Python scripts for each major use case

NetApp Solutions

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Python scripts for each major use case

Previous: Hybrid cloud solution.

The following three Python scripts correspond to the three major use cases tested. First is `sentiment_analysis_sparknlp.py`.

```
# TR-4570 Refresh NLP testing by Rick Huang
from sys import argv
import os
import sparknlp
import pyspark.sql.functions as F
from sparknlp import Finisher
from pyspark.ml import Pipeline
from sparknlp.base import *
from sparknlp.annotator import *
from sparknlp.pretrained import PretrainedPipeline
from sparknlp import Finisher
# Start Spark Session with Spark NLP
spark = sparknlp.start()
print("Spark NLP version:")
print(sparknlp.version())
print("Apache Spark version:")
print(spark.version)
spark = sparknlp.SparkSession.builder \
     .master("yarn") \
     .appName("test_hdfs_read_write") \
     .config("spark.executor.cores", "1") \
     .config("spark.jars.packages", "com.johnsnowlabs.nlp:spark-
nlp_2.12:3.4.3")\
     .config('spark.executor.memory', '5gb') \
     .config('spark.executor.memoryOverhead','1000')\
     .config('spark.driver.memoryOverhead','1000')\
     .config("spark.sql.shuffle.partitions", "480")\
     .getOrCreate()
sc = spark.sparkContext
from pyspark.sql import SQLContext
sql = SQLContext(sc)
sqlContext = SQLContext(sc)
# Download pre-trained pipelines & sequence classifier
explain_pipeline_model = PretrainedPipeline('explain_document_dl',
lang='en').model#pipeline_sa =
PretrainedPipeline("classifierdl_bertwiki_finance_sentiment_pipeline",
lang="en")
# pipeline_finbert =
BertForSequenceClassification.loadSavedModel('/sparkusecase/bert_sequence_
classifier_finbert_en_3', spark)
sequenceClassifier = BertForSequenceClassification \
        .pretrained('bert_sequence_classifier_finbert', 'en') \
        .setInputCols(['token', 'document']) \
        .setOutputCol('class') \
        .setCaseSensitive(True) \
        .setMaxSentenceLength(512)
def process_sentence_df(data):
    # Pre-process: begin
    print("1. Begin DataFrame pre-processing...\n")
    print(f"\n\t2. Attaching DocumentAssembler Transformer to the
pipeline")
    documentAssembler = DocumentAssembler() \
        .setInputCol("text") \
        .setOutputCol("document") \
        .setCleanupMode("inplace_full")
        #.setCleanupMode("shrink", "inplace_full")
    doc_df = documentAssembler.transform(data)
    doc_df.printSchema()
    doc_df.show(truncate=50)
    # Pre-process: get rid of  blank lines
    clean_df = doc_df.withColumn("tmp", F.explode("document")) \
        .select("tmp.result").where("tmp.end !=
-1").withColumnRenamed("result", "text").dropna()
    print("[OK!] DataFrame after initial cleanup:\n")
    clean_df.printSchema()
    clean_df.show(truncate=80)
    # for FinBERT
    tokenizer = Tokenizer() \
        .setInputCols(['document']) \
        .setOutputCol('token')
    print(f"\n\t3. Attaching Tokenizer Annotator to the pipeline")
    pipeline_finbert = Pipeline(stages=[
        documentAssembler,
        tokenizer,
        sequenceClassifier
        ])
    # Use Finisher() & construct PySpark ML pipeline
    finisher = Finisher().setInputCols(["token", "lemma", "pos",
"entities"])
    print(f"\n\t4. Attaching Finisher Transformer to the pipeline")
    pipeline_ex = Pipeline() \
        .setStages([
           explain_pipeline_model,
           finisher
           ])
    print("\n\t\t\t ---- Pipeline Built Successfully ----")
    # Loading pipelines to annotate
    #result_ex_df = pipeline_ex.transform(clean_df)
    ex_model = pipeline_ex.fit(clean_df)
    annotations_finished_ex_df = ex_model.transform(clean_df)
    # result_sa_df = pipeline_sa.transform(clean_df)
    result_finbert_df = pipeline_finbert.fit(clean_df).transform(clean_df)
    print("\n\t\t\t ----Document Explain, Sentiment Analysis & FinBERT
Pipeline Fitted Successfully ----")
    # Check the result entities
    print("[OK!] Simple explain ML pipeline result:\n")
    annotations_finished_ex_df.printSchema()
    annotations_finished_ex_df.select('text',
'finished_entities').show(truncate=False)
    # Check the result sentiment from FinBERT
    print("[OK!] Sentiment Analysis FinBERT pipeline result:\n")
    result_finbert_df.printSchema()
    result_finbert_df.select('text', 'class.result').show(80, False)
    sentiment_stats(result_finbert_df)
    return
def sentiment_stats(finbert_df):
    result_df = finbert_df.select('text', 'class.result')
    sa_df = result_df.select('result')
    sa_df.groupBy('result').count().show()
    # total_lines = result_clean_df.count()
    # num_neutral = result_clean_df.where(result_clean_df.result ==
['neutral']).count()
    # num_positive = result_clean_df.where(result_clean_df.result ==
['positive']).count()
    # num_negative = result_clean_df.where(result_clean_df.result ==
['negative']).count()
    # print(f"\nRatio of neutral sentiment = {num_neutral/total_lines}")
    # print(f"Ratio of positive sentiment = {num_positive / total_lines}")
    # print(f"Ratio of negative sentiment = {num_negative /
total_lines}\n")
    return
def process_input_file(file_name):
    # Turn input file to Spark DataFrame
    print("START processing input file...")
