НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ ИТМО

Факультет систем управления и робототехники

Прикладной искусственный интеллект

Лабораторная работа № 3

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Классификация цветов с помощью свёрточных нейронных сетей.

В работе необходимо познакомится с различными архитектурами сверхточных нейронных сетей и их обучением на GPU (англ. graphics processing, графический процессор) на языке программирования Python 3 и фреймворка Torch (PyTorch). Для этого предлагается использовать ресурсы Google Colab - Colaboratory, для выполнения вычислений на GPU. После с ознакомления, выполнить практическое задане в конце данной тетради (notebook).

Рассмотрим Датасет содержащий 4242 изображения цветов размеченных по 5 видам (тюльпан, ромашка, подсолнух, роза, одуванчик). Данный набор данных можно скачать по ссылке с сайте kaggle.

Загрузите папку с картинками на гугл диск, чтобы не загружать ее каждый раз заново при перезапуске колаба. Структура файлов (можно посмотреть в меню слева) может быть такой: "/content/drive/My Drive/data/flowers". Обязательно подключите аппаратный ускоритель (GPU) к среде выполнения, чтобы вычисления были. В меню сверху: Среда выполнения -> Сменить среду выполнения

Первым делом разберите более детально код выполнив код ниже.

Подготовка

Загружаем библиотеки. Фиксируем random.seed для воспроизводимости

```
import numpy as np # linear algebra
import os
import torch
import torchvision
from torchvision.datasets.utils import download_url
from torch.utils.data import random_split
from torchvision.datasets import ImageFolder
from torchvision import transforms
from torchvision.transforms import ToTensor
from torch.utils.data.dataloader import DataLoader
import torch.nn as nn
import torch.nn.functional as F
import random
from tqdm import tqdm
import matplotlib.pyplot as plt

random.seed(0)
torch.manual_seed(0)
```

```
<torch._C.Generator at 0x7f9f3cc9cab0>
```

Выбираем на чем будем делать вычисления - CPU или GPU (cuda)

```
device = 'cuda' if torch.cuda.is_available() else 'cpu'
print(device)
```

```
cuda
```

```
from google.colab import drive

drive.mount('/content/drive', force_remount=True)

FOLDERNAME = 'data/flowers'

assert FOLDERNAME is not None, "[!] Enter the foldername."

%cd drive/My\ Drive
#%cp -r $FOLDERNAME ../../
#%cd ../../
%cd data/flowers/
#!bash get_datasets.sh
#%cd ../../
```

```
Mounted at /content/drive
/content/drive/My Drive
/content/drive/My Drive/data/flowers
```

```
prepare_imgs = torchvision.transforms.Compose(
    [
        torchvision.transforms.Resize((224, 224)), #приводим картинки
к одному размеру
        torchvision.transforms.ToTensor(), # упаковывем их в тензор
        torchvision.transforms.Normalize(
            mean=[0.485, 0.456, 0.406], std=[0.229, 0.224, 0.225] #
нормализуем картинки по каналам
        ),
    ]
)
# задаем датасет. Лейблы - имена папок:
dataset = ImageFolder('/content/drive/My Drive/data/flowers',
transform=prepare_imgs)

dataset.imgs[2]
```

```
('/content/drive/My
Drive/data/flowers/daisy/10172379554_b296050f82_n.jpg', 0)
```

```
class ValueMeter(object):
  """
  Вспомогательный класс, чтобы отслеживать loss и метрику
  """
```

```
  def __init__(self):
      self.sum = 0
      self.total = 0

  def add(self, value, n):
      self.sum += value*n
      self.total += n

  def value(self):
      return self.sum/self.total

def log(mode, epoch, loss_meter, accuracy_meter, best_perf=None):
  """
  Вспомогательная функция, чтобы
  """
  print(
      f"[{mode}] Epoch: {epoch:0.2f}. "
      f"Loss: {loss_meter.value():.2f}. "
      f"Accuracy: {100*accuracy_meter.value():.2f}% ", end="\n")

  if best_perf:
      print(f"[best: {best_perf:0.2f}]%", end="")
```

Сверточная нейросеть с нуля

Вручную прописываем слои

```
model = nn.Sequential(
            nn.Conv2d(in_channels=3, out_channels=32, kernel_size=3,
stride=1, padding=1),
            nn.ReLU(),
            nn.Conv2d(32, 64, kernel_size=3, stride=1, padding=1),
            nn.ReLU(),
            nn.MaxPool2d(2, 2), # output: 64 x 16 x 16

            nn.Conv2d(64, 128, kernel_size=3, stride=1, padding=1),
            nn.ReLU(),
            nn.Conv2d(128, 128, kernel_size=3, stride=1, padding=1),
            nn.ReLU(),
            nn.MaxPool2d(2, 2), # output: 128 x 8 x 8

            nn.Conv2d(128, 256, kernel_size=3, stride=1, padding=1),
            nn.ReLU(),
            nn.Conv2d(256, 256, kernel_size=3, stride=1, padding=1),
            nn.ReLU(),
            nn.MaxPool2d(2, 2), # output: 256 x 4 x 4

            nn.Flatten(),
            nn.Linear(256*28*28, 1024),
```

```
            nn.ReLU(),
            nn.Linear(1024, 512),
            nn.ReLU(),
            nn.Linear(512, 5))
model.to(device) # отправляем модель на девайс (GPU)
```

```
Sequential(
  (0): Conv2d(3, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1))
  (1): ReLU()
  (2): Conv2d(32, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1))
  (3): ReLU()
  (4): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  (5): Conv2d(64, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1))
  (6): ReLU()
  (7): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1), padding=(1,
1))
  (8): ReLU()
  (9): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  (10): Conv2d(128, 256, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1))
  (11): ReLU()
  (12): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1))
  (13): ReLU()
  (14): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
  (15): Flatten(start_dim=1, end_dim=-1)
  (16): Linear(in_features=200704, out_features=1024, bias=True)
  (17): ReLU()
  (18): Linear(in_features=1024, out_features=512, bias=True)
  (19): ReLU()
  (20): Linear(in_features=512, out_features=5, bias=True)
)
```

Задаем гиперпараметры для обучения:

Задаем параметры и функцию для обучения. Разбиваем датасет на train/validation

```
batch_size = 32 # размер батча
optimizer = torch.optim.Adam(params = model.parameters()) # алгоритм
оптимизации
lr = 0.001 # learning rate
```

Разбиваем датасет на train и validation

Задаем dataloader'ы - объекты для итеративной загрузки данных и лейблов для обучения и валидации

```
train_set, val_set = torch.utils.data.random_split(dataset,
[len(dataset)-1000, 1000])
print('Размер обучающего и валидационного датасета: ', len(train_set),
len(val_set))
loaders = {'training': DataLoader(train_set, batch_size,
pin_memory=True,num_workers=2, shuffle=True),
           'validation':DataLoader(val_set, batch_size,
pin_memory=True,num_workers=2, shuffle=False)}
```

```
Размер обучающего и валидационного датасета:  3317 1000
```

Функция для подсчета Accuracy

```
def accuracy(outputs, labels):
    _, preds = torch.max(outputs, dim=1)
    return torch.tensor(torch.sum(preds == labels).item() /
len(preds))
```

Функция для обучения и валидации модели

```
def trainval(model, loaders, optimizer, epochs=10):
    """
    model: модель, которую собираемся обучать
    loaders: dict с dataloader'ами для обучения и валидации
    optimizer: оптимизатор
    epochs: число обучающих эпох (сколько раз пройдемся по всему
датасету)
    """
    loss_meter = {'training': ValueMeter(), 'validation':
ValueMeter()}
    accuracy_meter = {'training': ValueMeter(), 'validation':
ValueMeter()}

    loss_track = {'training': [], 'validation': []}
    accuracy_track = {'training': [], 'validation': []}

    for epoch in range(epochs): # итерации по эпохам
        for mode in ['training', 'validation']: # обучение - валидация
            # считаем градиаент только при обучении:
            with torch.set_grad_enabled(mode == 'training'):
                # в зависимоти от фазы переводим модель в нужный
ружим:
                model.train() if mode == 'training' else model.eval()
                for imgs, labels in tqdm(loaders[mode]):
                    imgs = imgs.to(device) # отправляем тензор на GPU
                    labels = labels.to(device)
                    bs = labels.shape[0]  # размер батча (отличается
для последнего батча в лоадере)
```

```
                    preds = model(imgs) # forward pass - прогоняем
тензор с картинками через модель
                    loss = F.cross_entropy(preds, labels) # считаем
функцию потерь
                    acc = accuracy(preds, labels) # считаем метрику

                    # храним loss и accuracy для батча
                    loss_meter[mode].add(loss.item(), bs)
                    accuracy_meter[mode].add(acc, bs)

                    # если мы в фазе обучения
                    if mode == 'training':
                        optimizer.zero_grad() # обнуляем прошлый
градиент
                        loss.backward() # делаем backward pass
(считаем градиент)
                        optimizer.step() # обновляем веса
            # в конце фазы выводим значения loss и accuracy
            log(mode, epoch, loss_meter[mode], accuracy_meter[mode])

            # сохраняем результаты по всем эпохам
            loss_track[mode].append(loss_meter[mode].value())
            accuracy_track[mode].append(accuracy_meter[mode].value())
    return loss_track, accuracy_track
```

Обучаем базовую модель

Проверим загрузку видеокарты, прежде чем запустить обучение:

```
!nvidia-smi
```

```
Thu Dec 16 11:27:15 2021
+-----------------------------------------------------------------------
--------+
| NVIDIA-SMI 495.44       Driver Version: 460.32.03    CUDA Version:
11.2     |
|-------------------------------+----------------------
+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile
Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util
Compute M. |
|                               |                      |
MIG M. |
|
==============================+======================+==============
=======|
|   0  Tesla K80           Off  | 00000000:00:04.0 Off |
```

```
0 |
| N/A   66C    P0    74W / 149W |   1321MiB / 11441MiB |      0%
Default |
|                               |                      |
N/A |
+-------------------------------+----------------------
+----------------------+


+-----------------------------------------------------------------------
--------+
| Processes:
|
|  GPU   GI   CI        PID   Type   Process name                  GPU
Memory |
|        ID   ID
Usage      |
|
=======================================================================
=======|
|  No running processes found
|
+-----------------------------------------------------------------------
--------+
```

Запускаем обучение на 10 эпох

```
loss_track, accuracy_track = trainval(model, loaders, optimizer,
epochs=10)
```

```
100%|██████████| 104/104 [04:07<00:00,  2.38s/it]
[training] Epoch: 0.00. Loss: 1.43. Accuracy: 35.51%
100%|██████████| 32/32 [01:08<00:00,  2.14s/it]
[validation] Epoch: 0.00. Loss: 1.39. Accuracy: 38.20%
100%|██████████| 104/104 [01:16<00:00,  1.36it/s]
[training] Epoch: 1.00. Loss: 1.31. Accuracy: 42.36%
100%|██████████| 32/32 [00:10<00:00,  2.93it/s]
[validation] Epoch: 1.00. Loss: 1.26. Accuracy: 44.40%
100%|██████████| 104/104 [01:16<00:00,  1.37it/s]
[training] Epoch: 2.00. Loss: 1.21. Accuracy: 48.25%
100%|██████████| 32/32 [00:11<00:00,  2.80it/s]
[validation] Epoch: 2.00. Loss: 1.17. Accuracy: 49.87%
```

100%|██████████| 104/104 [01:16<00:00, 1.37it/s]

[training] Epoch: 3.00. Loss: 1.11. Accuracy: 53.27%

100%|██████████| 32/32 [00:11<00:00, 2.88it/s]

[validation] Epoch: 3.00. Loss: 1.12. Accuracy: 53.20%

100%|██████████| 104/104 [01:16<00:00, 1.36it/s]

[training] Epoch: 4.00. Loss: 1.01. Accuracy: 58.00%

100%|██████████| 32/32 [00:10<00:00, 3.07it/s]

[validation] Epoch: 4.00. Loss: 1.12. Accuracy: 55.04%

100%|██████████| 104/104 [01:16<00:00, 1.37it/s]

[training] Epoch: 5.00. Loss: 0.91. Accuracy: 62.67%

100%|██████████| 32/32 [00:10<00:00, 3.05it/s]

[validation] Epoch: 5.00. Loss: 1.17. Accuracy: 56.43%

100%|██████████| 104/104 [01:16<00:00, 1.37it/s]

[training] Epoch: 6.00. Loss: 0.81. Accuracy: 67.00%

100%|██████████| 32/32 [00:10<00:00, 3.02it/s]

[validation] Epoch: 6.00. Loss: 1.28. Accuracy: 57.17%

100%|██████████| 104/104 [01:16<00:00, 1.37it/s]

[training] Epoch: 7.00. Loss: 0.72. Accuracy: 70.65%

100%|██████████| 32/32 [00:11<00:00, 2.89it/s]

[validation] Epoch: 7.00. Loss: 1.42. Accuracy: 57.50%

100%|██████████| 104/104 [01:16<00:00, 1.36it/s]

[training] Epoch: 8.00. Loss: 0.66. Accuracy: 73.53%

100%|██████████| 32/32 [00:11<00:00, 2.88it/s]

