
tuning_job_name = tuner.latest_tuning_job.job_name

# Run this cell to check current status of hyperparameter tuning job
tuning_job_result = sage_client.describe_hyper_parameter_tuning_job(HyperParam
eterTuningJobName=tuning_job_name)

status = tuning_job_result['HyperParameterTuningJobStatus']
if status != 'Completed':
    print('Reminder: the tuning job has not been completed.')

job_count = tuning_job_result['TrainingJobStatusCounters']['Completed']
print("%d training jobs have completed" % job_count)

is_minimize = (tuning_job_result['HyperParameterTuningJobConfig']['HyperParame
terTuningJobObjective']['Type'] != 'Maximize')
objective_name = tuning_job_result['HyperParameterTuningJobConfig']['HyperPara
meterTuningJobObjective']['MetricName']


from pprint import pprint
if tuning_job_result.get('BestTrainingJob',None):
    print("Best model found so far:")
    pprint(tuning_job_result['BestTrainingJob'])
else:
    print("No training jobs have reported results yet.")

### Get the hyperparameter tuning job results in a dataframe
tuner_df = sagemaker.HyperparameterTuningJobAnalytics(tuning_job_name).datafra
me()

if len(tuner_df) > 0:
    df = tuner_df[tuner_df['FinalObjectiveValue'] > -float('inf')]
    if len(df) > 0:
        df = df.sort_values('FinalObjectiveValue', ascending=is_minimize)
        print("Number of training jobs with valid objective: %d" % len(df))
        print({"lowest":min(df['FinalObjectiveValue']),"highest": max(df['Fina
lObjectiveValue'])})
        pd.set_option('display.max_colwidth', -1)  # Don't truncate TrainingJo
bName
    else:
        print("No training jobs have reported valid results yet.")

tuner_df
```

```
10 training jobs have completed
Best model found so far:
{'CreationTime': datetime.datetime(2020, 11, 12, 15, 37, 53, tzinfo=tzlocal
()),
 'FinalHyperParameterTuningJobObjectiveMetric': {'MetricName': 'validation:au
c',
                                                 'Value': 0.771565020084381
1},
 'ObjectiveStatus': 'Succeeded',
 'TrainingEndTime': datetime.datetime(2020, 11, 12, 16, 16, 44, tzinfo=tzloca
l()),
 'TrainingJobArn': 'arn:aws:sagemaker:us-west-2:772141828457:training-job/sag
emaker-xgboost-201112-1435-009-7fafc153',
 'TrainingJobName': 'sagemaker-xgboost-201112-1435-009-7fafc153',
 'TrainingJobStatus': 'Completed',
 'TrainingStartTime': datetime.datetime(2020, 11, 12, 15, 40, 25, tzinfo=tzlo
cal()),
 'TunedHyperParameters': {'alpha': '0.3297463183905762',
                          'eta': '0.1652018477805134',
                          'max_depth': '13',
                          'min_child_weight': '6.604298910334063',
                          'num_round': '142'}}
Number of training jobs with valid objective: 10
{'lowest': 0.5, 'highest': 0.7715650200843811}
```

Out[80]:

	alpha	eta	max_depth	min_child_weight	num_round	TrainingJobName	TrainingJobS
0	0.175410	0.000000	14.0	7.930334	139.0	sagemaker-xgboost-201112-1435-010-e4d99dcd	Com
1	0.329746	0.165202	13.0	6.604299	142.0	sagemaker-xgboost-201112-1435-009-7fafc153	Com
2	0.249096	0.141841	15.0	3.407003	150.0	sagemaker-xgboost-201112-1435-008-b3005fef	Com
3	0.089573	0.365159	14.0	9.554937	98.0	sagemaker-xgboost-201112-1435-007-1a613f9d	Com
4	0.378758	0.252223	13.0	9.966375	73.0	sagemaker-xgboost-201112-1435-006-1f38f162	Com
5	1.808955	0.134379	10.0	5.461067	12.0	sagemaker-xgboost-201112-1435-005-90dd7708	Com
6	0.070735	0.104853	12.0	6.286505	145.0	sagemaker-xgboost-201112-1435-004-99737bb2	Com
7	0.096772	0.252389	14.0	9.260357	140.0	sagemaker-xgboost-201112-1435-003-276e93d6	Com
8	0.036230	0.325462	14.0	5.528563	26.0	sagemaker-xgboost-201112-1435-002-5c180eea	Com
9	0.848831	0.486379	12.0	7.307691	139.0	sagemaker-xgboost-201112-1435-001-d2f60704	Com

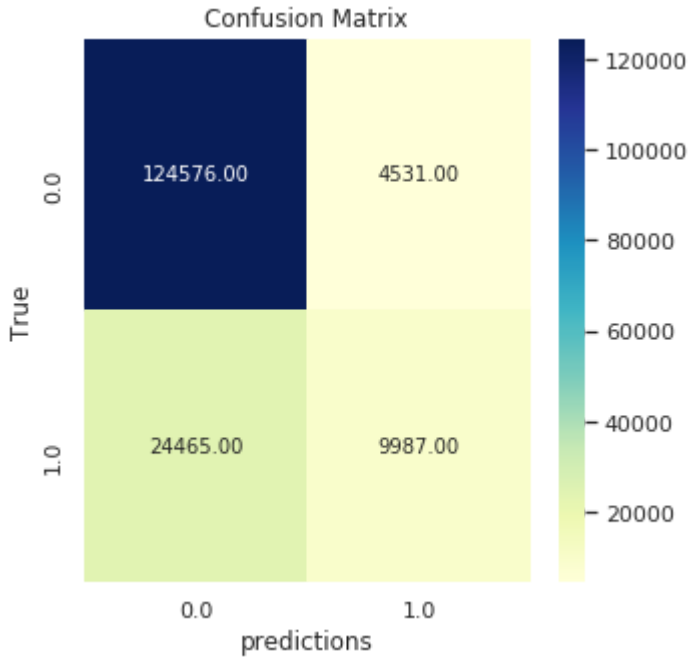
Deploy the best model from the hyperparameter optimization training.

In [81]:
```
xgb_predictor_hpo = tuner.deploy(initial_instance_count = 1,
                                 instance_type = 'ml.m4.xlarge',
                                serializer=CSVSerializer())
```