    data_df = spark.read.text(file_name)
    data_df.show()
    # rename first column 'text' for sparknlp
    output_df = data_df.withColumnRenamed("value", "text").dropna()
    output_df.printSchema()
    return output_dfdef process_local_dir(directory):
```

```
    filelist = []
    for subdir, dirs, files in os.walk(directory):
        for filename in files:
            filepath = subdir + os.sep + filename
            print("[OK!] Will process the following files:")
            if filepath.endswith(".txt"):
                print(filepath)
                filelist.append(filepath)
    return filelist
def process_local_dir_or_file(dir_or_file):
    numfiles = 0
    if os.path.isfile(dir_or_file):
        input_df = process_input_file(dir_or_file)
        print("Obtained input_df.")
        process_sentence_df(input_df)
        print("Processed input_df")
        numfiles += 1
    else:
        filelist = process_local_dir(dir_or_file)
        for file in filelist:
            input_df = process_input_file(file)
            process_sentence_df(input_df)
            numfiles += 1
    return numfiles
def process_hdfs_dir(dir_name):
    # Turn input files to Spark DataFrame
    print("START processing input HDFS directory...")
    data_df = spark.read.option("recursiveFileLookup",
"true").text(dir_name)
    data_df.show()
    print("[DEBUG] total lines in data_df = ", data_df.count())
    # rename first column 'text' for sparknlp
    output_df = data_df.withColumnRenamed("value", "text").dropna()
    print("[DEBUG] output_df looks like: \n")
    output_df.show(40, False)
    print("[DEBUG] HDFS dir resulting data_df schema: \n")
    output_df.printSchema()
    process_sentence_df(output_df)
    print("Processed HDFS directory: ", dir_name)
    returnif __name__ == '__main__':
    try:
        if len(argv) == 2:
            print("Start processing input...\n")
    except:
        print("[ERROR] Please enter input text file or path to
process!\n")
```

```
        exit(1)
    # This is for local file, not hdfs:
    numfiles = process_local_dir_or_file(str(argv[1]))
    # For HDFS single file & directory:
    input_df = process_input_file(str(argv[1]))
    print("Obtained input_df.")
    process_sentence_df(input_df)
    print("Processed input_df")
    numfiles += 1
    # For HDFS directory of subdirectories of files:
    input_parse_list = str(argv[1]).split('/')
    print(input_parse_list)
    if input_parse_list[-2:-1] == ['Transcripts']:
        print("Start processing HDFS directory: ", str(argv[1]))
        process_hdfs_dir(str(argv[1]))
    print(f"[OK!] All done. Number of files processed = {numfiles}")
```

The second script is `keras_spark_horovod_rossmann_estimator.py`.

```
# Copyright 2022 NetApp, Inc.
# Authored by Rick Huang
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# limitations under the License.
