```
pip install torchviz
```

```
Collecting torchviz
  Downloading torchviz-0.0.2.tar.gz (4.9 kB)
  Preparing metadata (setup.py) ... ent already satisfied: torch in
/usr/local/lib/python3.10/dist-packages (from torchviz) (2.1.0+cu118)
Requirement already satisfied: graphviz in
/usr/local/lib/python3.10/dist-packages (from torchviz) (0.20.1)
Requirement already satisfied: filelock in
/usr/local/lib/python3.10/dist-packages (from torch->torchviz)
(3.13.1)
Requirement already satisfied: typing-extensions in
/usr/local/lib/python3.10/dist-packages (from torch->torchviz) (4.5.0)
Requirement already satisfied: sympy in
/usr/local/lib/python3.10/dist-packages (from torch->torchviz) (1.12)
Requirement already satisfied: networkx in
/usr/local/lib/python3.10/dist-packages (from torch->torchviz) (3.2.1)
Requirement already satisfied: jinja2 in
/usr/local/lib/python3.10/dist-packages (from torch->torchviz) (3.1.2)
Requirement already satisfied: fsspec in
/usr/local/lib/python3.10/dist-packages (from torch->torchviz)
(2023.6.0)
Requirement already satisfied: triton==2.1.0 in
/usr/local/lib/python3.10/dist-packages (from torch->torchviz) (2.1.0)
Requirement already satisfied: MarkupSafe>=2.0 in
/usr/local/lib/python3.10/dist-packages (from jinja2->torch->torchviz)
(2.1.3)
Requirement already satisfied: mpmath>=0.19 in
/usr/local/lib/python3.10/dist-packages (from sympy->torch->torchviz)
(1.3.0)
Building wheels for collected packages: torchviz
  Building wheel for torchviz (setup.py) ... e=torchviz-0.0.2-py3-
none-any.whl size=4133
sha256=b8d750eb8290d20c86e90cb55bc60b83bc41974fa622440a0e960df35c3acd4
4
  Stored in directory:
/root/.cache/pip/wheels/4c/97/88/a02973217949e0db0c9f4346d154085f4725f
99c4f15a87094
Successfully built torchviz
Installing collected packages: torchviz
Successfully installed torchviz-0.0.2
```

```python
import multiprocessing as mp
import time
from typing import Any, Generator, Literal
import os
import torch
import torchvision
import torchvision.datasets
import torchvision.transforms
import torch.utils.data
import torch.nn

from torchvision import models as torch_model
import seaborn as sns
from torchviz import make_dot
from IPython.display import display
import time
from torchsummary import summary
from matplotlib import pyplot as plot

device = torch.device("cuda:0" if torch.cuda.is_available() else
"cpu")
device
```

```
device(type='cuda', index=0)
```

```
CLASSES = ['plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog',
'horse', 'ship', 'truck']
N_CLASSES = len(CLASSES)

def show_images(images, title):
    num_showed_imgs_x = 10
    num_showed_imgs_y = 10

    figsize = (10, 10)
    fig, axes = plot.subplots(num_showed_imgs_y, num_showed_imgs_x,
figsize = figsize)
    fig.suptitle(title)
    plot.setp(plot.gcf().get_axes(), xticks = [], yticks = [])
    dataiter = iter(images)
    for i, ax in enumerate(axes.flat):
        img = images[i][0].numpy().transpose(1, 2, 0)
        ax.imshow(img)
        ax.text(1, 1, CLASSES[images[i][1]], bbox=dict(fill=False,
edgecolor='red', linewidth=2))

def download_data(transforms, batch_size):
  dir_name = os.getcwd()

  train_dataset = torchvision.datasets.CIFAR10(
      root = dir_name, train = True, download = True,
      transform = transforms
  )
  test_dataset = torchvision.datasets.CIFAR10(
      root = dir_name, train = False, download = True,
      transform = transforms
  )

  print('Number of train samples: {}'.format(len(train_dataset)))
  show_images(train_dataset, 'Train samples')
  print('Number of test samples: {}'.format(len(test_dataset)))
  show_images(test_dataset, 'Test samples')

  train_data_loader = torch.utils.data.DataLoader(
      train_dataset, batch_size = batch_size, shuffle = True
  )
  test_data_loader = torch.utils.data.DataLoader(
      test_dataset, batch_size = batch_size, shuffle = False
  )
  return train_data_loader, test_data_loader

num_epochs = 20

def get_accuracy(data_loader, model):
    tp = 0
    n = 0
    with torch.no_grad():
        for images, labels in data_loader:
            labels = labels.to(device)
            images = images.to(device)
            outputs = model(images)
            _, predicted = torch.max(outputs.data, 1)
            n += labels.size(0)
            tp += (predicted == labels).sum()
    return tp / n

def train_loop(model, train_dataloader, optimizer, loss_function):
  start_all = time.time()
  for epoch in range(num_epochs):
      start = time.time()
      for images, labels in train_dataloader:
          images = images.to(device)
          labels = labels.to(device)

          outputs = model(images)
          loss = loss_function(outputs.type(torch.float32),
torch.nn.functional.one_hot(labels,
num_classes=10).type(torch.float32))

          optimizer.zero_grad()
          loss.backward()
          optimizer.step()
      end = time.time()
      print('Epoch[{}]: accuracy = {}, time = {}'.format(epoch,
get_accuracy(train_dataloader, model), (end - start)))
  end_all = time.time()
  print('train time = {}'.format((end_all - start_all)))
  # yield model
```

```python
def test_model(model, test_dataloader):
  model.eval()
  print('Test accuracy: {}'.format(get_accuracy(test_dataloader,
model)))
  # yield model
```