```
2020-11-12 16:16:44 Starting - Preparing the instances for training
2020-11-12 16:16:44 Downloading - Downloading input data
2020-11-12 16:16:44 Training - Training image download completed. Training in
progress.
2020-11-12 16:16:44 Uploading - Uploading generated training model
2020-11-12 16:16:44 Completed - Training job completed
---------------!
```

In [82]:
```
predictions = predict(xgb_predictor_hpo, test_data.values[:, 1:] ,  test_data.
iloc[:, 0:1].values, prob_threshold = 0.5)
```

```
Accuracy: 0.8227184074248436
AUC     : 0.7736010671123233
Precision: 0.6879046700647472
Recall: 0.289881574364333
F1_score: 0.40788237696548907
```



Feature importance

The model files for all hyperparameter tuning jobs are saved by the training job name as in the table above in the folder: "{bucket}/{prefix}/output/". You can load the model and use it like a regular sklearn model object for interpretation.

In [86]:
```
# best_hpo_model_path = "s3://" + bucket + "/sagemaker/xgboost/output/<Best model TrainingJobName>/output/model.tar.gz"
best_hpo_model_path = "s3://" + bucket + "/sagemaker/xgboost/output/sagemaker-xgboost-201112-1435-009-7fafc153/output/model.tar.gz"
### Download best_hpo_model_path to local
!aws s3 cp {best_hpo_model_path} .
```

```
download: s3://qls-163855-7bcdbc5dca898ae8-labbucket-gb2viqdpbzup/sagemaker/xgboost/output/sagemaker-xgboost-201112-1435-009-7fafc153/output/model.tar.gz to ./model.tar.gz
```

In [84]:
```
!pip install xgboost=='0.90'
```

```
Collecting xgboost==0.90
  Downloading xgboost-0.90-py2.py3-none-manylinux1_x86_64.whl (142.8 MB)
     |████████████████████████████████| 142.8 MB 63 kB/s s eta 0:00:01
Requirement already satisfied: scipy in /home/ec2-user/anaconda3/envs/mxnet_p36/lib/python3.6/site-packages (from xgboost==0.90) (1.4.1)
Requirement already satisfied: numpy in /home/ec2-user/anaconda3/envs/mxnet_p36/lib/python3.6/site-packages (from xgboost==0.90) (1.18.1)
Installing collected packages: xgboost
Successfully installed xgboost-0.90
WARNING: You are using pip version 20.0.2; however, version 20.2.4 is available.
You should consider upgrading via the '/home/ec2-user/anaconda3/envs/mxnet_p36/bin/python -m pip install --upgrade pip' command.
```

Load picked model file

In [87]:
```
import pickle
import tarfile
import xgboost

with open('model.tar.gz', 'rb') as f:
    with tarfile.open(fileobj=f, mode='r') as tar_f:
        with tar_f.extractfile('xgboost-model') as extracted_f:
            xgbooster = pickle.load(extracted_f)
```

Map column names to XGBoost model

In [88]:
```
columns = list(data.columns)
columns.remove('target')
```

In [89]:
```
feature_importance = xgbooster.get_fscore()
feature_importance_col = {}

