

Memory__data__generator

December 13, 2025

1 Part1 4bit-activation and 4bit-weight

```
[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 *

global best_prec
use_gpu = torch.cuda.is_available()
print('=> Building model...')

batch_size = 512
model_name = "VGG16_quant_project_part1_92_prec"    #"Resnet20_quant"
model = VGG16_quant_project_part1()

print(model)

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()
    data_time = AverageMeter()
    losses = AverageMeter()
    top1 = AverageMeter()

    model.train()

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

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

        # compute output
        output = model(input)

```

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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)
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)

            # 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
    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...

```

VGG_quant(
    (features): Sequential(
      (0): QuantConv2d(
        3, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
        (weight_quant): weight_quantize_fn()
      )
      (1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (2): ReLU(inplace=True)
      (3): QuantConv2d(
        64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
        (weight_quant): weight_quantize_fn()
      )
      (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): QuantConv2d(
  64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
  (weight_quant): weight_quantize_fn()
)
(8): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
(9): ReLU(inplace=True)
(10): QuantConv2d(
  128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
  (weight_quant): weight_quantize_fn()
)
(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): QuantConv2d(
  128, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
  (weight_quant): weight_quantize_fn()
)
(15): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
(16): ReLU(inplace=True)
(17): QuantConv2d(
  256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
  (weight_quant): weight_quantize_fn()
)
(18): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
(19): ReLU(inplace=True)
(20): QuantConv2d(
  256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
  (weight_quant): weight_quantize_fn()
)
(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): QuantConv2d(
  256, 8, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
  (weight_quant): weight_quantize_fn()
)
(25): BatchNorm2d(8, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
(26): ReLU(inplace=True)
(27): QuantConv2d(
  8, 8, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False

```

```

        (weight_quant): weight_quantize_fn()
    )
    (28): ReLU(inplace=True)
    (29): QuantConv2d(
      8, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
      (weight_quant): weight_quantize_fn()
    )
    (30): ReLU(inplace=True)
    (31): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (32): QuantConv2d(
      512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
      (weight_quant): weight_quantize_fn()
    )
    (33): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (34): ReLU(inplace=True)
    (35): QuantConv2d(
      512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
      (weight_quant): weight_quantize_fn()
    )
    (36): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (37): ReLU(inplace=True)
    (38): QuantConv2d(
      512, 512, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False
      (weight_quant): weight_quantize_fn()
    )
    (39): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (40): ReLU(inplace=True)
    (41): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    (42): AvgPool2d(kernel_size=1, stride=1, padding=0)
  )
  (classifier): Linear(in_features=512, out_features=10, bias=True)
)

```

```
[12]: fdir = 'result/'+str(model_name)+'/' + 'model_best.pth.tar'
```

```

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

model.cuda()
model.eval()

```

```

test_loss = 0
correct = 0

with torch.no_grad():
    for data, target in testloader:
        data, target = data.to(device), target.to(device) # loading to GPU
        output = model(data)
        pred = output.argmax(dim=1, keepdim=True)
        correct += pred.eq(target.view_as(pred)).sum().item()

test_loss /= len(testloader.dataset)

print('\nTest set: Accuracy: {}/{} ({:.0f}%) \n'.format(
    correct, len(testloader.dataset),
    100. * correct / len(testloader.dataset)))

```

Test set: Accuracy: 9162/10000 (92%)

```

[13]: class SaveOutput:
        def __init__(self):
            self.outputs = []
        def __call__(self, module, module_in):
            self.outputs.append(module_in)
        def clear(self):
            self.outputs = []
        ##### Save inputs from selected layer #####
save_output = SaveOutput()
i = 0
for layer in model.modules():
    i = i+1
    if isinstance(layer, (QuantConv2d, torch.nn.ReLU)):
        layer.register_forward_pre_hook(save_output)
#####

dataiter = iter(testloader)
images, labels = next(dataiter)
images = images.to(device)
out = model(images)

```

```

[16]: model.features[27].show_params()

```

clipping threshold weight alpha: 2.374000, activation alpha: 4.564000

```

[36]: weight_q = model.features[27].weight_q
w_alpha = model.features[27].weight_quant.wgt_alpha
w_bit = 4

```



```
weight_int = weight_q / (w_alpha / (2**(w_bit-1)-1))
w_delta = w_alpha / (2 ** (w_bit-1) - 1)
```

```
[42]: act = save_output.outputs[15][0]
      act_alpha = model.features[27].act_alpha
      act_bit = 4
      act_quant_fn = act_quantization(act_bit)
      act_q = act_quant_fn(act, act_alpha)
      act_int = act_q / (act_alpha / (2**act_bit-1))
      act_delta = act_alpha / (2 ** act_bit - 1)
```

```
[46]: conv_int = torch.nn.Conv2d(in_channels = 8, out_channels=8, kernel_size = 3,
      ↪padding=1, bias = False)
      conv_int.weight = torch.nn.parameter.Parameter(weight_int)
      output_int = conv_int(act_int) # output_int can be calculated with conv_int
      ↪and x_int
      output_recovered = output_int * act_delta * w_delta # recover with x_delta and
      output_recovered = F.relu(output_recovered)
```

```
[54]: output_ref = save_output.outputs[17][0]
```

```
[55]: difference = abs(output_ref - output_recovered )
      print(difference.mean())
```

```
tensor(3.2444e-07, device='cuda:0', grad_fn=<MeanBackward0>)
```

```
[ ]: out_relu = F.relu(output_int)
```

```
[8]: out = torch.reshape(out_relu, (out_relu.size(0), out_relu.size(1), -1))
```

```
[9]: out = out[0]
```

```
[10]: # act_int.size = torch.Size([128, 64, 32, 32]) <- batch_size, input_ch, ni, nj
      a_int = act_int[0,:,:,:] # pick only one input out of batch
      # a_int.size() = [64, 32, 32]

      # conv_int.weight.size() = torch.Size([64, 64, 3, 3]) <- output_ch, input_ch,
      ↪ki, kj
      w_int = torch.reshape(weight_int, (weight_int.size(0), weight_int.size(1), -1))
      ↪ # merge ki, kj index to kij
      # w_int.weight.size() = torch.Size([64, 64, 9])

      padding = 1
      stride = 1
      array_size = 8 # row and column number

      nig = range(a_int.size(1)) ## ni group
      njg = range(a_int.size(2)) ## nj group
```

```

icg = range(int(w_int.size(1)))  ## input channel
ocg = range(int(w_int.size(0)))  ## output channel

ic_tileg = range(int(len(icg)/array_size))
oc_tileg = range(int(len(ocg)/array_size))

kijg = range(w_int.size(2))
ki_dim = int(math.sqrt(w_int.size(2)))  ## Kernel's 1 dim size

##### Padding before Convolution #####
a_pad = torch.zeros(len(icg), len(nig)+padding*2, len(nig)+padding*2).cuda()
# a_pad.size() = [64, 32+2pad, 32+2pad]
a_pad[:, padding:padding+len(nig), padding:padding+len(njg)] = a_int.cuda()
a_pad = torch.reshape(a_pad, (a_pad.size(0), -1))
# a_pad.size() = [64, (32+2pad)*(32+2pad)]

a_tile = torch.zeros(len(ic_tileg), array_size, a_pad.size(1)).cuda()
w_tile = torch.zeros(len(oc_tileg)*len(ic_tileg), array_size, array_size,
    ↪ len(kijg)).cuda()

for ic_tile in ic_tileg:
    a_tile[ic_tile, :, :] = a_pad[ic_tile*array_size:(ic_tile+1)*array_size, :]

for ic_tile in ic_tileg:
    for oc_tile in oc_tileg:
        w_tile[oc_tile*len(oc_tileg) + ic_tile, :, :] =
    ↪ w_int[oc_tile*array_size:(oc_tile+1)*array_size, ic_tile*array_size:
    ↪ (ic_tile+1)*array_size, :]

#####

p_nijg = range(a_pad.size(1))  ## psum nij group

psum = torch.zeros(len(ic_tileg), len(oc_tileg), array_size, len(p_nijg),
    ↪ len(kijg)).cuda()

for kij in kijg:
    for ic_tile in ic_tileg:  # Tiling into array_sizeXarray_size array
        for oc_tile in oc_tileg:  # Tiling into array_sizeXarray_size array
            ↪
                for nij in p_nijg:  # time domain, sequentially given input
                    m = nn.Linear(array_size, array_size, bias=False)

```

```

        #m.weight = torch.nn.Parameter(w_int[oc_tile*array_size:
↪(oc_tile+1)*array_size, ic_tile*array_size:(ic_tile+1)*array_size, kij])
        m.weight = torch.nn.
↪Parameter(w_tile[len(oc_tileg)*oc_tile+ic_tile,:,:,kij])
        psum[ic_tile, oc_tile, :, nij, kij] = m(a_tile[ic_tile,:
↪,nij]).cuda()

```

[]: *### show this cell partially. The following cells should be printed by students*

```

↪###
tile_id = 0
nij = 0 # just a random number
X = a_tile[tile_id,:,nij:nij+36] # [tile_num, array row num, time_steps]

bit_precision = 4
file = open('activation_tile0.txt', 'w') #write to file
# file.write('#time0row7[msb-lsb],time0row6[msb-lst],....
↪,time0row0[msb-lst]#\n')
# file.write('#time1row7[msb-lsb],time1row6[msb-lst],....
↪,time1row0[msb-lst]#\n')
# file.write('#.....#\n')

for i in range(X.size(1)): # time step
    for j in range(X.size(0)): # row #
        X_bin = '{0:04b}'.format(round(X[7-j,i].item()))
        for k in range(bit_precision):
            file.write(X_bin[k])
            #file.write(' ') # for visibility with blank between words, you can use
        file.write('\n')
file.close() #close file

```

[]: *### Complete this cell ###*

```

tile_id = 0
kij = 9
# w_tile[tile_num, array col num, array row num, kij]

bit_precision = 4
for i in range(kij):
    file = open(f'weight_itile0_otile0_kij{i}.txt', 'w') #write to file
    # file.write('#col0row7[msb-lsb],col0row6[msb-lst],....
↪,col0row0[msb-lst]#\n')
    # file.write('#col1row7[msb-lsb],col1row6[msb-lst],....
↪,col1row0[msb-lst]#\n')
    # file.write('#.....#\n')

    W = w_tile[tile_id,:,:,i]
    for col in range(W.size(1)):

```

```

        for row in range(W.size(0)):
            W_value = W[col, 7 - row]
            if W_value < 0:
                W_value += 2 ** bit_precision
            W_bin = '{0:04b}'.format(round(W_value.item()))
            for k in range(bit_precision):
                file.write(W_bin[k])
            file.write('\n')
        file.close()

```

```

[ ]: bit_precision = 16

file = open('out.txt', 'w') #write to file
# file.write('#time0col7[msb-lsb],time0col6[msb-lst],....
# file.write('#time1col7[msb-lsb],time1col6[msb-lst],....
# file.write('#.....#\n')

for t in range(out.size(1)):
    for col in range(out.size(0)):
        p_value = out[7 - col, t]
        if p_value < 0:
            p_value += 2 ** bit_precision
        psum_bin = '{0:016b}'.format(round(p_value.item()))
        for k in range(bit_precision):
            file.write(psum_bin[k])
        file.write('\n')
file.close()

```

2 Part2 2bit-activation and 4bit-weight

```

[2]: model = VGG16_quant_project_part2()

model_name = "VGG16_quant_project_part2_90_prec"
fdir = 'result/'+model_name+'/model_best.pth.tar'

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

model.cuda()
model.eval()

test_loss = 0

```

```

correct = 0

with torch.no_grad():
    for data, target in testloader:
        data, target = data.to(device), target.to(device) # loading to GPU
        output = model(data)
        pred = output.argmax(dim=1, keepdim=True)
        correct += pred.eq(target.view_as(pred)).sum().item()

test_loss /= len(testloader.dataset)

print('\nTest set: Accuracy: {}/{} ({:.0f}%) \n'.format(
    correct, len(testloader.dataset),
    100. * correct / len(testloader.dataset)))

```

Test set: Accuracy: 9010/10000 (90%)

```

[4]: class SaveOutput:
    def __init__(self):
        self.outputs = []
    def __call__(self, module, module_in):
        self.outputs.append(module_in)
    def clear(self):
        self.outputs = []
    ##### Save inputs from selected layer #####

save_output = SaveOutput()
i = 0
for layer in model.modules():
    i = i+1
    if isinstance(layer, (QuantConv2d, torch.nn.ReLU)):
        layer.register_forward_pre_hook(save_output)
    #####

dataiter = iter(testloader)
images, labels = next(dataiter)
images = images.to(device)
out = model(images)

```

```

[5]: weight_q = model.features[27].weight_q
w_alpha = model.features[27].weight_quant.wgt_alpha
w_bit = 4
weight_int = weight_q / (w_alpha / (2**(w_bit-1)-1))
w_delta = w_alpha / (2 ** (w_bit-1) - 1)

```

```
[6]: act = save_output.outputs[15][0]
act_alpha = model.features[27].act_alpha
act_bit = 2
act_quant_fn = act_quantization(act_bit)
act_q = act_quant_fn(act, act_alpha)
act_int = act_q / (act_alpha / (2**act_bit-1))
act_delta = act_alpha / (2 ** act_bit - 1)
```

```
[7]: conv_int = torch.nn.Conv2d(in_channels = 8, out_channels=8, kernel_size = 3,
    ↪padding=1, bias = False)
conv_int.weight = torch.nn.parameter.Parameter(weight_int)
output_int = conv_int(act_int) # output_int can be calculated with conv_int
    ↪and x_int
output_recovered = output_int * act_delta * w_delta # recover with x_delta and
output_recovered = F.relu(output_recovered)
```

```
[8]: output_ref = save_output.outputs[17][0]
```

```
[9]: difference = abs(output_ref - output_recovered )
print(difference.mean())
```

```
tensor(1.9340e-06, device='cuda:0', grad_fn=<MeanBackward0>)
```

```
[11]: out_relu = F.relu(output_int)
```

```
[12]: out = torch.reshape(out_relu, (out_relu.size(0), out_relu.size(1), -1))
```

```
[16]: # act_int.size = torch.Size([128, 64, 32, 32]) <- batch_size, input_ch, ni, nj
a_int = act_int[0,:,:,:] # pick only one input out of batch
# a_int.size() = [64, 32, 32]

# conv_int.weight.size() = torch.Size([64, 64, 3, 3]) <- output_ch, input_ch,
    ↪ki, kj
w_int = torch.reshape(weight_int, (weight_int.size(0), weight_int.size(1), -1))
    ↪ # merge ki, kj index to kij
# w_int.weight.size() = torch.Size([64, 64, 9])

padding = 1
stride = 1
array_size = 16 # row and column number

nig = range(a_int.size(1)) ## ni group
njg = range(a_int.size(2)) ## nj group

icg = range(int(w_int.size(1))) ## input channel
ocg = range(int(w_int.size(0))) ## output channel
```

```

ic_tileg = range(int(len(icg)/array_size))
oc_tileg = range(int(len(ocg)/array_size))

kijg = range(w_int.size(2))
ki_dim = int(math.sqrt(w_int.size(2)))  ## Kernel's 1 dim size

##### Padding before Convolution #####
a_pad = torch.zeros(len(icg), len(nig)+padding*2, len(nig)+padding*2).cuda()
# a_pad.size() = [64, 32+2pad, 32+2pad]
a_pad[:, padding:padding+len(nig), padding:padding+len(njg)] = a_int.cuda()
a_pad = torch.reshape(a_pad, (a_pad.size(0), -1))
# a_pad.size() = [64, (32+2pad)*(32+2pad)]

a_tile = torch.zeros(len(ic_tileg), array_size, a_pad.size(1)).cuda()
w_tile = torch.zeros(len(oc_tileg)*len(ic_tileg), array_size, array_size,
    ↪len(kijg)).cuda()

for ic_tile in ic_tileg:
    a_tile[ic_tile,:,:] = a_pad[ic_tile*array_size:(ic_tile+1)*array_size,:]

for ic_tile in ic_tileg:
    for oc_tile in oc_tileg:
        w_tile[oc_tile*len(oc_tileg) + ic_tile,:,:,:] =
    ↪w_int[oc_tile*array_size:(oc_tile+1)*array_size, ic_tile*array_size:
    ↪(ic_tile+1)*array_size, :]

#####

p_nijg = range(a_pad.size(1))  ## psum nij group

psum = torch.zeros(len(ic_tileg), len(oc_tileg), array_size, len(p_nijg),
    ↪len(kijg)).cuda()

for kij in kijg:
    for ic_tile in ic_tileg:  # Tiling into array_sizeXarray_size array
        for oc_tile in oc_tileg:  # Tiling into array_sizeXarray_size array
            ↪
                for nij in p_nijg:  # time domain, sequentially given input
                    m = nn.Linear(array_size, array_size, bias=False)
                    #m.weight = torch.nn.Parameter(w_int[oc_tile*array_size:
    ↪(oc_tile+1)*array_size, ic_tile*array_size:(ic_tile+1)*array_size, kij])
                    m.weight = torch.nn.
    ↪Parameter(w_tile[len(oc_tileg)*oc_tile+ic_tile,:,:,:kij])