#
==============================================================================
====
# The below code was modified from: https://www.kaggle.com/c/rossmann-
store-sales
import argparse
import datetime
import os
import sys
from distutils.version import LooseVersion
import pyspark.sql.types as T
import pyspark.sql.functions as F
```

```
from pyspark import SparkConf, Row
from pyspark.sql import SparkSession
import tensorflow as tf
import tensorflow.keras.backend as K
from tensorflow.keras.layers import Input, Embedding, Concatenate, Dense,
Flatten, Reshape, BatchNormalization, Dropout
import horovod.spark.keras as hvd
from horovod.spark.common.backend import SparkBackend
from horovod.spark.common.store import Store
from horovod.tensorflow.keras.callbacks import BestModelCheckpoint
parser = argparse.ArgumentParser(description='Horovod Keras Spark Rossmann
Estimator Example',

formatter_class=argparse.ArgumentDefaultsHelpFormatter)
parser.add_argument('--master',
                    help='spark cluster to use for training. If set to
None, uses current default cluster. Cluster'
                         'should be set up to provide a Spark task per
multiple CPU cores, or per GPU, e.g. by'
                         'supplying `-c <NUM_GPUS>` in Spark Standalone
mode')
parser.add_argument('--num-proc', type=int,
                    help='number of worker processes for training,
default: `spark.default.parallelism`')
parser.add_argument('--learning_rate', type=float, default=0.0001,
                    help='initial learning rate')
parser.add_argument('--batch-size', type=int, default=100,
                    help='batch size')
parser.add_argument('--epochs', type=int, default=100,
                    help='number of epochs to train')
parser.add_argument('--sample-rate', type=float,
                    help='desired sampling rate. Useful to set to low
number (e.g. 0.01) to make sure that '
                         'end-to-end process works')
parser.add_argument('--data-dir', default='file://' + os.getcwd(),
                    help='location of data on local filesystem (prefixed
with file://) or on HDFS')
parser.add_argument('--local-submission-csv', default='submission.csv',
                    help='output submission predictions CSV')
parser.add_argument('--local-checkpoint-file', default='checkpoint',
                    help='model checkpoint')
parser.add_argument('--work-dir', default='/tmp',
                    help='temporary working directory to write
intermediate files (prefix with hdfs:// to use HDFS)')
if __name__ == '__main__':
    args = parser.parse_args()
    # ================ #
    # DATA PREPARATION #
    # ================ #
    print('================')
    print('Data preparation')
    print('================')
    # Create Spark session for data preparation.
    conf = SparkConf() \
        .setAppName('Keras Spark Rossmann Estimator Example') \
        .set('spark.sql.shuffle.partitions', '480') \
        .set("spark.executor.cores", "1") \
        .set('spark.executor.memory', '5gb') \
        .set('spark.executor.memoryOverhead','1000')\
        .set('spark.driver.memoryOverhead','1000')
    if args.master:
        conf.setMaster(args.master)
    elif args.num_proc:
        conf.setMaster('local[{}]'.format(args.num_proc))
    spark = SparkSession.builder.config(conf=conf).getOrCreate()
    train_csv = spark.read.csv('%s/train.csv' % args.data_dir,
header=True)
    test_csv = spark.read.csv('%s/test.csv' % args.data_dir, header=True)
    store_csv = spark.read.csv('%s/store.csv' % args.data_dir,
header=True)
    store_states_csv = spark.read.csv('%s/store_states.csv' %
args.data_dir, header=True)
    state_names_csv = spark.read.csv('%s/state_names.csv' % args.data_dir,
header=True)
    google_trend_csv = spark.read.csv('%s/googletrend.csv' %
args.data_dir, header=True)
    weather_csv = spark.read.csv('%s/weather.csv' % args.data_dir,
header=True)
    def expand_date(df):
        df = df.withColumn('Date', df.Date.cast(T.DateType()))
        return df \
            .withColumn('Year', F.year(df.Date)) \
            .withColumn('Month', F.month(df.Date)) \
            .withColumn('Week', F.weekofyear(df.Date)) \
            .withColumn('Day', F.dayofmonth(df.Date))
    def prepare_google_trend():
        # Extract week start date and state.
        google_trend_all = google_trend_csv \
            .withColumn('Date', F.regexp_extract(google_trend_csv.week,
'(.*?) -', 1)) \
            .withColumn('State', F.regexp_extract(google_trend_csv.file,
'Rossmann_DE_(.*)', 1))
```

```
        # Map state NI -> HB,NI to align with other data sources.
        google_trend_all = google_trend_all \
            .withColumn('State', F.when(google_trend_all.State == 'NI',
'HB,NI').otherwise(google_trend_all.State))
        # Expand dates.
        return expand_date(google_trend_all)
    def add_elapsed(df, cols):
        def add_elapsed_column(col, asc):
            def fn(rows):
                last_store, last_date = None, None
                for r in rows:
                    if last_store != r.Store:
                        last_store = r.Store
                        last_date = r.Date
                    if r[col]:
                        last_date = r.Date
                    fields = r.asDict().copy()
                    fields[('After' if asc else 'Before') + col] = (r.Date
- last_date).days
                    yield Row(**fields)
            return fn
        df = df.repartition(df.Store)
        for asc in [False, True]:
            sort_col = df.Date.asc() if asc else df.Date.desc()
            rdd = df.sortWithinPartitions(df.Store.asc(), sort_col).rdd
            for col in cols:
                rdd = rdd.mapPartitions(add_elapsed_column(col, asc))
            df = rdd.toDF()
        return df
    def prepare_df(df):
        num_rows = df.count()
