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Lab 01 - Predicting Runtimes

Introduction

In this lab, we will be experimentally comparing the time it takes to train a GAN located on ROSIE at `/data/datasets/pokemon/gan.py` using various resources including a different number of CPUs as well as a comparison between the T4 and V100 GPUs. Tests will be run to determine how long it takes to train a single epoch of the provided GAN, as well as 20 epochs. The following resource allocations will be run for each number of epochs: T4 node with 2 CPUs, T4 node with 16 CPUs, T4 node with 1 GPU and 8 CPUs, and DGX node with 1 GPU (NVIDIA V100) and 8 CPUs. The main focus of this lab is to experience how using a GPU affects the training time of a deep learning model as well as the performance differences between the two types of GPUs available on ROSIE. We will be running tests on the T4 nodes which have NVIDIA T4 GPUs as well as on the DGX nodes which have NVIDIA V100 GPUs. Based on the specifications of each of these GPUs, we will be hypothesizing the ratio of time it will take to train the same network on each type of GPU. In addition, one goal of this lab is to regain familiarity with interacting with ROSIE from the command line and using SLURM commands to run jobs.

I. Predict Relative Runtimes from GPU Specs

Given the fact that the NVIDIA V100 has a double-precision throughput of 16.4 TFLOPS and the NVIDIA T4 has a single-precision throughput of 8.1 TFLOPS, we can estimate that the ratio between the times these two systems will take to train a neural network. The ratio of these two values can be interpreted as the amount of calculations each GPU can complete in a unit time. The ratio of the V100 and T4 is $16.4 : 8.1$ which is approximately $2.02 : 1$. This ratio represents the number of calculations either GPU can calculate in a unit time, therefore, we can interpret the ratio, $2.02 : 1$, as the NVIDIA V100 completes 2.02 times as many calculations in the same time it takes the NVIDIA T4 to complete a single calculation. This ratio can be restated in terms of time using the idea that training a network requires a set amount of calculations and the V100 can complete twice the calculations in the same time the T4 takes to complete a single calculation, so in other words, the V100 is about twice as fast as the T4. Assuming that the training of a neural network mostly relies on floating point operations, we can predict that the NVIDIA T4 will take about 2 times as long to train the same neural network as the NVIDIA V100.

II. Experimentally Determine the Runtime from Running One Epoch

Running on a T4 - 2 CPUs:

```
Processing batch: 1-158
loss_D 0.637, loss_G 1.344, 27.3 examples/sec on cpu (40597.0 examples in 1486.4 seconds during this epoch)
<Figure size 500x500 with 2 Axes>
loss_D 0.637, loss_G 1.344, 1486.7 sec/epoch on cpu
Num epochs: 1
Total training time: 1486.7 seconds
Started at: Sat, 11 Mar 2023 15:18:59 local
Ended at: Sat, 11 Mar 2023 15:43:46 local
```

Running on a T4 Node - 16 Hyperthreaded CPU Cores

```
Processing batch: 1-158
loss_D 0.616, loss_G 1.425, 81.3 examples/sec on cpu (40597.0 examples in 499.5 seconds during this epoch)
<Figure size 500x500 with 2 Axes>
loss_D 0.616, loss_G 1.425, 499.8 sec/epoch on cpu
Num epochs: 1
Total training time: 499.8 seconds
Started at: Sat, 11 Mar 2023 15:48:48 local
Ended at: Sat, 11 Mar 2023 15:57:08 local
```

T4 Node - 1 GPU (+ 8 CPUs)

```
Processing batch: 1-158
loss_D 0.651, loss_G 1.188, 471.1 examples/sec on cuda:0 (40597.0 examples in 86.2 seconds during this epoch)
<Figure size 500x500 with 2 Axes>
loss_D 0.651, loss_G 1.188, 86.5 sec/epoch on cuda:0
Num epochs: 1
Total training time: 86.5 seconds
Started at: Sat, 11 Mar 2023 16:00:50 local
Ended at: Sat, 11 Mar 2023 16:02:16 local
```

DGX Node - 1 GPU (+ 8 CPUs)

```
Processing batch: 1-158
loss_D 0.662, loss_G 1.175, 1229.0 examples/sec on cuda:0 (40597.0 examples in 33.0 seconds during this epoch)
<Figure size 500x500 with 2 Axes>
loss_D 0.662, loss_G 1.175, 33.4 sec/epoch on cuda:0
Num epochs: 1
Total training time: 33.4 seconds
Started at: Sat, 11 Mar 2023 15:04:40 local
Ended at: Sat, 11 Mar 2023 15:05:13 local
```

III. Experimentally Determine the Runtime from Running 20 Epochs

Before repeating the experiment on 20 epochs, I predicted the number of seconds required to train the network for 20 epochs based on the time the environment took to train a single epoch. I calculated each prediction for each of the environments using the equation: $time\ to\ train\ 1\ epoch\ *\ 20\ epochs\ =\ time\ to\ train\ 20\ epochs$. The runtime predictions for training 20 epochs are reported in the experiment results table in section IV.