```

```

        psum[ic_tile, oc_tile, :, nij, kij] = m(a_tile[ic_tile, :
↪,nij]).cuda()

```

```

[22]: ### show this cell partially. The following cells should be printed by students
↪###
tile_id = 0
nij = 0 # just a random number
X = a_tile[tile_id,:,nij:nij+36] # [tile_num, array row num, time_steps]

bit_precision = 4
file = open('activation_tile0.txt', 'w') #write to file
# file.write('#time0row7[msb-lsb],time0row6[msb-lst],....
↪,time0row0[msb-lst]#\n')
# file.write('#time1row7[msb-lsb],time1row6[msb-lst],....
↪,time1row0[msb-lst]#\n')
# file.write('#.....#\n')

for i in range(X.size(1)): # time step
    for j in range(0, X.size(0), 2): # row #
        act1 = round(X[15-j, i].item())
        act2 = round(X[15-j - 1, i].item())
        act_comb = act1 << 2 | act2
        X_bin = '{0:04b}'.format(act_comb)
        for k in range(bit_precision):
            file.write(X_bin[k])
            #file.write(' ') # for visibility with blank between words, you can use
        file.write('\n')
file.close() #close file

```

```

[38]: ### Complete this cell ###
tile_id = 0
kij = 9
# w_tile[tile_num, array col num, array row num, kij]

bit_precision = 4
for i in range(kij):
    file = open(f'weight_itile0_otile0_kij{i}.txt', 'w') #write to file
    # file.write('#col0row7[msb-lsb],col0row6[msb-lst],....
↪,col0row0[msb-lst]#\n')
    # file.write('#col1row7[msb-lsb],col1row6[msb-lst],....
↪,col1row0[msb-lst]#\n')
    # file.write('#.....#\n')

    W = w_tile[tile_id,:,:,i]
    for col in range(W.size(1)):
        for row in list(range(W.size(0)))[::2]:
            W_value = W[col, 14 - row]

```



```

        if W_value < 0:
            W_value += 2 ** bit_precision
        W_bin = '{0:04b}'.format(round(W_value.item()))
        for k in range(bit_precision):
            file.write(W_bin[k])
    file.write('\n')
    for row in list(range(W.size(0)))[1::2]:
        W_value = W[col, 15 - row + 1]
        if W_value < 0:
            W_value += 2 ** bit_precision
        W_bin = '{0:04b}'.format(round(W_value.item()))
        for k in range(bit_precision):
            file.write(W_bin[k])
    file.write('\n')
file.close()

```

```

[37]: W = w_tile[tile_id, :, :, 0][0, :]
      W

```

```

[37]: tensor([ 9.0000,  7.0000,  6.0000,  6.0000,  7.0000,  7.0000,  7.0000, 11.0000,
              7.0000,  1.0000,  1.0000, 10.0000,  7.0000,  9.0000, 14.0000,  9.0000],
          device='cuda:0', grad_fn=<SliceBackward0>)

```

```

[ ]: bit_precision = 16

file = open('out.txt', 'w') #write to file
# file.write('#time0col7[msb-lsb],time0col6[msb-lst],....
#         ↪,time0col0[msb-lst]#\n')
# file.write('#time1col7[msb-lsb],time1col6[msb-lst],....
#         ↪,time1col0[msb-lst]#\n')
# file.write('#.....#\n')

for t in range(out.size(1)):
    for col in range(out.size(0)):
        p_value = out[7 - col, t]
        if p_value < 0:
            p_value += 2 ** bit_precision
        psum_bin = '{0:016b}'.format(round(p_value.item()))
        for k in range(bit_precision):
            file.write(psum_bin[k])
    file.write('\n')
file.close()

```