        # Expand dates.
        df = expand_date(df)
        df = df \
            .withColumn('Open', df.Open != '0') \
            .withColumn('Promo', df.Promo != '0') \
            .withColumn('StateHoliday', df.StateHoliday != '0') \
            .withColumn('SchoolHoliday', df.SchoolHoliday != '0')
        # Merge in store information.
        store = store_csv.join(store_states_csv, 'Store')
        df = df.join(store, 'Store')
        # Merge in Google Trend information.
        google_trend_all = prepare_google_trend()
        df = df.join(google_trend_all, ['State', 'Year',
'Week']).select(df['*'], google_trend_all.trend)
        # Merge in Google Trend for whole Germany.
        google_trend_de = google_trend_all[google_trend_all.file ==
'Rossmann_DE'].withColumnRenamed('trend', 'trend_de')
        df = df.join(google_trend_de, ['Year', 'Week']).select(df['*'],
google_trend_de.trend_de)
        # Merge in weather.
        weather = weather_csv.join(state_names_csv, weather_csv.file ==
state_names_csv.StateName)
        df = df.join(weather, ['State', 'Date'])
        # Fix null values.
        df = df \
            .withColumn('CompetitionOpenSinceYear',
F.coalesce(df.CompetitionOpenSinceYear, F.lit(1900))) \
            .withColumn('CompetitionOpenSinceMonth',
F.coalesce(df.CompetitionOpenSinceMonth, F.lit(1))) \
            .withColumn('Promo2SinceYear', F.coalesce(df.Promo2SinceYear,
F.lit(1900))) \
            .withColumn('Promo2SinceWeek', F.coalesce(df.Promo2SinceWeek,
F.lit(1)))
        # Days & months competition was open, cap to 2 years.
        df = df.withColumn('CompetitionOpenSince',
                           F.to_date(F.format_string('%s-%s-15',
df.CompetitionOpenSinceYear,

df.CompetitionOpenSinceMonth)))
        df = df.withColumn('CompetitionDaysOpen',
                           F.when(df.CompetitionOpenSinceYear > 1900,
                                  F.greatest(F.lit(0), F.least(F.lit(360 *
2), F.datediff(df.Date, df.CompetitionOpenSince))))
                           .otherwise(0))
        df = df.withColumn('CompetitionMonthsOpen',
(df.CompetitionDaysOpen / 30).cast(T.IntegerType()))
        # Days & weeks of promotion, cap to 25 weeks.
        df = df.withColumn('Promo2Since',
                           F.expr('date_add(format_string("%s-01-01",
Promo2SinceYear), (cast(Promo2SinceWeek as int) - 1) * 7)'))
        df = df.withColumn('Promo2Days',
                           F.when(df.Promo2SinceYear > 1900,
                                  F.greatest(F.lit(0), F.least(F.lit(25 *
7), F.datediff(df.Date, df.Promo2Since))))
                           .otherwise(0))
        df = df.withColumn('Promo2Weeks', (df.Promo2Days /
7).cast(T.IntegerType()))
        # Check that we did not lose any rows through inner joins.
        assert num_rows == df.count(), 'lost rows in joins'
        return df
    def build_vocabulary(df, cols):
        vocab = {}
        for col in cols:
            values = [r[0] for r in df.select(col).distinct().collect()]
            col_type = type([x for x in values if x is not None][0])
            default_value = col_type()
            vocab[col] = sorted(values, key=lambda x: x or default_value)
        return vocab
    def cast_columns(df, cols):
        for col in cols:
            df = df.withColumn(col,
F.coalesce(df[col].cast(T.FloatType()), F.lit(0.0)))
        return df
    def lookup_columns(df, vocab):
        def lookup(mapping):
            def fn(v):
                return mapping.index(v)
            return F.udf(fn, returnType=T.IntegerType())
        for col, mapping in vocab.items():
            df = df.withColumn(col, lookup(mapping)(df[col]))
        return df
    if args.sample_rate:
        train_csv = train_csv.sample(withReplacement=False,
fraction=args.sample_rate)
        test_csv = test_csv.sample(withReplacement=False,
fraction=args.sample_rate)
    # Prepare data frames from CSV files.
    train_df = prepare_df(train_csv).cache()
    test_df = prepare_df(test_csv).cache()
    # Add elapsed times from holidays & promos, the data spanning training
& test datasets.