Modifications:

```python
def last_layer(in_features):
  return torch.nn.Linear(in_features, 10)

def last_sequental_layer(in_features):
  return torch.nn.Sequential(
      torch.nn.Linear(in_features, in_features//2),
      torch.nn.ReLU(),
      torch.nn.Linear(in_features//2, 10),
      )

def init_weights(model):
  print(model)
  if type(model) == torch.nn.Linear:
    torch.nn.init.xavier_uniform_(model.weight)
    print(model.weight)
```

1. ResNet18
1. Single layer

```python
model = torch_model.resnet18(torch_model.ResNet18_Weights.DEFAULT)
```

```
/usr/local/lib/python3.10/dist-packages/torchvision/models/
_utils.py:135: UserWarning: Using 'weights' as positional parameter(s)
is deprecated since 0.13 and may be removed in the future. Please use
keyword parameter(s) instead.
  warnings.warn(
```

```python
# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))
```

```
Модель "CNN":
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1           [-1, 64, 16, 16]           9,408
       BatchNorm2d-2           [-1, 64, 16, 16]             128
              ReLU-3           [-1, 64, 16, 16]               0
         MaxPool2d-4            [-1, 64, 8, 8]               0
            Conv2d-5            [-1, 64, 8, 8]          36,864
       BatchNorm2d-6            [-1, 64, 8, 8]             128
              ReLU-7            [-1, 64, 8, 8]               0
            Conv2d-8            [-1, 64, 8, 8]          36,864
       BatchNorm2d-9            [-1, 64, 8, 8]             128
             ReLU-10            [-1, 64, 8, 8]               0
       BasicBlock-11            [-1, 64, 8, 8]               0
           Conv2d-12            [-1, 64, 8, 8]          36,864
      BatchNorm2d-13            [-1, 64, 8, 8]             128
             ReLU-14            [-1, 64, 8, 8]               0
           Conv2d-15            [-1, 64, 8, 8]          36,864
      BatchNorm2d-16            [-1, 64, 8, 8]             128
             ReLU-17            [-1, 64, 8, 8]               0
       BasicBlock-18            [-1, 64, 8, 8]               0
           Conv2d-19           [-1, 128, 4, 4]          73,728
      BatchNorm2d-20           [-1, 128, 4, 4]             256
             ReLU-21           [-1, 128, 4, 4]               0
           Conv2d-22           [-1, 128, 4, 4]         147,456
      BatchNorm2d-23           [-1, 128, 4, 4]             256
           Conv2d-24           [-1, 128, 4, 4]           8,192
      BatchNorm2d-25           [-1, 128, 4, 4]             256
             ReLU-26           [-1, 128, 4, 4]               0
       BasicBlock-27           [-1, 128, 4, 4]               0
           Conv2d-28           [-1, 128, 4, 4]         147,456
      BatchNorm2d-29           [-1, 128, 4, 4]             256
             ReLU-30           [-1, 128, 4, 4]               0
           Conv2d-31           [-1, 128, 4, 4]         147,456
      BatchNorm2d-32           [-1, 128, 4, 4]             256