for column, fname in zip(columns, xgbooster.feature_names):
    try:
         feature_importance_col[column] = feature_importance[fname]
    except Exception:
        pass
```

Sort by feature importance value

In [90]:
```
sorted(feature_importance_col.items(), key=lambda kv: kv[1], reverse=True)
```

Out[90]:
```
[('DepHourofDay', 27578),
 ('AWND_O', 23395),
 ('AWND_D', 22912),
 ('TAVG_O', 22152),
 ('TAVG_D', 21949),
 ('Distance', 15873),
 ('PRCP_O', 7515),
 ('PRCP_D', 7443),
 ('Reporting_Airline_UA', 3620),
 ('Year_2017', 2289),
 ('Year_2015', 2175),
 ('Year_2018', 2164),
 ('Year_2016', 2097),
 ('Reporting_Airline_DL', 1688),
 ('Reporting_Airline_WN', 1576),
 ('Quarter_4', 1526),
 ('DayOfWeek_5', 1448),
 ('DayOfWeek_4', 1422),
 ('DayOfWeek_7', 1287),
 ('DayOfWeek_3', 1226),
 ('Quarter_2', 1195),
 ('Reporting_Airline_OO', 1143),
 ('DayOfWeek_2', 1139),
 ('DayOfWeek_6', 1100),
 ('Origin_LAX', 1086),
 ('Origin_ORD', 1064),
 ('Dest_LAX', 1059),
 ('SNOW_O', 1052),
 ('Month_12', 981),
 ('Dest_ORD', 962),
 ('Month_8', 951),
 ('Origin_DFW', 948),
 ('Month_7', 937),
 ('Origin_DEN', 909),
 ('Month_3', 896),
 ('Month_2', 880),
 ('Month_11', 872),
 ('Dest_DFW', 863),
 ('Month_5', 861),
 ('SNOW_D', 803),
 ('Month_4', 798),
 ('Dest_SFO', 784),
 ('Month_9', 781),
 ('Origin_SFO', 780),
 ('Origin_IAH', 764),
 ('Month_6', 762),
 ('Dest_DEN', 746),
 ('Month_10', 713),
 ('Quarter_3', 659),
 ('Dest_IAH', 656),
 ('Origin_PHX', 647),
 ('DayofMonth_18', 631),
 ('DayofMonth_19', 631),
 ('DayofMonth_17', 615),
 ('Dest_PHX', 609),
```

```
('DayofMonth_20', 606),
('DayofMonth_14', 604),
('DayofMonth_4', 598),
('DayofMonth_3', 594),
('DayofMonth_8', 594),
('DayofMonth_27', 590),
('DayofMonth_28', 585),
('DayofMonth_5', 584),
('DayofMonth_13', 579),
('DayofMonth_12', 574),
('DayofMonth_7', 571),
('DayofMonth_23', 568),
('DayofMonth_6', 564),
('DayofMonth_26', 560),
('DayofMonth_10', 557),
('DayofMonth_22', 544),
('DayofMonth_21', 542),
('DayofMonth_30', 535),
('DayofMonth_9', 533),
('DayofMonth_2', 532),
('Origin_CLT', 530),
('DayofMonth_24', 529),
('DayofMonth_15', 528),
('DayofMonth_11', 527),
('DayofMonth_16', 455),
('Dest_CLT', 455),
('DayofMonth_29', 424),
('is_holiday_1', 422),
('DayofMonth_25', 398),
('DayofMonth_31', 285)]
```

Based on the feature importance above, you can see that DepHourofDay, Airwind, and Temperature at both source and destination are the major influencers in deciding the flight delay.

This is one way to validate what is intuitive in terms of features and what the model actually learns.

Conclusion

You've now gone through at least a couple iterations of training and evaluating your model. It's time to wrap up this project and reflect on what you've learned and what types of steps you might take moving forward (assuming you had more time). Use the cell below to answer some of these and other relevant questions:

1. Does your model performance meet your business goal? If not, what are some things you'd like to do differently if you had more time for tuning?
2. To what extent did your model improve as you made changes to your dataset, features, and hyperparameters? What types of techniques did you employ throughout this project that you felt yielded the greatest improvements in your model?
3. What were some of the biggest challenges you encountered throughout this project?
4. Are there outstanding questions you have about aspects of the pipeline that just didn't make sense to you?
5. What were the three most important things you learned about machine learning while completing this project?

Project presentation: Summarize your answers to these questions in your project presentation as well. Pull together all of your notes for your project presentation at this point and prepare to present your

In [ ]: