[HW3_prob1]_CNN_Training_with_VGG16

October 15, 2022

[1]:

```
import argparse
import os
import time
import shutil

import torch
import torch.nn as nn
import torch.optim as optim
import torch.nn.functional as F
import torch.backends.cudnn as cudnn



import torchvision
import torchvision.transforms as transforms

from models import *    # bring everything in the folder models

global best_prec
use_gpu = torch.cuda.is_available()
device = torch.device("cuda" if use_gpu else "cpu")
print('=> Building model...')


batch_size = 128

model_name = "VGG16"
model = VGG16()



normalize = transforms.Normalize(mean=[0.491, 0.482, 0.447], std=[0.247, 0.243,␣
 ↪0.262])


train_dataset = torchvision.datasets.CIFAR10(
    root='./data',
```

```
    train=True,
    download=True,
    transform=transforms.Compose([
        transforms.RandomCrop(32, padding=4),
        transforms.RandomHorizontalFlip(),
        transforms.ToTensor(),
        normalize,
    ]))
trainloader = torch.utils.data.DataLoader(train_dataset, batch_size=batch_size,␣
 ↪shuffle=True, num_workers=2)


test_dataset = torchvision.datasets.CIFAR10(
    root='./data',
    train=False,
    download=True,
    transform=transforms.Compose([
        transforms.ToTensor(),
        normalize,
    ]))

testloader = torch.utils.data.DataLoader(test_dataset, batch_size=batch_size,␣
 ↪shuffle=False, num_workers=2)


print_freq = 100 # every 100 batches, accuracy printed. Here, each batch␣
 ↪includes "batch_size" data points
# CIFAR10 has 50,000 training data, and 10,000 validation data.

def train(trainloader, model, criterion, optimizer, epoch):
    batch_time = AverageMeter()   ## at the begining of each epoch, this should␣
 ↪be reset
    data_time = AverageMeter()
    losses = AverageMeter()
    top1 = AverageMeter()

    model.train()

    end = time.time()  # measure current time

    for i, (input, target) in enumerate(trainloader):
        # measure data loading time
        data_time.update(time.time() - end)  # data loading time

        input, target = input.cuda(), target.cuda()

        # compute output
```

```
        output = model(input)
        loss = criterion(output, target)

        # measure accuracy and record loss
        prec = accuracy(output, target)[0]
        losses.update(loss.item(), input.size(0))
        top1.update(prec.item(), input.size(0))

        # compute gradient and do SGD step
        optimizer.zero_grad()
        loss.backward()
        optimizer.step()

        # measure elapsed time
        batch_time.update(time.time() - end) # time spent to process one batch
        end = time.time()


        if i % print_freq == 0:
            print('Epoch: [{0}][{1}/{2}]\t'
                  'Time {batch_time.val:.3f} ({batch_time.avg:.3f})\t'
                  'Data {data_time.val:.3f} ({data_time.avg:.3f})\t'
                  'Loss {loss.val:.4f} ({loss.avg:.4f})\t'
                  'Prec {top1.val:.3f}% ({top1.avg:.3f}%)'.format(
                   epoch, i, len(trainloader), batch_time=batch_time,
                   data_time=data_time, loss=losses, top1=top1))



def validate(val_loader, model, criterion ):
    batch_time = AverageMeter()
    losses = AverageMeter()
    top1 = AverageMeter()

    # switch to evaluate mode
    model.eval()

    end = time.time()
    with torch.no_grad():
        for i, (input, target) in enumerate(val_loader):

            input, target = input.cuda(), target.cuda()

            # compute output
            output = model(input)
            loss = criterion(output, target)
```

```python
            # measure accuracy and record loss
            prec = accuracy(output, target)[0]
            losses.update(loss.item(), input.size(0))
            top1.update(prec.item(), input.size(0))

            # measure elapsed time
            batch_time.update(time.time() - end)
            end = time.time()

            if i % print_freq == 0:  # This line shows how frequently print out the status. e.g., i%5 => every 5 batch, prints out
                print('Test: [{0}/{1}]\t'
                  'Time {batch_time.val:.3f} ({batch_time.avg:.3f})\t'
                  'Loss {loss.val:.4f} ({loss.avg:.4f})\t'
                  'Prec {top1.val:.3f}% ({top1.avg:.3f}%)'.format(
                   i, len(val_loader), batch_time=batch_time, loss=losses,
                   top1=top1))

    print(' * Prec {top1.avg:.3f}% '.format(top1=top1))
    return top1.avg


def accuracy(output, target, topk=(1,)):
    """Computes the precision@k for the specified values of k"""
    maxk = max(topk)
    batch_size = target.size(0)

    _, pred = output.topk(maxk, 1, True, True)
    pred = pred.t()
    correct = pred.eq(target.view(1, -1).expand_as(pred))

    res = []
    for k in topk:
        correct_k = correct[:k].view(-1).float().sum(0)
        res.append(correct_k.mul_(100.0 / batch_size))
    return res


class AverageMeter(object):
    """Computes and stores the average and current value"""
    def __init__(self):
        self.reset()

    def reset(self):
        self.val = 0
        self.avg = 0
        self.sum = 0
```

```
        self.count = 0

    def update(self, val, n=1):
        self.val = val
        self.sum += val * n     ## n is impact factor
        self.count += n
        self.avg = self.sum / self.count


def save_checkpoint(state, is_best, fdir):
    filepath = os.path.join(fdir, 'checkpoint.pth')
    torch.save(state, filepath)
    if is_best:
        shutil.copyfile(filepath, os.path.join(fdir, 'model_best.pth.tar'))


def adjust_learning_rate(optimizer, epoch):
    """For resnet, the lr starts from 0.1, and is divided by 10 at 80 and 120␣
 ↪epochs"""
    adjust_list = [150, 225]
    if epoch in adjust_list:
        for param_group in optimizer.param_groups:
            param_group['lr'] = param_group['lr'] * 0.1

#model = nn.DataParallel(model).cuda()
#all_params = checkpoint['state_dict']
#model.load_state_dict(all_params, strict=False)
#criterion = nn.CrossEntropyLoss().cuda()
#validate(testloader, model, criterion)
```