[validation] Epoch: 8.00. Loss: 1.50. Accuracy: 57.90%

100%|██████████| 104/104 [01:16<00:00, 1.36it/s]

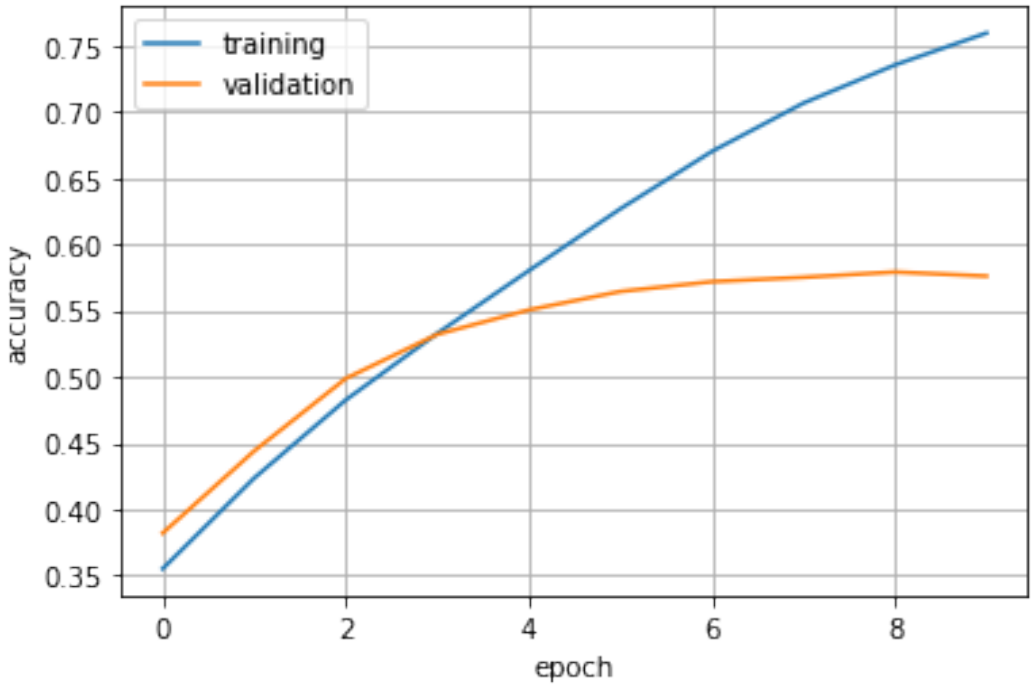
[training] Epoch: 9.00. Loss: 0.60. Accuracy: 75.93%

100%|██████████| 32/32 [00:11<00:00, 2.83it/s]

[validation] Epoch: 9.00. Loss: 1.56. Accuracy: 57.59%

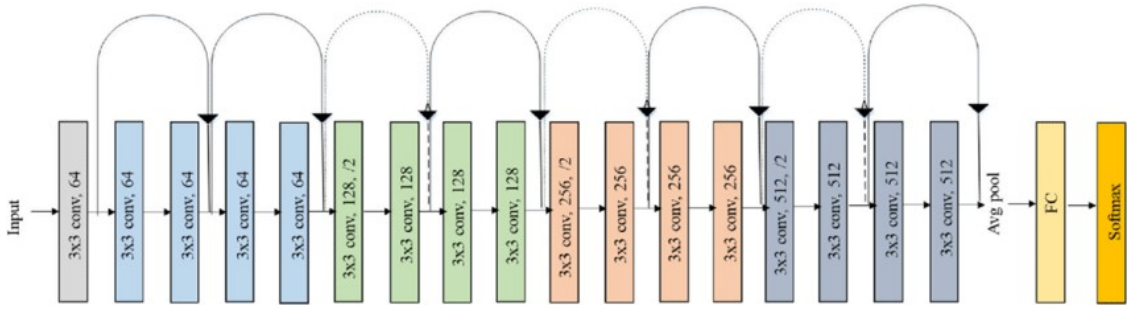
```
from matplotlib import pyplot as plt
%matplotlib inline
plt.plot(accuracy_track['training'], label='training')
plt.plot(accuracy_track['validation'], label='validation')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.grid()
plt.legend()
```

```
<matplotlib.legend.Legend at 0x7f9f33be8510>
```



Fine-tuning предобученной модели

Теперь попробуем поработать с предобученной сетью ResNet-18



```
resnet = torchvision.models.resnet18(pretrained=True) # инициализируем модель
resnet
```

```
Downloading: "https://download.pytorch.org/models/resnet18-f37072fd.pth" to /root/.cache/torch/hub/checkpoints/resnet18-f37072fd.pth
```


```
{"version_major":2,"version_minor":0,"model_id":"85880191086b49f99723ee1c88aa1a4e"}
```


```
ResNet(
  (conv1): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2), padding=(3, 3), bias=False)
  (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
  (relu): ReLU(inplace=True)
  (maxpool): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1, ceil_mode=False)
  (layer1): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
    (1): BasicBlock(
      (conv1): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(64, 64, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
    )
  )
  (layer2): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(64, 128, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True, track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1),
```

```
padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(64, 128, kernel_size=(1, 1), stride=(2, 2),
bias=False)
        (1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(128, 128, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(128, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
  )
  (layer3): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(128, 256, kernel_size=(3, 3), stride=(2, 2),
padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(128, 256, kernel_size=(1, 1), stride=(2, 2),
bias=False)
        (1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
```

```
    )
  )
  (layer4): Sequential(
    (0): BasicBlock(
      (conv1): Conv2d(256, 512, kernel_size=(3, 3), stride=(2, 2),
padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (downsample): Sequential(
        (0): Conv2d(256, 512, kernel_size=(1, 1), stride=(2, 2),
bias=False)
        (1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      )
    )
    (1): BasicBlock(
      (conv1): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    )
  )
  (avgpool): AdaptiveAvgPool2d(output_size=(1, 1))
  (fc): Linear(in_features=512, out_features=1000, bias=True)
)
```

```python
def set_parameter_requires_grad(model):
  """
  Функция для заморозки весов модели
  """
  for param in model.parameters():
    param.requires_grad = False

set_parameter_requires_grad(resnet)

# Меняем последний слой модели, чтобы он предсказывал 5 классов, а не
1000
# Когда мы заново определяем слой, у него по умолчанию стоит аттрибут
requires_grad = True
# То есть этот полносвязный слой будет обучаться
resnet.fc = nn.Linear(512, 5)
```

```
# Проверим все ли сработало правильно, выведем веса, которые будут обучаться
for name, param in resnet.named_parameters():
    if param.requires_grad:
        print(name)
```

```
fc.weight
fc.bias
```

Запустим функцию обучения модели. Внимание - необходимо заново задать оптимизатор, чтобы он теперь работал с весами resnet

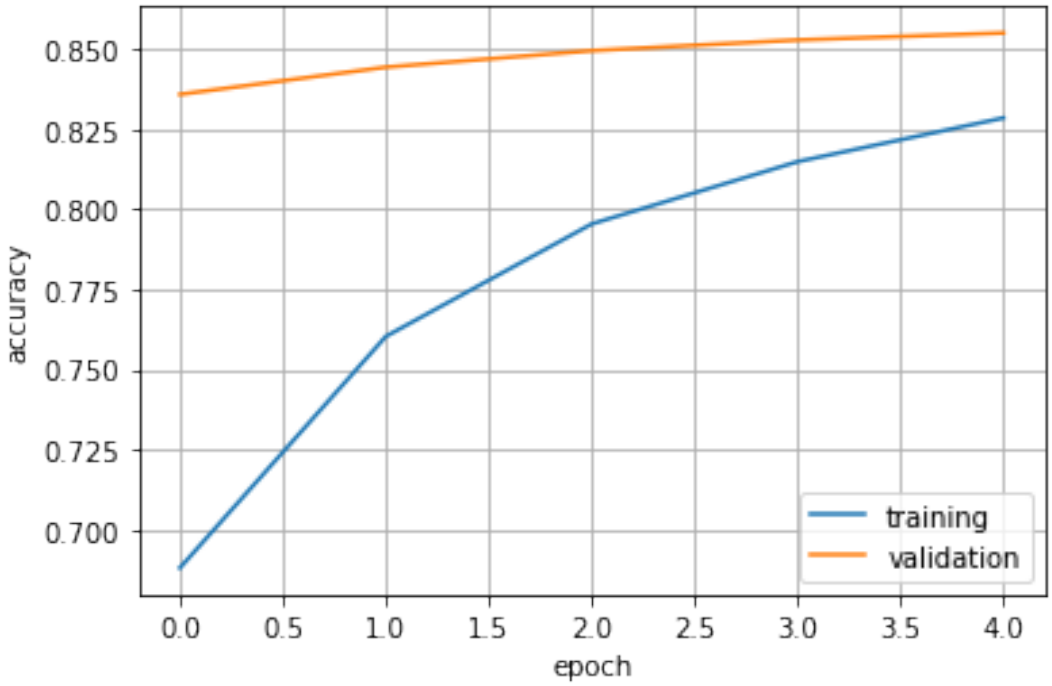
```
resnet.to(device)
optimizer = torch.optim.Adam(params = resnet.parameters()) # алгоритм оптимизации
loss_track, accuracy_track = trainval(resnet, loaders, optimizer, epochs=5)
```

```
100%|██████████| 104/104 [00:21<00:00,  4.79it/s]

[training] Epoch: 0.00. Loss: 0.89. Accuracy: 68.80%

100%|██████████| 32/32 [00:06<00:00,  4.81it/s]

[validation] Epoch: 0.00. Loss: 0.54. Accuracy: 83.60%

100%|██████████| 104/104 [00:21<00:00,  4.79it/s]

[training] Epoch: 1.00. Loss: 0.70. Accuracy: 76.03%

100%|██████████| 32/32 [00:06<00:00,  4.83it/s]

[validation] Epoch: 1.00. Loss: 0.48. Accuracy: 84.45%

100%|██████████| 104/104 [00:21<00:00,  4.84it/s]

[training] Epoch: 2.00. Loss: 0.60. Accuracy: 79.55%

100%|██████████| 32/32 [00:06<00:00,  4.84it/s]

[validation] Epoch: 2.00. Loss: 0.46. Accuracy: 84.97%

100%|██████████| 104/104 [00:21<00:00,  4.85it/s]

[training] Epoch: 3.00. Loss: 0.54. Accuracy: 81.50%

100%|██████████| 32/32 [00:06<00:00,  4.79it/s]

[validation] Epoch: 3.00. Loss: 0.44. Accuracy: 85.30%

100%|██████████| 104/104 [00:21<00:00,  4.74it/s]

[training] Epoch: 4.00. Loss: 0.51. Accuracy: 82.86%

100%|██████████| 32/32 [00:06<00:00,  4.83it/s]
```

```
[validation] Epoch: 4.00. Loss: 0.42. Accuracy: 85.52%
```

```
plt.plot(accuracy_track['training'], label='training')
plt.plot(accuracy_track['validation'], label='validation')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.grid()
plt.legend()
```

```
<matplotlib.legend.Legend at 0x7fae3d184d10>
```



Сохраним веса модели:

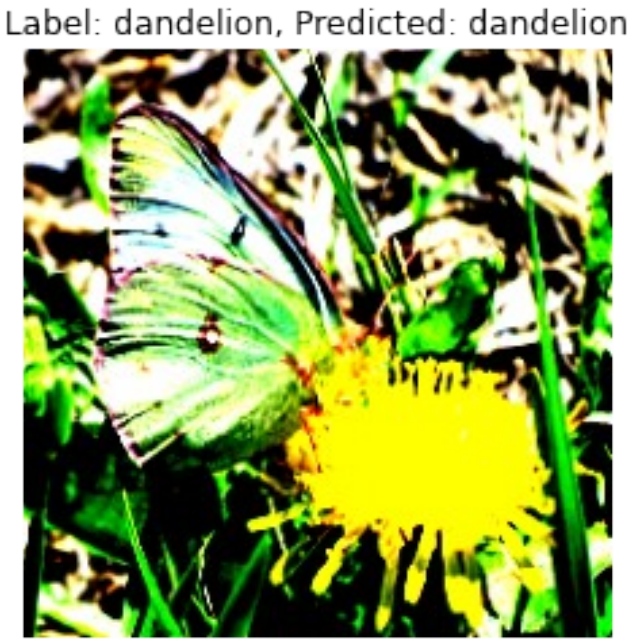
```
weights_fname = '/content/drive/My Drive/data/flower-resnet.pth'
torch.save(resnet.state_dict(), weights_fname)
```

Смотрим результат

И посмотрим как модель предсказывает

```
import matplotlib.pyplot as plt
%matplotlib inline
import warnings
warnings.filterwarnings("ignore")

def predict_image(img, model):
    # Преобразование to a batch of 1
```

```
    xb = img.unsqueeze(0).to(device)
    # Получение прогнозов от модели
    yb = model(xb)
    # Выбираем индекс с наибольшей вероятностью
    _, preds  = torch.max(yb, dim=1)
    # Получение метки класса
    return dataset.classes[preds[0].item()]

for i in range(1,10):
  img, label = val_set[i]
  plt.imshow(img.clip(0,1).permute(1, 2, 0))
  plt.axis('off')
  plt.title('Label: {}, Predicted:
{}'.format(dataset.classes[label],predict_image(img, resnet)))
  plt.show()
  # print('Label:', dataset.classes[label], ',Predicted:',
predict_image(img, resnet))
```



Label: sunflower, Predicted: daisy

Label: sunflower, Predicted: sunflower

Label: dandelion, Predicted: dandelion

Label: sunflower, Predicted: sunflower

Label: rose, Predicted: rose

Label: daisy, Predicted: daisy

Label: sunflower, Predicted: sunflower

Label: rose, Predicted: tulip

Практическое задание

В пракическом задание необходимо обучить еще одну сверточную архитектуру для задач классификации цветов.

В выбранной Вами архитектуре также необходимо разобраться с основными её параметрами и принципами работы.

Посмотрите как использовать модели в PyTorch, выберите одну и используя transfer learning до-обучите модель на классификацию цветов. Чтобы это сделать замените ___ в ячейках ниже на работающий код.

```
# Выберите модель из списка доступных в PyTorch моделей
# Не забудьте указать, что она модель должна быть предобучена!
model =torchvision.models.densenet169(pretrained=True)
model
```

```
Downloading: "https://download.pytorch.org/models/densenet169-
b2777c0a.pth" to /root/.cache/torch/hub/checkpoints/densenet169-
b2777c0a.pth
```


```
{"version_major":2,"version_minor":0,"model_id":"b2e2ea5997a643df8c119
316336ce371"}
```


```
DenseNet(
  (features): Sequential(
    (conv0): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2),
padding=(3, 3), bias=False)
    (norm0): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (relu0): ReLU(inplace=True)
    (pool0): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1,
ceil_mode=False)
    (denseblock1): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(64, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(96, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(96, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer3): _DenseLayer(
```

```
        (norm1): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(160, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(160, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(192, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(192, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(224, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(224, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
    )
    (transition1): _Transition(
      (norm): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
```

```
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock2): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(160, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(160, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(192, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(192, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(224, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(224, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
```

```
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(256, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(288, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(288, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(320, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(320, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(352, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(352, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
```

```
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(384, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(384, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(416, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(416, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(448, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(448, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(480, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(480, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
```

```
      )
    )
    (transition2): _Transition(
      (norm): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1),
bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock3): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(256, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(288, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(288, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(320, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(320, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(352, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
```

```
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(352, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(384, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(384, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(416, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(416, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(448, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(448, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(480, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(480, 128, kernel_size=(1, 1), stride=(1, 1),
```

```
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(512, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(544, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(544, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(576, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(576, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(608, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(608, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
```

```
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer13): _DenseLayer(
        (norm1): BatchNorm2d(640, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(640, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer14): _DenseLayer(
        (norm1): BatchNorm2d(672, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(672, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer15): _DenseLayer(
        (norm1): BatchNorm2d(704, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(704, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer16): _DenseLayer(
        (norm1): BatchNorm2d(736, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(736, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
```

```
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer17): _DenseLayer(
        (norm1): BatchNorm2d(768, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer18): _DenseLayer(
        (norm1): BatchNorm2d(800, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(800, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer19): _DenseLayer(
        (norm1): BatchNorm2d(832, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(832, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer20): _DenseLayer(
        (norm1): BatchNorm2d(864, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(864, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
```

```
      )
      (denselayer21): _DenseLayer(
        (norm1): BatchNorm2d(896, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(896, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer22): _DenseLayer(
        (norm1): BatchNorm2d(928, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(928, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer23): _DenseLayer(
        (norm1): BatchNorm2d(960, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(960, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer24): _DenseLayer(
        (norm1): BatchNorm2d(992, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(992, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer25): _DenseLayer(
```

```
        (norm1): BatchNorm2d(1024, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1024, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer26): _DenseLayer(
        (norm1): BatchNorm2d(1056, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1056, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer27): _DenseLayer(
        (norm1): BatchNorm2d(1088, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1088, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer28): _DenseLayer(
        (norm1): BatchNorm2d(1120, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1120, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer29): _DenseLayer(
        (norm1): BatchNorm2d(1152, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
```

```
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1152, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer30): _DenseLayer(
        (norm1): BatchNorm2d(1184, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1184, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer31): _DenseLayer(
        (norm1): BatchNorm2d(1216, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1216, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer32): _DenseLayer(
        (norm1): BatchNorm2d(1248, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1248, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
    )
    (transition3): _Transition(
      (norm): BatchNorm2d(1280, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
```

```
      (conv): Conv2d(1280, 640, kernel_size=(1, 1), stride=(1, 1),
bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock4): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(640, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(640, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(672, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(672, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(704, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(704, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(736, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(736, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
```

```
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(768, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(800, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(800, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(832, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(832, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(864, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(864, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
```

```
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(896, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(896, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(928, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(928, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(960, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(960, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(992, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(992, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer13): _DenseLayer(
```

```
        (norm1): BatchNorm2d(1024, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1024, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer14): _DenseLayer(
        (norm1): BatchNorm2d(1056, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1056, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer15): _DenseLayer(
        (norm1): BatchNorm2d(1088, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1088, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer16): _DenseLayer(
        (norm1): BatchNorm2d(1120, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1120, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer17): _DenseLayer(
        (norm1): BatchNorm2d(1152, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
```

```
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1152, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer18): _DenseLayer(
        (norm1): BatchNorm2d(1184, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1184, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer19): _DenseLayer(
        (norm1): BatchNorm2d(1216, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1216, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer20): _DenseLayer(
        (norm1): BatchNorm2d(1248, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1248, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer21): _DenseLayer(
        (norm1): BatchNorm2d(1280, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1280, 128, kernel_size=(1, 1), stride=(1, 1),
```

```
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer22): _DenseLayer(
        (norm1): BatchNorm2d(1312, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1312, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer23): _DenseLayer(
        (norm1): BatchNorm2d(1344, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1344, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer24): _DenseLayer(
        (norm1): BatchNorm2d(1376, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1376, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer25): _DenseLayer(
        (norm1): BatchNorm2d(1408, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1408, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
```

```
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer26): _DenseLayer(
        (norm1): BatchNorm2d(1440, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1440, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer27): _DenseLayer(
        (norm1): BatchNorm2d(1472, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1472, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer28): _DenseLayer(
        (norm1): BatchNorm2d(1504, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1504, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer29): _DenseLayer(
        (norm1): BatchNorm2d(1536, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1536, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
```

```
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer30): _DenseLayer(
        (norm1): BatchNorm2d(1568, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1568, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer31): _DenseLayer(
        (norm1): BatchNorm2d(1600, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1600, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer32): _DenseLayer(
        (norm1): BatchNorm2d(1632, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1632, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
    )
    (norm5): BatchNorm2d(1664, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  )
  (classifier): Linear(in_features=1664, out_features=1000, bias=True)
)

set_parameter_requires_grad(model) # передайте модель в функцию для
"заморозки" градиента

model.classifier = nn.Linear(1664,5) # Меняем последний слой модели
model
```

```
DenseNet(
  (features): Sequential(
    (conv0): Conv2d(3, 64, kernel_size=(7, 7), stride=(2, 2),
padding=(3, 3), bias=False)
    (norm0): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
    (relu0): ReLU(inplace=True)
    (pool0): MaxPool2d(kernel_size=3, stride=2, padding=1, dilation=1,
ceil_mode=False)