             ReLU-33           [-1, 128, 4, 4]               0
       BasicBlock-34           [-1, 128, 4, 4]               0
           Conv2d-35           [-1, 256, 2, 2]         294,912
      BatchNorm2d-36           [-1, 256, 2, 2]             512
             ReLU-37           [-1, 256, 2, 2]               0
           Conv2d-38           [-1, 256, 2, 2]         589,824
      BatchNorm2d-39           [-1, 256, 2, 2]             512
           Conv2d-40           [-1, 256, 2, 2]          32,768
      BatchNorm2d-41           [-1, 256, 2, 2]             512
             ReLU-42           [-1, 256, 2, 2]               0
       BasicBlock-43           [-1, 256, 2, 2]               0
           Conv2d-44           [-1, 256, 2, 2]         589,824
      BatchNorm2d-45           [-1, 256, 2, 2]             512
             ReLU-46           [-1, 256, 2, 2]               0
           Conv2d-47           [-1, 256, 2, 2]         589,824
      BatchNorm2d-48           [-1, 256, 2, 2]             512
             ReLU-49           [-1, 256, 2, 2]               0
       BasicBlock-50           [-1, 256, 2, 2]               0
           Conv2d-51           [-1, 512, 1, 1]       1,179,648
      BatchNorm2d-52           [-1, 512, 1, 1]           1,024
```

```
             ReLU-53            [-1, 512, 1, 1]               0
           Conv2d-54            [-1, 512, 1, 1]       2,359,296
      BatchNorm2d-55            [-1, 512, 1, 1]           1,024
           Conv2d-56            [-1, 512, 1, 1]         131,072
      BatchNorm2d-57            [-1, 512, 1, 1]           1,024
             ReLU-58            [-1, 512, 1, 1]               0
       BasicBlock-59            [-1, 512, 1, 1]               0
           Conv2d-60            [-1, 512, 1, 1]       2,359,296
      BatchNorm2d-61            [-1, 512, 1, 1]           1,024
             ReLU-62            [-1, 512, 1, 1]               0
           Conv2d-63            [-1, 512, 1, 1]       2,359,296
      BatchNorm2d-64            [-1, 512, 1, 1]           1,024
             ReLU-65            [-1, 512, 1, 1]               0
       BasicBlock-66            [-1, 512, 1, 1]               0
AdaptiveAvgPool2d-67            [-1, 512, 1, 1]               0
           Linear-68                 [-1, 1000]         513,000
================================================================
Total params: 11,689,512
Trainable params: 11,689,512
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.01
Forward/backward pass size (MB): 1.29
Params size (MB): 44.59
Estimated Total Size (MB): 45.90
----------------------------------------------------------------
Визуализация модели:
```

```python
for param in model.parameters():
    param.requires_grad = False
model.fc = last_layer(512)
model = model.to(device)

transforms = torch_model.ResNet18_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)
```

```
Files already downloaded and verified
Files already downloaded and verified
Number of train samples: 50000
```

