







DLI Accelerated Data Science Teaching Kit

Lecture 14.12 - XGBoost with RAPIDS



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What is XGBoosting?

- A more robust and flexible version of gradient boosting
- What does it do?
 - Uses second-order gradients of the loss function in addition to the first-order gradients, based on Taylor expansion of the loss function
- Transforms the loss function into a more sophisticated objective function containing regularization terms

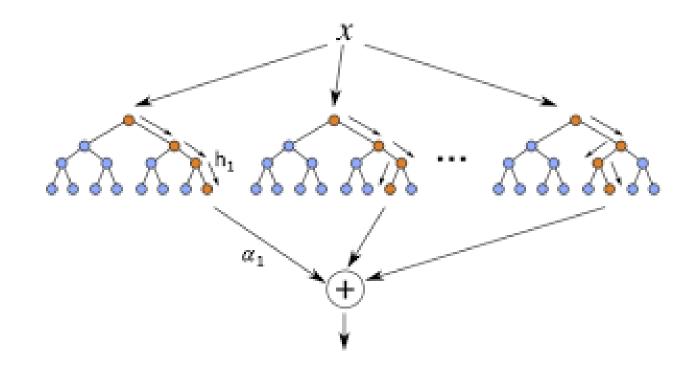






How does XGBoosting improve on Gradient Boosting?

- The extended loss function inhibits overfitting
 - Adds penalty proportional to size of the leaf weights
- This inhibits the growth of the model and prevents it from growing too large
- If the model overfits on the training data, it will not generalize well to new data









Example of XGBoost

- Let's consider a scenario in which we are trying to predict the income of an individual
- Instead of following the process used for gradient boosting, we will use quantiles:
 - Cut points that divide a feature into equal-sized groups







Original Dataset

Instance	Age	Has Job	Owns House	Income
0	12	N	N	0
1	32	Y	Y	90
2	25	Y	Y	50
3	48	N	N	25
4	67	N	Y	35
5	18	Y	N	10





Converted Quantile Dataset

- Reprocess each feature using quantiles:
 - Age separated into strata:
 - <18: One individual
 - <32: Two individuals
 - <67: Two individuals
 - 67+: One individual
 - Separates datapoints into roughly even groups

Instance	Age	Has Job	Owns House	Income
0	0	0	0	0
1	2	1	1	90
2	1	1	1	50
3	2	0	0	25
4	3	0	1	35
5	1	1	0	10







Finding Splits in Decision Trees

- We want to optimize trees that limit the depth of the overall model
- To achieve this, we need to build nodes that split the data well by minimizing error, in this case sum of squared error (SSE)
 - We can reformat the SSE equation into a split loss equation that can be used in our RAPIDS code

Split Loss
$$(R_a, R_b, n_a, n_b) = -\frac{1}{2} \left(\frac{R_a^2}{n_a}\right) - \frac{1}{2} \left(\frac{R_b^2}{n_b}\right)$$





Apply Split Loss Function to Dataset

The split (<18) has the greatest reduction in the SSE function

Quantile	n	Quantile Sum <i>r</i>	Inclusive Scan <i>n</i>	Inclusive Scan <i>r</i>	Split Loss
<18	1	0	1	0	
<32	2	60	3	60	4410
<67	2	115	5	175	4350
\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\		113	J	1/3	3675
67+	1	35	6	210	





Performing XGBoost on RAPIDS

- To run XGBoost efficiently using CUDA, RAPIDS uses bit compression and memory compression
 - Implements parallel primitives for processing sparse CSR (Compressed Sparse Row) format input
 - Uses symbol compression to store the quantised input matrix
- Next, we will see an example of XGBoost on the UCI Higgs dataset









Example: Setting up GPUs

```
import csv
import numpy as np
import os.path
import pandas
import time
import xgboost as xgb
import sys
if sys.version info[0] >= 3:
    from urllib.request import urlretrieve
else:
    from urllib import urlretrieve
data url = "https://archive.ics.uci.edu/ml/machine-learning-databases/00280/HIGGS.csv.gz"
dmatrix_train_filename = "higgs train.dmatrix"
dmatrix test filename = "higgs test.dmatrix"
csv filename = "HIGGS.csv.gz"
train rows = 10500000
test rows = 500000
num round = 1000
plot = True
```