    (denseblock1): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(64, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(64, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(96, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(96, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(160, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
```

```
        (conv1): Conv2d(160, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(192, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(192, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(224, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(224, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
    )
    (transition1): _Transition(
      (norm): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock2): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(128, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
```

```
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(160, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(160, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(192, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(192, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(224, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(224, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(256, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
```

```
padding=(1, 1), bias=False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(288, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(288, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(320, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(320, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(352, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(352, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(384, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(384, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
```

```
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(416, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(416, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(448, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(448, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(480, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(480, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
    )
    (transition2): _Transition(
      (norm): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv): Conv2d(512, 256, kernel_size=(1, 1), stride=(1, 1),
bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock3): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(256, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
```

```
        (conv1): Conv2d(256, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(288, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(288, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(320, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(320, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(352, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(352, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(384, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(384, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
```

```
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(416, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(416, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(448, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(448, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(480, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(480, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(512, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(512, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
```

```
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(544, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(544, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(576, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(576, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(608, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(608, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer13): _DenseLayer(
        (norm1): BatchNorm2d(640, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(640, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
```

```
padding=(1, 1), bias=False)
      )
      (denselayer14): _DenseLayer(
        (norm1): BatchNorm2d(672, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(672, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer15): _DenseLayer(
        (norm1): BatchNorm2d(704, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(704, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer16): _DenseLayer(
        (norm1): BatchNorm2d(736, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(736, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer17): _DenseLayer(
        (norm1): BatchNorm2d(768, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
```

```
      (denselayer18): _DenseLayer(
        (norm1): BatchNorm2d(800, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(800, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer19): _DenseLayer(
        (norm1): BatchNorm2d(832, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(832, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer20): _DenseLayer(
        (norm1): BatchNorm2d(864, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(864, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer21): _DenseLayer(
        (norm1): BatchNorm2d(896, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(896, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer22): _DenseLayer(
        (norm1): BatchNorm2d(928, eps=1e-05, momentum=0.1,
```

```
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(928, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer23): _DenseLayer(
        (norm1): BatchNorm2d(960, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(960, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer24): _DenseLayer(
        (norm1): BatchNorm2d(992, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(992, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer25): _DenseLayer(
        (norm1): BatchNorm2d(1024, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1024, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer26): _DenseLayer(
        (norm1): BatchNorm2d(1056, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
```

```
        (conv1): Conv2d(1056, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer27): _DenseLayer(
        (norm1): BatchNorm2d(1088, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1088, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer28): _DenseLayer(
        (norm1): BatchNorm2d(1120, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1120, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer29): _DenseLayer(
        (norm1): BatchNorm2d(1152, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1152, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer30): _DenseLayer(
        (norm1): BatchNorm2d(1184, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1184, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
```

```
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer31): _DenseLayer(
        (norm1): BatchNorm2d(1216, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1216, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer32): _DenseLayer(
        (norm1): BatchNorm2d(1248, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1248, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
    )
    (transition3): _Transition(
      (norm): BatchNorm2d(1280, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv): Conv2d(1280, 640, kernel_size=(1, 1), stride=(1, 1),
bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock4): _DenseBlock(
      (denselayer1): _DenseLayer(
        (norm1): BatchNorm2d(640, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(640, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
```

```
padding=(1, 1), bias=False)
      )
      (denselayer2): _DenseLayer(
        (norm1): BatchNorm2d(672, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(672, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer3): _DenseLayer(
        (norm1): BatchNorm2d(704, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(704, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer4): _DenseLayer(
        (norm1): BatchNorm2d(736, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(736, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer5): _DenseLayer(
        (norm1): BatchNorm2d(768, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(768, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
```

```
      (denselayer6): _DenseLayer(
        (norm1): BatchNorm2d(800, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(800, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer7): _DenseLayer(
        (norm1): BatchNorm2d(832, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(832, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer8): _DenseLayer(
        (norm1): BatchNorm2d(864, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(864, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer9): _DenseLayer(
        (norm1): BatchNorm2d(896, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(896, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer10): _DenseLayer(
        (norm1): BatchNorm2d(928, eps=1e-05, momentum=0.1,
```

```
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(928, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer11): _DenseLayer(
        (norm1): BatchNorm2d(960, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(960, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer12): _DenseLayer(
        (norm1): BatchNorm2d(992, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(992, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer13): _DenseLayer(
        (norm1): BatchNorm2d(1024, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1024, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer14): _DenseLayer(
        (norm1): BatchNorm2d(1056, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
```

```
        (conv1): Conv2d(1056, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer15): _DenseLayer(
        (norm1): BatchNorm2d(1088, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1088, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer16): _DenseLayer(
        (norm1): BatchNorm2d(1120, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1120, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer17): _DenseLayer(
        (norm1): BatchNorm2d(1152, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1152, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer18): _DenseLayer(
        (norm1): BatchNorm2d(1184, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1184, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
```

```
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer19): _DenseLayer(
        (norm1): BatchNorm2d(1216, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1216, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer20): _DenseLayer(
        (norm1): BatchNorm2d(1248, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1248, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer21): _DenseLayer(
        (norm1): BatchNorm2d(1280, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1280, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer22): _DenseLayer(
        (norm1): BatchNorm2d(1312, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1312, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
```

```
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer23): _DenseLayer(
        (norm1): BatchNorm2d(1344, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1344, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer24): _DenseLayer(
        (norm1): BatchNorm2d(1376, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1376, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer25): _DenseLayer(
        (norm1): BatchNorm2d(1408, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1408, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer26): _DenseLayer(
        (norm1): BatchNorm2d(1440, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1440, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
```

```
padding=(1, 1), bias=False)
      )
      (denselayer27): _DenseLayer(
        (norm1): BatchNorm2d(1472, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1472, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer28): _DenseLayer(
        (norm1): BatchNorm2d(1504, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1504, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer29): _DenseLayer(
        (norm1): BatchNorm2d(1536, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1536, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer30): _DenseLayer(
        (norm1): BatchNorm2d(1568, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1568, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
```

```
      (denselayer31): _DenseLayer(
        (norm1): BatchNorm2d(1600, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1600, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
      (denselayer32): _DenseLayer(
        (norm1): BatchNorm2d(1632, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu1): ReLU(inplace=True)
        (conv1): Conv2d(1632, 128, kernel_size=(1, 1), stride=(1, 1),
bias=False)
        (norm2): BatchNorm2d(128, eps=1e-05, momentum=0.1,
affine=True, track_running_stats=True)
        (relu2): ReLU(inplace=True)
        (conv2): Conv2d(128, 32, kernel_size=(3, 3), stride=(1, 1),
padding=(1, 1), bias=False)
      )
    )
    (norm5): BatchNorm2d(1664, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  )
  (classifier): Linear(in_features=1664, out_features=5, bias=True)
)
```

```
# Проверим все ли сработало правильно, выведем веса, которые будут
обучаться
for name, param in model.named_parameters():
    if param.requires_grad:
        print(name)
```

```
classifier.weight
classifier.bias
```

```
model.to(device) # Отправляем модель на GPU
optimizer = torch.optim.Adam(params = model.parameters()) # алгоритм
оптимизации
loss_track, accuracy_track = trainval(model, loaders, optimizer,
epochs=10) # запускаем обучение
```

```
100%|██████████| 104/104 [00:33<00:00,  3.12it/s]

[training] Epoch: 0.00. Loss: 0.75. Accuracy: 76.45%

100%|██████████| 32/32 [00:09<00:00,  3.23it/s]
```