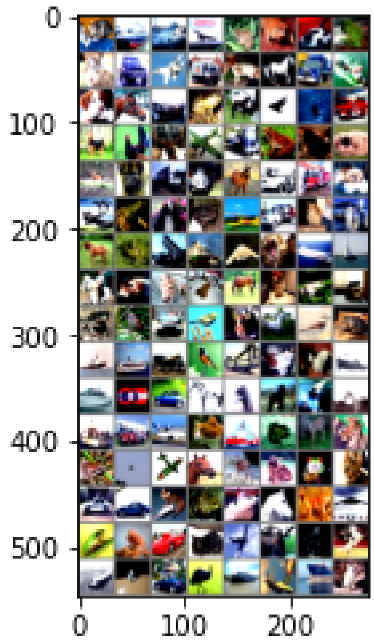
```
=> Building model…
Files already downloaded and verified
Files already downloaded and verified
```

[2]:

```
import matplotlib.pyplot as plt
import numpy as np

# functions to show an image

def imshow(img):
    img = img / 2 + 0.5     # unnormalize
    npimg = img.numpy()
    plt.imshow(np.transpose(npimg, (1, 2, 0)))
    plt.show()

# get some random training images
dataiter = iter(testloader)
```

```
images, labels = dataiter.next() ## If you run this line, the next data batch␣
↪is called subsequently.

# show images
imshow(torchvision.utils.make_grid(images))
```

Clipping input data to the valid range for imshow with RGB data ([0..1] for floats or [0..255] for integers).



[ ]:
```
# This cell is from the websitehttps://datahub.ucsd.edu/user/chw080/notebooks/
↪private/Homework3/ece284fa22/software/
↪%5BHW3_prob1%5D_CNN_Training_with_VGG16.ipynb#

lr = 4.5e-2
weight_decay = 1e-4
epochs = 100
best_prec = 0

model = model.cuda()
criterion = nn.CrossEntropyLoss().cuda()
optimizer = torch.optim.SGD(model.parameters(), lr=lr, momentum=0.9,␣
↪weight_decay=weight_decay)
# weight decay: for regularization to prevent overfitting
```

```python
if not os.path.exists('result'):
    os.makedirs('result')

fdir = 'result/'+str(model_name)

if not os.path.exists(fdir):
    os.makedirs(fdir)


for epoch in range(0, epochs):
    adjust_learning_rate(optimizer, epoch)

    train(trainloader, model, criterion, optimizer, epoch)

    # evaluate on test set
    print("Validation starts")
    prec = validate(testloader, model, criterion)

    # remember best precision and save checkpoint
    is_best = prec > best_prec
    best_prec = max(prec,best_prec)
    print('best acc: {:1f}'.format(best_prec))
    save_checkpoint({
        'epoch': epoch + 1,
        'state_dict': model.state_dict(),
        'best_prec': best_prec,
        'optimizer': optimizer.state_dict(),
    }, is_best, fdir)
```