    elapsed_cols = ['Promo', 'StateHoliday', 'SchoolHoliday']
    elapsed = add_elapsed(train_df.select('Date', 'Store', *elapsed_cols)
                          .unionAll(test_df.select('Date', 'Store',
*elapsed_cols)),
                          elapsed_cols)
    # Join with elapsed times.
    train_df = train_df \
        .join(elapsed, ['Date', 'Store']) \
        .select(train_df['*'], *[prefix + col for prefix in ['Before',
'After'] for col in elapsed_cols])
    test_df = test_df \
        .join(elapsed, ['Date', 'Store']) \
        .select(test_df['*'], *[prefix + col for prefix in ['Before',
'After'] for col in elapsed_cols])
    # Filter out zero sales.
    train_df = train_df.filter(train_df.Sales > 0)
    print('===================')
    print('Prepared data frame')
    print('===================')
    train_df.show()
    categorical_cols = [
        'Store', 'State', 'DayOfWeek', 'Year', 'Month', 'Day', 'Week',
'CompetitionMonthsOpen', 'Promo2Weeks', 'StoreType',
        'Assortment', 'PromoInterval', 'CompetitionOpenSinceYear',
'Promo2SinceYear', 'Events', 'Promo',
        'StateHoliday', 'SchoolHoliday'
    ]
    continuous_cols = [
        'CompetitionDistance', 'Max_TemperatureC', 'Mean_TemperatureC',
'Min_TemperatureC', 'Max_Humidity',
        'Mean_Humidity', 'Min_Humidity', 'Max_Wind_SpeedKm_h',
'Mean_Wind_SpeedKm_h', 'CloudCover', 'trend', 'trend_de',
        'BeforePromo', 'AfterPromo', 'AfterStateHoliday',
'BeforeStateHoliday', 'BeforeSchoolHoliday', 'AfterSchoolHoliday'
    ]
    all_cols = categorical_cols + continuous_cols
    # Select features.
    train_df = train_df.select(*(all_cols + ['Sales', 'Date'])).cache()
    test_df = test_df.select(*(all_cols + ['Id', 'Date'])).cache()
    # Build vocabulary of categorical columns.
    vocab = build_vocabulary(train_df.select(*categorical_cols)

.unionAll(test_df.select(*categorical_cols)).cache(),
                             categorical_cols)
    # Cast continuous columns to float & lookup categorical columns.
    train_df = cast_columns(train_df, continuous_cols + ['Sales'])
    train_df = lookup_columns(train_df, vocab)
    test_df = cast_columns(test_df, continuous_cols)
    test_df = lookup_columns(test_df, vocab)
    # Split into training & validation.
    # Test set is in 2015, use the same period in 2014 from the training
set as a validation set.
    test_min_date = test_df.agg(F.min(test_df.Date)).collect()[0][0]
    test_max_date = test_df.agg(F.max(test_df.Date)).collect()[0][0]
    one_year = datetime.timedelta(365)
    train_df = train_df.withColumn('Validation',
                                   (train_df.Date > test_min_date -
one_year) & (train_df.Date <= test_max_date - one_year))
    # Determine max Sales number.
    max_sales = train_df.agg(F.max(train_df.Sales)).collect()[0][0]
    # Convert Sales to log domain
    train_df = train_df.withColumn('Sales', F.log(train_df.Sales))
    print('===================================')
    print('Data frame with transformed columns')
    print('===================================')
    train_df.show()
    print('================')
    print('Data frame sizes')
    print('================')
    train_rows = train_df.filter(~train_df.Validation).count()
    val_rows = train_df.filter(train_df.Validation).count()
    test_rows = test_df.count()
    print('Training: %d' % train_rows)
    print('Validation: %d' % val_rows)
    print('Test: %d' % test_rows)
    # ============== #
    # MODEL TRAINING #
    # ============== #
    print('==============')
    print('Model training')
    print('==============')
    def exp_rmspe(y_true, y_pred):
        """Competition evaluation metric, expects logarithic inputs."""
        pct = tf.square((tf.exp(y_true) - tf.exp(y_pred)) /
tf.exp(y_true))
        # Compute mean excluding stores with zero denominator.
        x = tf.reduce_sum(tf.where(y_true > 0.001, pct,
tf.zeros_like(pct)))
        y = tf.reduce_sum(tf.where(y_true > 0.001, tf.ones_like(pct),
tf.zeros_like(pct)))
        return tf.sqrt(x / y)
    def act_sigmoid_scaled(x):
        """Sigmoid scaled to logarithm of maximum sales scaled by 20%."""