[validation] Epoch: 0.00. Loss: 0.42. Accuracy: 88.40%

100%|██████████| 104/104 [00:32<00:00, 3.15it/s]

[training] Epoch: 1.00. Loss: 0.57. Accuracy: 82.14%

100%|██████████| 32/32 [00:10<00:00, 3.20it/s]

[validation] Epoch: 1.00. Loss: 0.38. Accuracy: 88.60%

100%|██████████| 104/104 [00:32<00:00, 3.16it/s]

[training] Epoch: 2.00. Loss: 0.49. Accuracy: 84.70%

100%|██████████| 32/32 [00:09<00:00, 3.24it/s]

[validation] Epoch: 2.00. Loss: 0.35. Accuracy: 89.47%

100%|██████████| 104/104 [00:32<00:00, 3.17it/s]

[training] Epoch: 3.00. Loss: 0.44. Accuracy: 86.31%

100%|██████████| 32/32 [00:09<00:00, 3.25it/s]

[validation] Epoch: 3.00. Loss: 0.34. Accuracy: 89.67%

100%|██████████| 104/104 [00:32<00:00, 3.17it/s]

[training] Epoch: 4.00. Loss: 0.40. Accuracy: 87.34%

100%|██████████| 32/32 [00:09<00:00, 3.25it/s]

[validation] Epoch: 4.00. Loss: 0.33. Accuracy: 89.96%

100%|██████████| 104/104 [00:32<00:00, 3.17it/s]

[training] Epoch: 5.00. Loss: 0.37. Accuracy: 88.16%

100%|██████████| 32/32 [00:09<00:00, 3.24it/s]

[validation] Epoch: 5.00. Loss: 0.32. Accuracy: 90.18%

100%|██████████| 104/104 [00:32<00:00, 3.16it/s]

[training] Epoch: 6.00. Loss: 0.35. Accuracy: 88.79%

100%|██████████| 32/32 [00:09<00:00, 3.24it/s]

[validation] Epoch: 6.00. Loss: 0.31. Accuracy: 90.49%

100%|██████████| 104/104 [00:32<00:00, 3.16it/s]

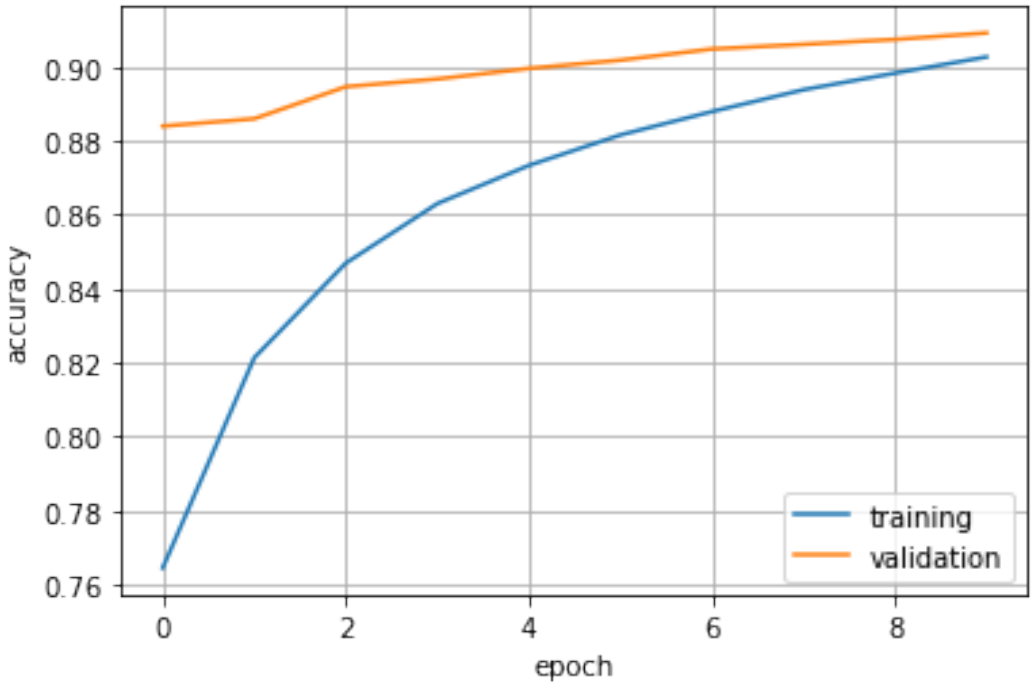
[training] Epoch: 7.00. Loss: 0.33. Accuracy: 89.38%

100%|██████████| 32/32 [00:09<00:00, 3.25it/s]

```
[validation] Epoch: 7.00. Loss: 0.30. Accuracy: 90.61%

100%|██████████| 104/104 [00:32<00:00,  3.16it/s]

[training] Epoch: 8.00. Loss: 0.32. Accuracy: 89.83%

100%|██████████| 32/32 [00:09<00:00,  3.24it/s]

[validation] Epoch: 8.00. Loss: 0.30. Accuracy: 90.74%

100%|██████████| 104/104 [00:32<00:00,  3.16it/s]

[training] Epoch: 9.00. Loss: 0.30. Accuracy: 90.27%

100%|██████████| 32/32 [00:09<00:00,  3.25it/s]

[validation] Epoch: 9.00. Loss: 0.29. Accuracy: 90.92%
```