[3]:

```python
fdir = 'result/'+str(model_name)+'/model_best.pth.tar'

checkpoint = torch.load(fdir)
model.load_state_dict(checkpoint['state_dict'])


criterion = nn.CrossEntropyLoss().cuda()

model.eval()
model.cuda()


prec = validate(testloader, model, criterion)
```

```
/opt/conda/lib/python3.9/site-packages/torch/nn/functional.py:718: UserWarning:
Named tensors and all their associated APIs are an experimental feature and
subject to change. Please do not use them for anything important until they are
```

```
released as stable. (Triggered internally at
/pytorch/c10/core/TensorImpl.h:1156.)
  return torch.max_pool2d(input, kernel_size, stride, padding, dilation,
ceil_mode)
```

```
Test: [0/79]    Time 0.248 (0.248)      Loss 0.2583 (0.2583)    Prec 92.969%
(92.969%)
 * Prec 90.280%
```

[4]:

```python
class SaveOutput:
    def __init__(self):
        self.outputs = []
    def __call__(self,module,module_in):
        self.outputs.append(module_in)
    def clear(self):
        self.outputs = []

save_output = SaveOutput()

for layer in model.modules():
    if isinstance(layer, torch.nn.Conv2d):
        print("prehooked")
        layer.register_forward_pre_hook(save_output)

dataiter = iter(trainloader)
images. labels = dataiter.next()
images = images.to(device)
out = model(images)
```

```
prehooked
prehooked
prehooked
prehooked
prehooked
prehooked
prehooked
prehooked
prehooked
prehooked
prehooked
prehooked
prehooked
```

[5]:

```python
for layer in model.modules():
    print(layer)
```

```
VGG(
  (features): Sequential(
```

```
    (0): Conv2d(3, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (2): ReLU(inplace=True)
    (3): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (4): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (5): ReLU(inplace=True)
    (6): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (7): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (8): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (9): ReLU(inplace=True)
    (10): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (11): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (12): ReLU(inplace=True)
    (13): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (14): Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (15): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (16): ReLU(inplace=True)
    (17): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (18): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (19): ReLU(inplace=True)
    (20): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (21): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (22): ReLU(inplace=True)
    (23): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (24): Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (25): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (26): ReLU(inplace=True)
    (27): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
```

```
    (28): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (29): ReLU(inplace=True)
    (30): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (31): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (32): ReLU(inplace=True)
    (33): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (34): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (35): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (36): ReLU(inplace=True)
    (37): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (38): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (39): ReLU(inplace=True)
    (40): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
    (41): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (42): ReLU(inplace=True)
    (43): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (44): AvgPool2d(kernel_size=1, stride=1, padding=0)
  )
  (classifier): Linear(in_features=512, out_features=10, bias=True)
)
Sequential(
  (0): Conv2d(3, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (2): ReLU(inplace=True)
  (3): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (4): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (5): ReLU(inplace=True)
  (6): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  (7): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (8): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
```

```
  (9): ReLU(inplace=True)
  (10): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (11): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (12): ReLU(inplace=True)
  (13): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  (14): Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (15): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (16): ReLU(inplace=True)
  (17): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (18): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (19): ReLU(inplace=True)
  (20): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (21): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (22): ReLU(inplace=True)
  (23): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  (24): Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (25): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (26): ReLU(inplace=True)
  (27): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (28): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (29): ReLU(inplace=True)
  (30): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (31): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (32): ReLU(inplace=True)
  (33): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  (34): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (35): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (36): ReLU(inplace=True)
  (37): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
```

```
bias=False)
  (38): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (39): ReLU(inplace=True)
  (40): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
  (41): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  (42): ReLU(inplace=True)
  (43): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  (44): AvgPool2d(kernel_size=1, stride=1, padding=0)
)
Conv2d(3, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
Conv2d(256, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
```

```
BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
ReLU(inplace=True)
MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1, ceil_mode=False)
AvgPool2d(kernel_size=1, stride=1, padding=0)
Linear(in_features=512, out_features=10, bias=True)
```

[ ]:

[6]:
```
my_input = save_output.outputs[0][0]
images.size()
```

[6]:
```
torch.Size([128, 3, 32, 32])
```

[8]:
```
con = model.features[0]
Norm = model.features[1]
Rel = model.features[2]
```

[9]:
```
my_output = Rel(Norm((con(my_input))))
```

[10]:
```
(my_output - save_output.outputs[1][0]).sum()
```

[10]:
```
tensor(0., device='cuda:0', grad_fn=<SumBackward0>)
```

[ ]:
```
# HW

#  1. train resnet20 and vgg16 to achieve >90% accuracy
#  2. save your trained model in the result folder
#  3. Restart your jupyter notebook by "Kernel - Restart & Clear Output"
#  4. Load your saved model for vgg16 and validate to see the accuracy
#  5. such as the last part of "[W2S2_example2]_CNN_for_MNIST.ipynb", prehook␣
↪the input layers of all the conv layers.
#  6. from the first prehooked input, compute to get the second prehooked input.
↪
#  7. Compare your computed second input vs. the prehooked second input.
```

[ ]:

[ ]:

[ ]:

[ ]:

```

```