        return tf.nn.sigmoid(x) * tf.math.log(max_sales) * 1.2
    CUSTOM_OBJECTS = {'exp_rmspe': exp_rmspe,
                      'act_sigmoid_scaled': act_sigmoid_scaled}
    # Disable GPUs when building the model to prevent memory leaks
    if LooseVersion(tf.__version__) >= LooseVersion('2.0.0'):
        # See https://github.com/tensorflow/tensorflow/issues/33168
        os.environ['CUDA_VISIBLE_DEVICES'] = '-1'
    else:

K.set_session(tf.Session(config=tf.ConfigProto(device_count={'GPU': 0})))
    # Build the model.
    inputs = {col: Input(shape=(1,), name=col) for col in all_cols}
    embeddings = [Embedding(len(vocab[col]), 10, input_length=1,
name='emb_' + col)(inputs[col])
                  for col in categorical_cols]
    continuous_bn = Concatenate()([Reshape((1, 1), name='reshape_' + 
col)(inputs[col])
                                   for col in continuous_cols])
    continuous_bn = BatchNormalization()(continuous_bn)
    x = Concatenate()(embeddings + [continuous_bn])
    x = Flatten()(x)
    x = Dense(1000, activation='relu', 
kernel_regularizer=tf.keras.regularizers.l2(0.00005))(x)
    x = Dense(1000, activation='relu', 
kernel_regularizer=tf.keras.regularizers.l2(0.00005))(x)
    x = Dense(1000, activation='relu', 
kernel_regularizer=tf.keras.regularizers.l2(0.00005))(x)
    x = Dense(500, activation='relu', 
kernel_regularizer=tf.keras.regularizers.l2(0.00005))(x)
    x = Dropout(0.5)(x)
    output = Dense(1, activation=act_sigmoid_scaled)(x)
    model = tf.keras.Model([inputs[f] for f in all_cols], output)
    model.summary()
    opt = tf.keras.optimizers.Adam(lr=args.learning_rate, epsilon=1e-3)
    # Checkpoint callback to specify options for the returned Keras model
    ckpt_callback = BestModelCheckpoint(monitor='val_loss', mode='auto', 
save_freq='epoch')
    # Horovod: run training.
    store = Store.create(args.work_dir)
    backend = SparkBackend(num_proc=args.num_proc,
                           stdout=sys.stdout, stderr=sys.stderr,
                           prefix_output_with_timestamp=True)
    keras_estimator = hvd.KerasEstimator(backend=backend,
                                         store=store,
                                         model=model,
                                         optimizer=opt,
                                         loss='mae',
                                         metrics=[exp_rmspe],
                                         custom_objects=CUSTOM_OBJECTS,
                                         feature_cols=all_cols,
                                         label_cols=['Sales'],
                                         validation='Validation',
                                         batch_size=args.batch_size,
                                         epochs=args.epochs,
                                         verbose=2,

checkpoint_callback=ckpt_callback)
    keras_model = 
keras_estimator.fit(train_df).setOutputCols(['Sales_output'])
    history = keras_model.getHistory()
    best_val_rmspe = min(history['val_exp_rmspe'])
    print('Best RMSPE: %f' % best_val_rmspe)
    # Save the trained model.
    keras_model.save(args.local_checkpoint_file)
    print('Written checkpoint to %s' % args.local_checkpoint_file)
    # ================ #
    # FINAL PREDICTION #
    # ================ #
    print('================')
    print('Final prediction')
    print('================')
    pred_df=keras_model.transform(test_df)
    pred_df.printSchema()
    pred_df.show(5)
    # Convert from log domain to real Sales numbers
    pred_df=pred_df.withColumn('Sales_pred', F.exp(pred_df.Sales_output))
    submission_df = pred_df.select(pred_df.Id.cast(T.IntegerType()),
pred_df.Sales_pred).toPandas()
    submission_df.sort_values(by=['Id']).to_csv(args.local_submission_csv,
index=False)
    print('Saved predictions to %s' % args.local_submission_csv)
    spark.stop()
```

The third script is `run_classification_criteo_spark.py`.