Running on a T4 - 2 CPUs:

```
Processing batch: 20-158
loss_D 0.025, loss_G 7.760, 27.3 examples/sec on cpu (40597.0 examples in 1484.5 seconds during this epoch)
<Figure size 500x500 with 2 Axes>
loss_D 0.025, loss_G 7.760, 1526.1 sec/epoch on cpu
Num epochs: 20
Total training time: 30522.1 seconds
Started at: Sat, 11 Mar 2023 17:58:05 local
Ended at: Sun, 12 Mar 2023 03:26:47 local
```

Running on a T4 Node - 16 Hyperthreaded CPU Cores

```
Processing batch: 20-158
loss_D 0.028, loss_G 7.285, 74.8 examples/sec on cpu (40597.0 examples in 542.9 seconds during this epoch)
<Figure size 500x500 with 2 Axes>
loss_D 0.028, loss_G 7.285, 515.7 sec/epoch on cpu
Num epochs: 20
Total training time: 10313.0 seconds
Started at: Sun, 12 Mar 2023 10:21:30 local
Ended at: Sun, 12 Mar 2023 13:13:23 local
```

T4 Node - 1 GPU (+ 8 CPUs)

```
Processing batch: 20-158
loss_D 0.023, loss_G 8.590, 534.8 examples/sec on cuda:0 (40597.0 examples in 75.9 seconds during this epoch)
<Figure size 500x500 with 2 Axes>
loss_D 0.023, loss_G 8.590, 76.4 sec/epoch on cuda:0
Num epochs: 20
Total training time: 1528.2 seconds
Started at: Sun, 12 Mar 2023 13:22:28 local
Ended at: Sun, 12 Mar 2023 13:47:56 local
```

DGX Node - 1 GPU (+ 8 CPUs)

```
Processing batch: 20-158
loss_D 0.171, loss_G 6.550, 1487.4 examples/sec on cuda:0 (40597.0 examples in 27.3 seconds during this epoch)
<Figure size 500x500 with 2 Axes>
loss_D 0.171, loss_G 6.550, 27.8 sec/epoch on cuda:0
Num epochs: 20
Total training time: 556.6 seconds
Started at: Sun, 12 Mar 2023 12:59:47 local
Ended at: Sun, 12 Mar 2023 13:09:03 local
```

IV. Experiment Results

Resources	**Runtime - 1 Epoch**	**Predicted - 20 Epochs (runtime 1 epoch * 20)**	**Actual Runtime - 20 Epochs**
T4 Node w/ 2 CPUs	1486.7 seconds	29734.0 seconds	30522.1 seconds
T4 Node w/ 16 CPUs (hyperthreaded)	499.8 seconds	9996.0 seconds	10313.0 seconds
T4 Node - 1 GPU (+ 8 CPUs)	86.5 seconds	1730.0 seconds	1528.2 seconds
DGX Node - 1 GPU (+ 8 CPUs)	33.4 seconds	668.0 seconds	556.6 seconds

The table above summarizes the results of each of the experiments performed in sections III and IV as well as the predictions made for training 20 epochs. From the table above, it can be observed that increasing the number of CPUs from 2 to 16 decreased the training time for 20 epochs from 30522.1 seconds or about 8.5 hours, to 10313.0 seconds or just under 3 hours, which is a generous improvement. However, the runtime results for training the GAN for 20 epochs using a GPU performed the best. The experiment run on the T4 node with 1 T4 GPU and 8 CPUs had a 20-epoch training time of 1528.2 seconds, which is about 26 minutes. Even better results were achieved in the 20-epoch training experiment run on the DGX node with one V100 GPU and 8 CPUs with a total training time of 556.6 seconds which is just under 10 minutes.

V. Discussion

Throughout this lab, we performed experiments to compare the time it took to train the provided GAN for 20 epochs using different resources on ROSIE. As shown in the results above, the addition of a GPU to train the provided GAN for 20 epochs drastically reduced the training time compared to the same training done on only CPUs. Additionally, the results of the experiments showed that the type of GPU used also has a significant effect on the training time.

My original hypothesis, based on the GPU specifications, was that the NVIDIA V100 GPU trains the same network in half of the time of the NVIDIA T4 GPU; or in other words, the T4 GPU should take 2 times as long to train as the V100 which is a ratio of 2: 1 for the training time. In general, the results support the original hypothesis that the V100 GPU takes half as long to train. However, the observed ratio of training time for the V100 and the T4 was better than predicted. As shown in the table above, the experiment run on the T4 node with 1 T4 GPU and 8 CPUs had a 20-epoch training time of 1528.2 seconds and the experiment run on the DGX node with one V100 GPU and 8 CPUs had a total training time of 556.6 seconds. The ratio of the T4 to the V100 runtimes can be calculated by: $\frac{1528.2\ s}{556.6\ s} \cong \frac{2.746\ s}{1\ s}$ which can be written as $2.746 : 1$. This ratio can be interpreted as, the T4 GPU with 8 CPUs took almost 3 times longer than the V100 GPU with 8 CPUs to train the GAN for 20 epochs. This difference in the predicted and observed runtime ratio is most likely due to the specific architecture of the GAN being tested. Lastly, it is worth noting that the predicted 20-epoch runtimes, calculated based on the runtime for 1 epoch, for the experiments running on only CPUs were underestimates of the observed time and the GPU experiments both were overestimates of what was observed. This indicates that the GPUs employ some sort of optimization between multiple epochs such that the time it takes to train the first epoch is not the same time each successive epoch will take. In conclusion, this lab demonstrated that using GPUs to train deep learning models drastically reduces the training time of the equivalent training using only CPUs.