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```
Number of test samples: 10000
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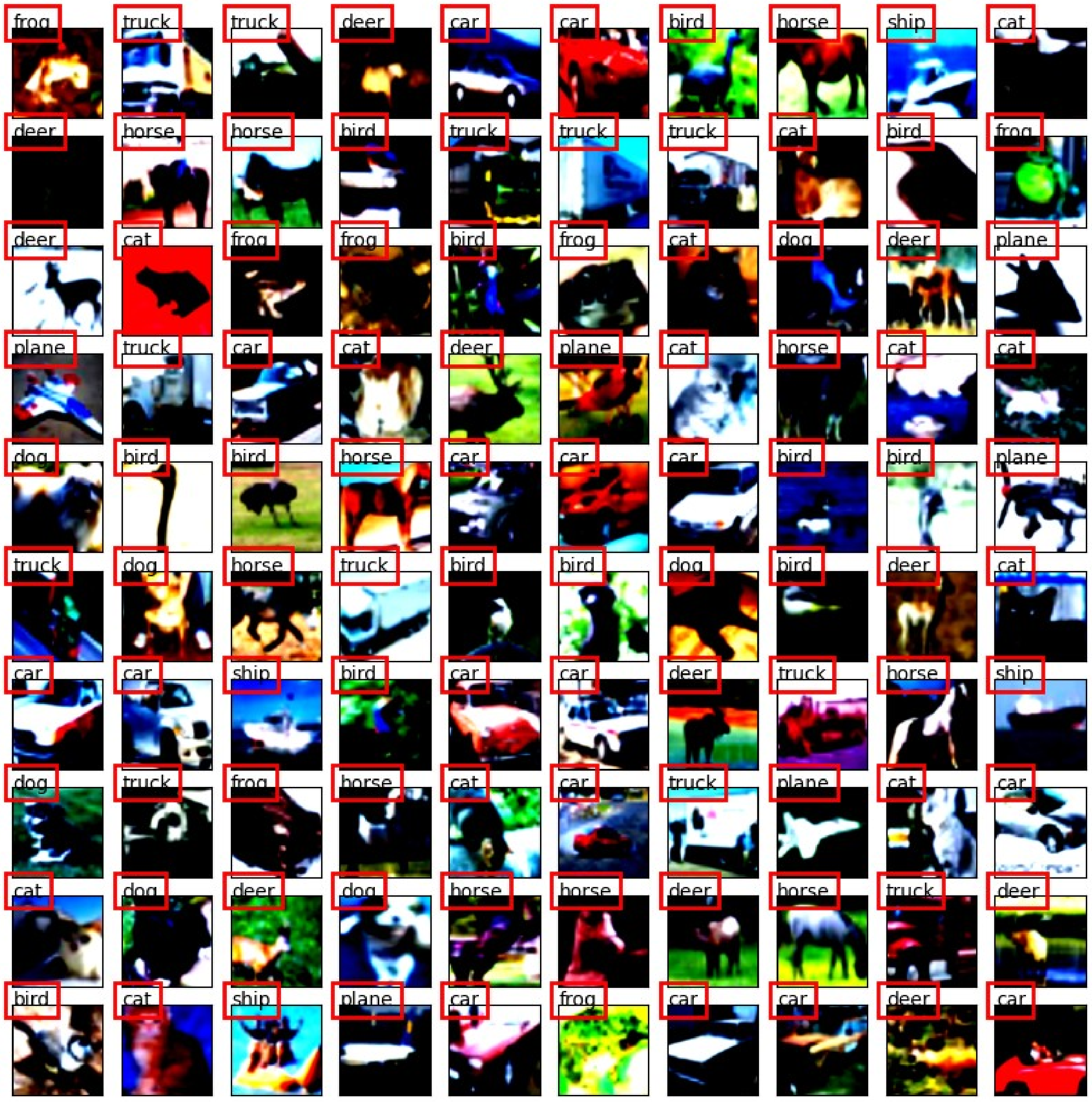
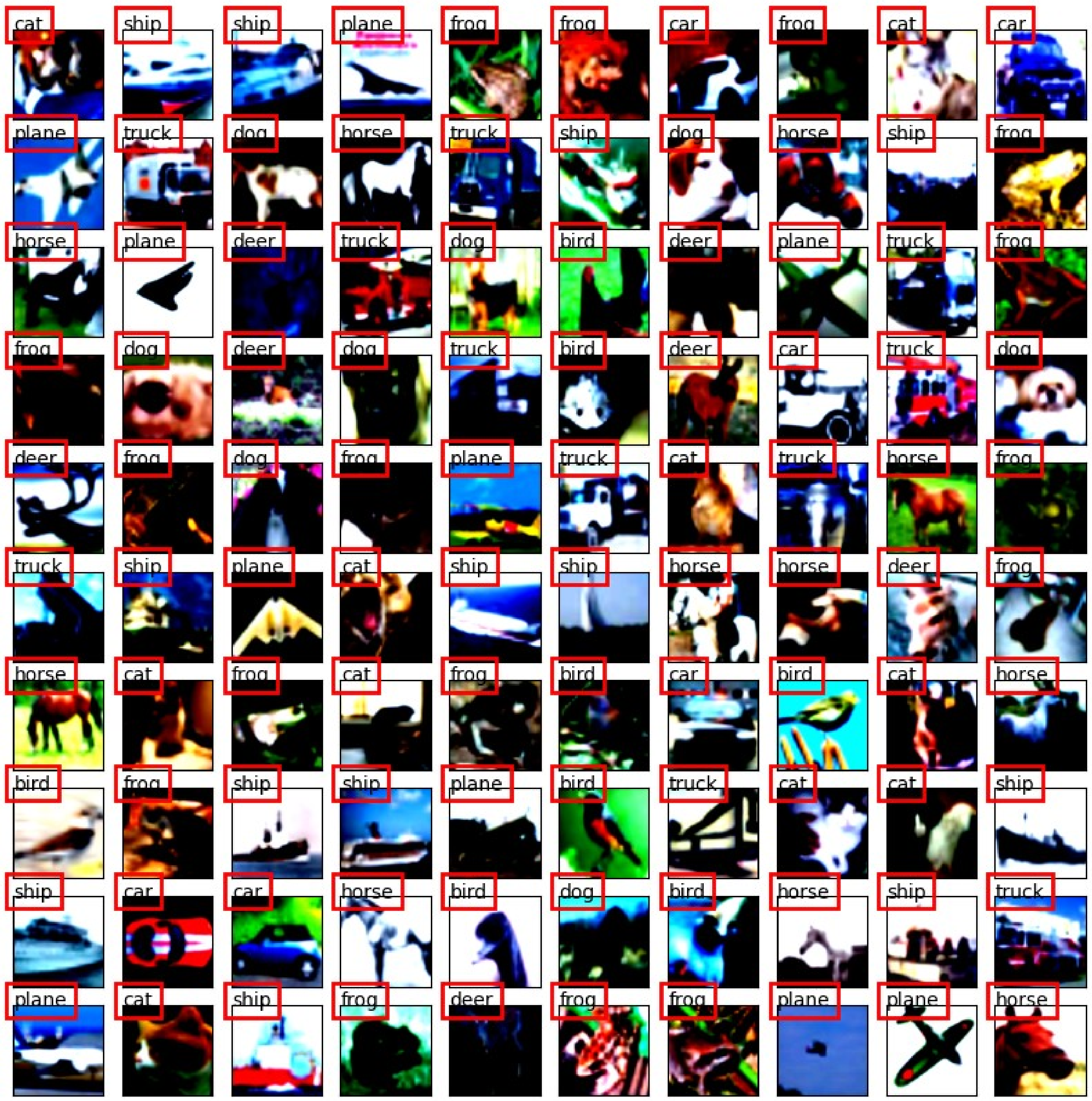
```

Train samples



Test samples