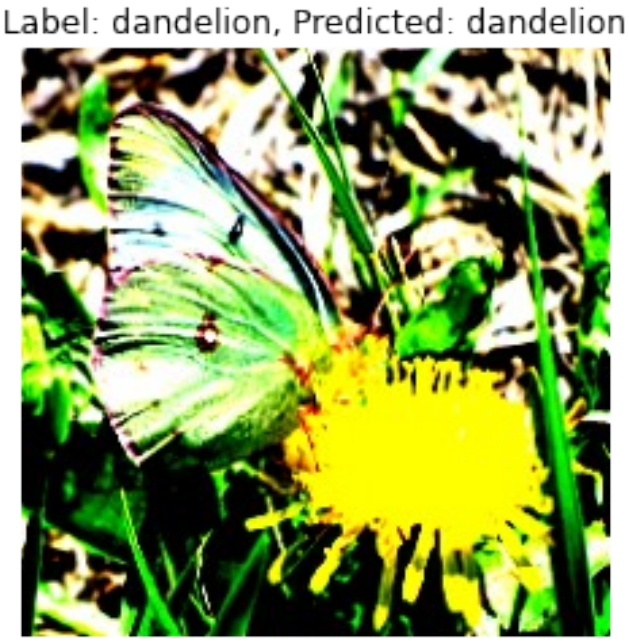
```
plt.plot(accuracy_track['training'], label='training')
plt.plot(accuracy_track['validation'], label='validation')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.grid()
plt.legend()
```

```
<matplotlib.legend.Legend at 0x7f9f1d275510>
```




```
import matplotlib.pyplot as plt
%matplotlib inline
```

```
import warnings
warnings.filterwarnings("ignore")

def predict_image(img, model):
    # Преобразование to a batch of 1
    xb = img.unsqueeze(0).to(device)
    # Получение прогнозов от модели
    yb = model(xb)
    # Выбираем индекс с наибольшей вероятностью
    _, preds  = torch.max(yb, dim=1)
    # Получение метки класса
    return dataset.classes[preds[0].item()]

for i in range(1,10):
  img, label = val_set[i]
  plt.imshow(img.clip(0,1).permute(1, 2, 0))
  plt.axis('off')
  plt.title('Label: {}, Predicted: {}'.format(dataset.classes[label],
predict_image(img, model)))
  plt.show()
  # print('Label:', dataset.classes[label], ',Predicted:',
predict_image(img, ______))
```



Label: sunflower, Predicted: sunflower

Label: sunflower, Predicted: sunflower

Label: dandelion, Predicted: dandelion

Label: sunflower, Predicted: sunflower

Label: rose, Predicted: rose

Label: daisy, Predicted: daisy

Label: sunflower, Predicted: sunflower

Label: rose, Predicted: rose

По желанию, можно сохранить веса модели.

```
weights_fname = '/content/drive/My Drive/data/***___**.pth'
torch.save(model.state_dict(), weights_fname)
```

Вопросы.

Как работает выбранная вами модель сверточной нейронной сети? Какие параметры?

В чем основные отличия между сверточной нейронной сетью и "обычной" полносвязной нейронной сетью?

Что такое transfer learning?

Что такое функция для заморозки весов модели?

Ответы на вопросы:

1. Сначала объясню мотивацию выбора модели. Почитал про несколько из них на сайте pyTorch. Позже узнал, у друга, что тот использовал alexnet в сравнении с resnet, поэтому данные две модели решил не использовать, а попробовать другие. Выполнил лабу для модели vgg, результаты получились чуть хуже, чем у представленной в отчете модели. Связываю с тем, что документация по vgg предлагает ее использовать для крупномасштабных изображений, а наш датасет из 4000 картинов занимает всего ~300 мб, поэтому вряд ли их можно отнести к такой категории. Далее я наткнулся на модель DenseNet и увидел в описании следующие ее преимущества:

   a) Сильный градиентный поток - показалось полезным, так как функция градиента используется в лабе

   b) Параметр и вычислительная эффективность - показалось полезным лично для меня из-за жадности Google, который два дня урезал мне ресурсы для GPU или не давал подключиться вовсе. Практика показала, что без GPU успеть обучить сеть и уложиться в дедлайны невозможно. Кроме того, последний месяц стабильно пару раз в день прохожу reCaptcha когда просто что-то гуглю, поэтому хотелось обучить все скорее, пока GPU работает.

   c) Разнообразие функций

   d) Поддерживает функции низкой сложности

Перечисленные 4 преимущества убедили меня остановить выбор на данной сверточной сети. Принцип ее работы - в увеличении уровня абстракций (как и в целом у сверточных сетей). При проходе через каждый слой сеть выделяет наиболее значимые, на ее взгляд, характеристики, которые объядиняет в более крупные сущности, отсекая незначительные элементы (т.е. "сворачивает" сеть). Таким образом, с каждым слоем определить требуемую характеристику становится все проще. В DenseNet же каждый слой получает карту характеристик со всех предыдущих слоев, а не с 1 предыдущего, что позволяет сделать сеть тоньше и компактнее - слоев меньше, меньше кол-во каналов, быстрее обучится => более высокая вычислительная эффективность и эффективность памяти, что мне и понравилось. Традиционные сверточные сети с L слоями имеют L соединений между каждым слоем и

его последующими слоями, в то время как сеть DenseNet имеет L (L + 1)/ 2 прямых соединений. Для каждого слоя в качестве входных данных используются карты характеристик всех предыдущих слоев, а его собственные карты характеристик также используются в качестве входных данных для всех последующих слоев. Параметры схожи с описанными в примере выполнения лабораторной работы, однако менять последний слой нужно в атрибуте classifier. Почему именно в нем - видно из описания модели. Кроме того, количество входных параметров нужно подгонять под параметры модели, чтобы не возникло неприятных ошибок в виде того, что входной и выходной слой с разнымии параметрами не сочетаются. В этом была основная сложность работы.

1. Отличия частично уже описал, но можно сказать еще раз: отличие полносвязных нейросетей в том, что они не выделяют абстракции от слоя к слою, а прогоняют через себя данные "как есть".
2. Transfer Learning (трансферное обучение) — это подраздел машинного обучения, целью которого является применение знаний, полученные из одной задачи, к другой целевой задаче.
3. Функция заморозки весов модели - функция, позволяющая "зафиксировать" веса некоторых элементов и исключить эти элементы из общего перестроения всей модели в будущем. Поэтому она и используется в концепции предобучения нейросетей.

Выводы: в ходе проделанной работы я ознакомился с принципами работы сверточных нейронных сетей, а так же узнал, что выполнение лабораторной работы может зависеть не только от меня, но и от наличия снисхождения алгоритмов Google к выделению мне ресурсов видеокарты.