```
import tempfile, string, random, os, uuid
import argparse, datetime, sys, shutil
import csv
import numpy as np
from sklearn.model_selection import train_test_split
from tensorflow.keras.callbacks import EarlyStopping
from pyspark import SparkContext
from pyspark.sql import SparkSession, SQLContext, Row, DataFrame
from pyspark.mllib import linalg as mllib_linalg
from pyspark.mllib.linalg import SparseVector as mllibSparseVector
from pyspark.mllib.linalg import VectorUDT as mllibVectorUDT
from pyspark.mllib.linalg import Vector as mllibVector, Vectors as
mllibVectors
from pyspark.mllib.regression import LabeledPoint
from pyspark.mllib.classification import LogisticRegressionWithSGD
from pyspark.ml import linalg as ml_linalg
from pyspark.ml.linalg import VectorUDT as mlVectorUDT
from pyspark.ml.linalg import SparseVector as mlSparseVector
from pyspark.ml.linalg import Vector as mlVector, Vectors as mlVectors
from pyspark.ml.classification import LogisticRegression
from pyspark.ml.feature import OneHotEncoder
from math import log
from math import exp  # exp(-t) = e^-t
from operator import add
from pyspark.sql.functions import udf, split, lit
from pyspark.sql.functions import size, sum as sqlsum
import pyspark.sql.functions as F
import pyspark.sql.types as T
from pyspark.sql.types import ArrayType, StructType, StructField,
LongType, StringType, IntegerType, FloatType
from pyspark.sql.functions import explode, col, log, when
from collections import defaultdict
import pandas as pd
import pyspark.pandas as ps
from sklearn.metrics import log_loss, roc_auc_score
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import LabelEncoder, MinMaxScaler
from deepctr.models import DeepFM
from deepctr.feature_column import SparseFeat, DenseFeat,
get_feature_names
spark = SparkSession.builder \
    .master("yarn") \
    .appName("deep_ctr_classification") \
    .config("spark.jars.packages", "io.github.ravwojdyla:spark-schema-
utils_2.12:0.1.0") \
    .config("spark.executor.cores", "1") \
    .config('spark.executor.memory', '5gb') \
    .config('spark.executor.memoryOverhead', '1500') \
    .config('spark.driver.memoryOverhead', '1500') \
    .config("spark.sql.shuffle.partitions", "480") \
    .config("spark.sql.execution.arrow.enabled", "true") \
    .config("spark.driver.maxResultSize", "50gb") \
    .getOrCreate()
# spark.conf.set("spark.sql.execution.arrow.enabled", "true") # deprecated
print("Apache Spark version:")
print(spark.version)
sc = spark.sparkContext
sqlContext = SQLContext(sc)
parser = argparse.ArgumentParser(description='Spark DCN CTR Prediction
Example',

formatter_class=argparse.ArgumentDefaultsHelpFormatter)
parser.add_argument('--data-dir', default='file://' + os.getcwd(),
                    help='location of data on local filesystem (prefixed
with file://) or on HDFS')
def process_input_file(file_name, sparse_feat, dense_feat):
    # Need this preprocessing to turn Criteo raw file into CSV:
```

```
    print("START processing input file...")
    # only convert the file ONCE
    # sample = open(file_name)
    # sample = '\n'.join([str(x.replace('\n', '').replace('\t', ',')) for
x in sample])
    # # Add header in data file and save as CSV
    # header = ','.join(str(x) for x in (['label'] + dense_feat +
sparse_feat))
    # with open('/sparkdemo/tr-4570-data/ctr_train.csv', mode='w',
encoding="utf-8") as f:
    #     f.write(header + '\n' + sample)
    #     f.close()
    # print("Raw training file processed and saved as CSV: ", f.name)
    raw_df = sqlContext.read.option("header", True).csv(file_name)
    raw_df.show(5, False)
    raw_df.printSchema()
    # convert columns I1 to I13 from string to integers
    conv_df = raw_df.select(col('label').cast("double"),
                            *(col(i).cast("float").alias(i) for i in
raw_df.columns if i in dense_feat),
                            *(col(c) for c in raw_df.columns if c in
sparse_feat))
    print("Schema of raw_df with integer columns type changed:")
    conv_df.printSchema()
    # result_pdf = conv_df.select("*").toPandas()
    tmp_df = conv_df.na.fill(0, dense_feat)
    result_df = tmp_df.na.fill('-1', sparse_feat)
    result_df.show()
    return result_df
if __name__ == "__main__":
    args = parser.parse_args()
    # Pandas read CSV
    # data = pd.read_csv('%s/criteo_sample.txt' % args.data_dir)
    # print("Obtained Pandas df.")
    dense_features = ['I' + str(i) for i in range(1, 14)]
    sparse_features = ['C' + str(i) for i in range(1, 27)]
    # Spark read CSV
    # process_input_file('%s/train.txt' % args.data_dir, sparse_features,
dense_features) # run only ONCE
    spark_df = process_input_file('%s/data.txt' % args.data_dir,
sparse_features, dense_features) # sample data
    # spark_df = process_input_file('%s/ctr_train.csv' % args.data_dir,
sparse_features, dense_features)
    print("Obtained Spark df and filled in missing features.")