```
learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.fc.parameters(), lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)
```

```
Epoch[0]: accuracy = 0.7552199959754944, time = 134.36429405212402
Epoch[1]: accuracy = 0.7705399990081787, time = 133.38727378845215
```

```
Epoch[2]: accuracy = 0.7748799920082092, time = 134.6206178665161
Epoch[3]: accuracy = 0.7821799516677856, time = 133.35160636901855
Epoch[4]: accuracy = 0.7877799868583679, time = 132.4030101299286
Epoch[5]: accuracy = 0.7893799543380737, time = 130.85477805137634
Epoch[6]: accuracy = 0.7927199602127075, time = 132.90481090545654
Epoch[7]: accuracy = 0.7902599573135376, time = 133.37981700897217
Epoch[8]: accuracy = 0.792739987373352, time = 138.0912709236145
Epoch[9]: accuracy = 0.7948399782180786, time = 140.2856011390686
Epoch[10]: accuracy = 0.7905199527740479, time = 133.56772112846375
Epoch[11]: accuracy = 0.7960399985313416, time = 132.52500438690186
Epoch[12]: accuracy = 0.7979399561882019, time = 131.02950859069824
Epoch[13]: accuracy = 0.799519956111908, time = 132.790180683136
Epoch[14]: accuracy = 0.800279974937439, time = 132.8993923664093
Epoch[15]: accuracy = 0.800059974193573, time = 133.1646978855133
Epoch[16]: accuracy = 0.8001199960708618, time = 133.71345162391663
Epoch[17]: accuracy = 0.7939800024032593, time = 133.75645112991333
Epoch[18]: accuracy = 0.8032400012016296, time = 132.00247764587402
Epoch[19]: accuracy = 0.8007599711418152, time = 130.65841007232666
train time = 5328.962197542191
```

```
test_model(model, test_dataloader)
```

```
Test accuracy: 0.7849000096321106
```

```
print(model)
```

```
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=10, bias=True)
)
```

1. Sequental layer

```
model = torch_model.resnet18(torch_model.ResNet18_Weights.DEFAULT)

/usr/local/lib/python3.10/dist-packages/torchvision/models/
_utils.py:135: UserWarning: Using 'weights' as positional parameter(s)
is deprecated since 0.13 and may be removed in the future. Please use
keyword parameter(s) instead.
  warnings.warn(

# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))

