Discussion on the Project of Analyzing Running Time of Stochastic Gradient Methods

Some General Comments I

- You should analyze your results
- Some just present tables or figures, but we want more insight

The Analysis I

- You should identify the major operations
- Then check percentage of these operations
- From the results you draw some conclusions
- Let's consider a good example (from P2 of Davis Cho's report in the UCLA 2019 course)
- I will show good examples this year later

The Analysis II

Forward

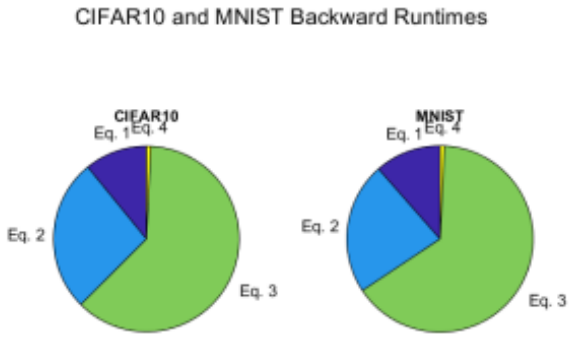
Eq. 1: $\phi pad(Z^{m,i})$

Eq. 2: $W^m \phi(\cdot)$

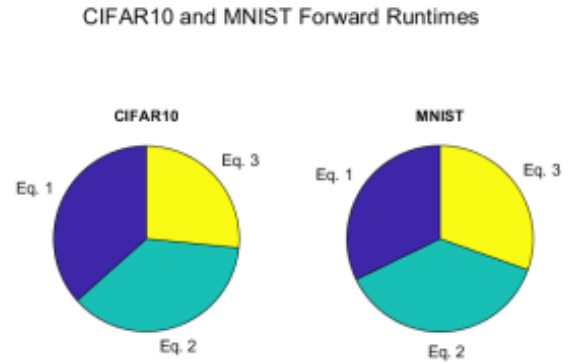
Eq. 3: $Z^{m+1,i} = mat(P_{pool}^{m,i} vec(\sigma(S^{m,i})))$

As can be seen, the vTP function from the backward process takes a majority of the run time of the whole program, as shown in figure 1c. The vTP function is used in both the first equation for pooling as well as the third equation mentioned in the slides. The next most time consuming portion would be the forward feeding equation 2, denoted as F Eq.2 in Figure 1c.

Given that the vTP function is a vector matrix multiplication function, indeed the prediction that the next most costly function is the bottleneck is true in Matlab optimizes matrix matrix operations well



(a) Backward Times



The Analysis III

- A typical analysis is as follows. In the forward procedure,

$$
\begin{aligned}
& W^m \mathrm{mat}(P_\phi^m P_{\mathrm{pad}}^m \mathrm{vec}(Z^{m,i})) \\
=& W^m \phi(\mathrm{pad}(Z^{m,i}))
\end{aligned}
$$

$$\phi(\mathrm{pad}(Z^{m,i})) : \mathcal{O}(I \times h^m h^m d^m a_{\mathrm{conv}}^m b_{\mathrm{conv}}^m)$$

$$W^m \phi(\cdot) : \mathcal{O}(I \times h^m h^m d^m d^{m+1} a_{\mathrm{conv}}^m b_{\mathrm{conv}}^m)$$

$$Z^{m+1,i} = \mathrm{mat}(P_{\mathrm{pool}}^{m,i} \mathrm{vec}(\sigma(S^{m,i})))$$

$$\mathcal{O}(I \times h^m h^m d^{m+1} a_{\mathrm{conv}}^m b_{\mathrm{conv}}^m)$$

The Analysis IV

- From this complexity analysis matrix-matrix products are the bottleneck
- Roughly,

  $$d^m \text{ times}$$

  more than others at layer m
- However, we see that matrix-matrix products take less than half (feedforward part)
- Thus optimized BLAS is very effective
- It is easier to optimize the computationally heavy part

The Analysis V

- But this also means that probably there is still room to improve other operations such as

$$\phi(\mathsf{pad}(Z^{m,i}))$$

Why Checking Main Steps is Important I

- We see that some simply list the percentage of each function

feedforward	?? %
max pooling	?? %

- But the problem is that max pooling is part of feedforward
- Thus you cannot say much from such a list of results

Single Versus Double I

- By default Tensorflow uses single
- Thus we should use single in MATLAB too
- But some may forget to use the option `-ftype` to specify the use of single

Why is Tensorflow Faster? I

Before a rough answer of this issue, let's discuss some differences between Tensorflow and our MATLAB-based implementation

- Automatic differentiation
- Computational graphs

Automatic differentiation I

We will discuss this in regular lectures

Computational Graphs I

- Let's borrow a description from `https://deepnotes.io/tensorflow`

  "Tensorflow approaches series of computations as a flow of data through a graph with nodes being computation units and edges being flow of Tensors (multidimensional arrays)."
- This means that we must build a graph first before the execution
- This is a bit unnatural
- For example, to do a matrix product

Computational Graphs II

```
C = A*B;
```

we cannot just write the above statement like in MATLAB.
We need two steps

- But using a graph does have some advantages
- One is the effective parallell computation
- Operations that are independent to each other (e.g., they need different input data) can be conducted in parallel
- Therefore, operations can be scheduled in a more efficient manner.

Computational Graphs III

- In contrast, our MATLAB code is a procedural setting
- For example, in the feed forward process for function evaluation we have

$$S^{m,i} = W^m \phi(\text{pad}(Z^{m,i}))_{h^m h^m d^m \times a^m_{\text{conv}} b^m_{\text{conv}}} + \boldsymbol{b}^m \mathbb{1}^T_{a^m_{\text{conv}} b^m_{\text{conv}}}, i = \quad (1)$$

and

$$Z^{m+1,i} = \text{mat}(P^{m,i}_{\text{pool}} \text{vec}(\sigma(S^{m,i})))_{d^{m+1} \times a^{m+1} b^{m+1}}, i = 1, .. \quad (2)$$

- Remember that this is over all data (in a batch)

Computational Graphs IV

- Thus if a graph has been constructed, easily (1)-(2) can be done in parallel

Why is Tensorflow Faster? I

- Now let's go back to this issue
- We think there are some possible reasons
- Some MATLAB operations are not efficiently implemented

  You have seen that index manipulation is time consuming

  We will try to make improvements in the next project
- Tensorflow's setting by computational graph leads to better overall optimization?

Why is Tensorflow Faster? II

- Tensorflow may have used some optimized packages dedicated to neural networks

  For example, they may use

  Intel MKL-DNN:

  `https://github.com/intel/mkl-dnn`

Other Comments I

- Please have both ID and name on the first page
- You should use the latex template
- I have no choice but to give you 0 point as we have said that many times