Download the Higgs Dataset







Example: Load Higgs Dataset

```
# return xgboost dmatrix
def load higgs():
    if os.path.isfile(dmatrix_train_filename)
                                                                                               Load the
      and os.path.isfile(dmatrix test filename):
                                                                                               Higgs dataset
        dtrain = xgb.DMatrix(dmatrix train filename)
        dtest = xgb.DMatrix(dmatrix test filename)
        if dtrain.num_row() == train_rows and dtest.num_row() == test_rows:
            print("Loading cached dmatrix...")
            return dtrain, dtest
    if not os.path.isfile(csv filename):
        print("Downloading higgs file...")
        urlretrieve(data url, csv filename)
                                                                                               Split dataset
    df_higgs_train = pandas.read_csv(csv_filename, dtype=np.float32,
                                                                                                into training
                                     nrows=train rows, header=None)
                                                                                                  and test
    dtrain = xgb.DMatrix(df higgs train.ix[:, 1:29], df higgs train[0])
    dtrain.save binary(dmatrix train filename)
    df_higgs_test = pandas.read_csv(csv_filename, dtype=np.float32,
                                    skiprows=train rows, nrows=test rows,
                                    header=None)
    dtest = xgb.DMatrix(df higgs test.ix[:, 1:29], df higgs test[0])
    dtest.save binary(dmatrix test filename)
    return dtrain, dtest
```







Example: Run on CPU and GPU

```
dtrain, dtest = load higgs()
param = \{\}
param['objective'] = 'binary:logitraw'
param['eval_metric'] = 'error'
param['tree method'] = 'gpu hist'
param['silent'] = 1
print("Training with GPU ...")
                                                                                         Run
tmp = time.time()
                                                                                         XGBoost
gpu res = {}
                                                                                         on GPU
xgb.train(param, dtrain, num_round, evals=[(dtest, "test")],
          evals_result=gpu_res)
gpu_time = time.time() - tmp
print("GPU Training Time: %s seconds" % (str(gpu time)))
print("Training with CPU ...")
param['tree method'] = 'hist'
                                                                                        Run
tmp = time.time()
                                                                                        XGBoost
cpu res = {}
                                                                                        on CPU
xgb.train(param, dtrain, num round, evals=[(dtest, "test")],
          evals result=cpu res)
cpu time = time.time() - tmp
print("CPU Training Time: %s seconds" % (str(cpu time)))
```







Example: Plot CPU/GPU Results

```
if plot:
   import matplotlib.pyplot as plt
   min error = min(min(gpu res["test"][param['eval metric']]),
                    min(cpu res["test"][param['eval metric']]))
    gpu_iteration_time =
        [x / (num round * 1.0) * gpu time for x in range(0, num round)]
    cpu iteration time =
        [x / (num_round * 1.0) * cpu_time for x in range(0, num_round)]
    plt.plot(gpu iteration time, gpu res['test'][param['eval metric']],
             label='Tesla P100')
    plt.plot(cpu_iteration_time, cpu_res['test'][param['eval_metric']],
             label='2x Haswell E5-2698 v3 (32 cores)')
    plt.legend()
   plt.xlabel('Time (s)')
    plt.ylabel('Test error')
    plt.axhline(y=min error, color='r', linestyle='dashed')
   plt.margins(x=0)
    plt.ylim((0.23, 0.35))
    plt.show()
```

Plot the Results for GPU and CPU







Difference in Performance

 4.15x speed improvement for the GPU algorithm with the same accuracy as the CPU algorithm

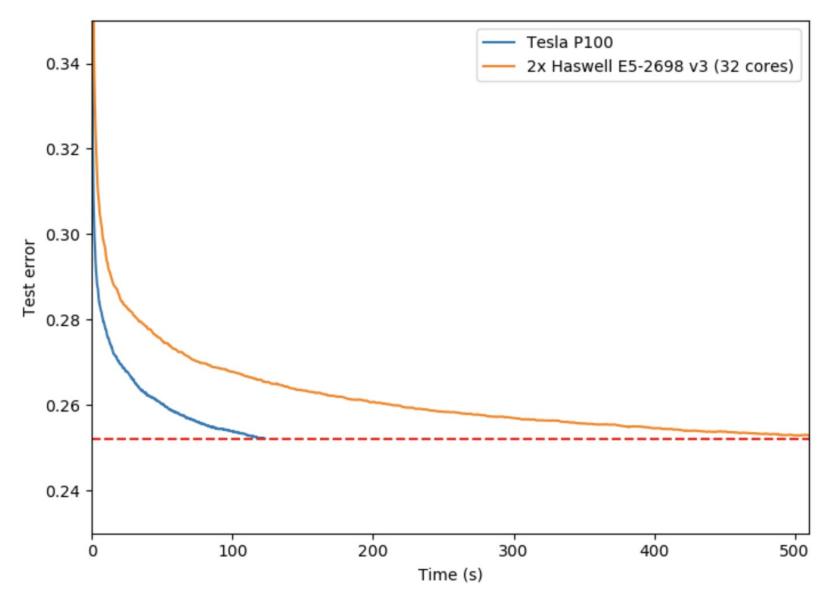


Figure 3. Test error over time for the Higgs dataset, 1000 boosting iterations.















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Thank You