    data = spark_df
    # Pandas
    #data[sparse_features] = data[sparse_features].fillna('-1', )
    #data[dense_features] = data[dense_features].fillna(0, )
    target = ['label']
    label_npa = data.select("label").toPandas().to_numpy()
    print("label numPy array has length = ", len(label_npa)) # 45,840,617
w/ 11GB dataset
    label_npa.ravel()
    label_npa.reshape(len(label_npa), )
    # 1.Label Encoding for sparse features,and do simple Transformation
for dense features
    print("Before LabelEncoder():")
    data.printSchema()  # label: float (nullable = true)
    for feat in sparse_features:
        lbe = LabelEncoder()
        tmp_pdf = data.select(feat).toPandas().to_numpy()
        tmp_ndarray = lbe.fit_transform(tmp_pdf)
        print("After LabelEncoder(), tmp_ndarray[0] =", tmp_ndarray[0])
        # print("Data tmp PDF after lbe transformation, the output ndarray
has length = ", len(tmp_ndarray)) # 45,840,617 for 11GB dataset
        tmp_ndarray.ravel()
        tmp_ndarray.reshape(len(tmp_ndarray), )
        out_ndarray = np.column_stack([label_npa, tmp_ndarray])
        pdf = pd.DataFrame(out_ndarray, columns=['label', feat])
        s_df = spark.createDataFrame(pdf)
        s_df.printSchema() # label: double (nullable = true)
        print("Before joining data df with s_df, s_df example rows:")
        s_df.show(1, False)
        data = data.drop(feat).join(s_df, 'label').drop('label')
        print("After LabelEncoder(), data df example rows:")
        data.show(1, False)
        print("Finished processing sparse_features: ", feat)
    print("Data DF after label encoding: ")
    data.show()
    data.printSchema()
    mms = MinMaxScaler(feature_range=(0, 1))
    # data[dense_features] = mms.fit_transform(data[dense_features]) # for
Pandas df
    tmp_pdf = data.select(dense_features).toPandas().to_numpy()
    tmp_ndarray = mms.fit_transform(tmp_pdf)
    tmp_ndarray.ravel()
    tmp_ndarray.reshape(len(tmp_ndarray), len(tmp_ndarray[0]))
    out_ndarray = np.column_stack([label_npa, tmp_ndarray])
    pdf = pd.DataFrame(out_ndarray, columns=['label'] + dense_features)
    s_df = spark.createDataFrame(pdf)
    s_df.printSchema()
    data.drop(*dense_features).join(s_df, 'label').drop('label')
    print("Finished processing dense_features: ", dense_features)
    print("Data DF after MinMaxScaler: ")
    data.show()

    # 2.count #unique features for each sparse field,and record dense
feature field name
    fixlen_feature_columns = [SparseFeat(feat,
vocabulary_size=data.select(feat).distinct().count() + 1, embedding_dim=4)
                              for i, feat in enumerate(sparse_features)] +
\
                             [DenseFeat(feat, 1, ) for feat in
dense_features]
    dnn_feature_columns = fixlen_feature_columns
    linear_feature_columns = fixlen_feature_columns
    feature_names = get_feature_names(linear_feature_columns +
dnn_feature_columns)
    # 3.generate input data for model
    # train, test = train_test_split(data.toPandas(), test_size=0.2,
random_state=2020) # Pandas; might hang for 11GB data
    train, test = data.randomSplit(weights=[0.8, 0.2], seed=200)
    print("Training dataset size = ", train.count())
    print("Testing dataset size = ", test.count())
    # Pandas:
    # train_model_input = {name: train[name] for name in feature_names}
    # test_model_input = {name: test[name] for name in feature_names}
    # Spark DF:
    train_model_input = {}
    test_model_input = {}
    for name in feature_names:
        if name.startswith('I'):
            tr_pdf = train.select(name).toPandas()
            train_model_input[name] = pd.to_numeric(tr_pdf[name])
            ts_pdf = test.select(name).toPandas()
            test_model_input[name] = pd.to_numeric(ts_pdf[name])
    # 4.Define Model,train,predict and evaluate
    model = DeepFM(linear_feature_columns, dnn_feature_columns,
task='binary')
    model.compile("adam", "binary_crossentropy",
                  metrics=['binary_crossentropy'], )
    lb_pdf = train.select(target).toPandas()
    history = model.fit(train_model_input,
pd.to_numeric(lb_pdf['label']).values,
                        batch_size=256, epochs=10, verbose=2,
validation_split=0.2, )
    pred_ans = model.predict(test_model_input, batch_size=256)
    print("test LogLoss",
round(log_loss(pd.to_numeric(test.select(target).toPandas()).values,
pred_ans), 4))
    print("test AUC",
round(roc_auc_score(pd.to_numeric(test.select(target).toPandas()).values,
pred_ans), 4))
```

Next: Conclusion.

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