Модель "CNN":
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1           [-1, 64, 16, 16]           9,408
       BatchNorm2d-2           [-1, 64, 16, 16]             128
              ReLU-3           [-1, 64, 16, 16]               0
         MaxPool2d-4             [-1, 64, 8, 8]               0
            Conv2d-5             [-1, 64, 8, 8]          36,864
       BatchNorm2d-6             [-1, 64, 8, 8]             128
              ReLU-7             [-1, 64, 8, 8]               0
            Conv2d-8             [-1, 64, 8, 8]          36,864
       BatchNorm2d-9             [-1, 64, 8, 8]             128
             ReLU-10             [-1, 64, 8, 8]               0
       BasicBlock-11             [-1, 64, 8, 8]               0
           Conv2d-12             [-1, 64, 8, 8]          36,864
      BatchNorm2d-13             [-1, 64, 8, 8]             128
             ReLU-14             [-1, 64, 8, 8]               0
           Conv2d-15             [-1, 64, 8, 8]          36,864
      BatchNorm2d-16             [-1, 64, 8, 8]             128
             ReLU-17             [-1, 64, 8, 8]               0
       BasicBlock-18             [-1, 64, 8, 8]               0
           Conv2d-19            [-1, 128, 4, 4]          73,728
      BatchNorm2d-20            [-1, 128, 4, 4]             256
             ReLU-21            [-1, 128, 4, 4]               0
           Conv2d-22            [-1, 128, 4, 4]         147,456
      BatchNorm2d-23            [-1, 128, 4, 4]             256
           Conv2d-24            [-1, 128, 4, 4]           8,192
      BatchNorm2d-25            [-1, 128, 4, 4]             256
             ReLU-26            [-1, 128, 4, 4]               0
       BasicBlock-27            [-1, 128, 4, 4]               0
           Conv2d-28            [-1, 128, 4, 4]         147,456
      BatchNorm2d-29            [-1, 128, 4, 4]             256
             ReLU-30            [-1, 128, 4, 4]               0
           Conv2d-31            [-1, 128, 4, 4]         147,456
      BatchNorm2d-32            [-1, 128, 4, 4]             256
             ReLU-33            [-1, 128, 4, 4]               0
       BasicBlock-34            [-1, 128, 4, 4]               0
           Conv2d-35            [-1, 256, 2, 2]         294,912
      BatchNorm2d-36            [-1, 256, 2, 2]             512
             ReLU-37            [-1, 256, 2, 2]               0
           Conv2d-38            [-1, 256, 2, 2]         589,824
      BatchNorm2d-39            [-1, 256, 2, 2]             512
           Conv2d-40            [-1, 256, 2, 2]          32,768
      BatchNorm2d-41            [-1, 256, 2, 2]             512
             ReLU-42            [-1, 256, 2, 2]               0
       BasicBlock-43            [-1, 256, 2, 2]               0
           Conv2d-44            [-1, 256, 2, 2]         589,824
      BatchNorm2d-45            [-1, 256, 2, 2]             512
             ReLU-46            [-1, 256, 2, 2]               0
           Conv2d-47            [-1, 256, 2, 2]         589,824
      BatchNorm2d-48            [-1, 256, 2, 2]             512
             ReLU-49            [-1, 256, 2, 2]               0
       BasicBlock-50            [-1, 256, 2, 2]               0
           Conv2d-51            [-1, 512, 1, 1]       1,179,648
      BatchNorm2d-52            [-1, 512, 1, 1]           1,024
             ReLU-53            [-1, 512, 1, 1]               0
           Conv2d-54            [-1, 512, 1, 1]       2,359,296
      BatchNorm2d-55            [-1, 512, 1, 1]           1,024
           Conv2d-56            [-1, 512, 1, 1]         131,072
      BatchNorm2d-57            [-1, 512, 1, 1]           1,024
             ReLU-58            [-1, 512, 1, 1]               0
       BasicBlock-59            [-1, 512, 1, 1]               0
           Conv2d-60            [-1, 512, 1, 1]       2,359,296
      BatchNorm2d-61            [-1, 512, 1, 1]           1,024
             ReLU-62            [-1, 512, 1, 1]               0
           Conv2d-63            [-1, 512, 1, 1]       2,359,296
      BatchNorm2d-64            [-1, 512, 1, 1]           1,024
             ReLU-65            [-1, 512, 1, 1]               0
       BasicBlock-66            [-1, 512, 1, 1]               0
AdaptiveAvgPool2d-67            [-1, 512, 1, 1]               0
           Linear-68                 [-1, 1000]         513,000
================================================================
Total params: 11,689,512
Trainable params: 11,689,512
Non-trainable params: 0
----------------------------------------------------------------
```

```
Input size (MB): 0.01
Forward/backward pass size (MB): 1.29
Params size (MB): 44.59
Estimated Total Size (MB): 45.90
----------------------------------------------------------------
Визуализация модели:
```

```
for param in model.parameters():
    param.requires_grad = False
model.fc = last_sequental_layer(512)
model = model.to(device)

print(model)
```

```
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): Sequential(
    (0): Linear(in_features=512, out_features=256, bias=True)
    (1): ReLU()
    (2): Linear(in_features=256, out_features=10, bias=True)
  )
)
```

```
transforms = torch_model.ResNet18_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)
```

```
Files already downloaded and verified
Files already downloaded and verified
Number of train samples: 50000
```

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```
Number of test samples: 10000
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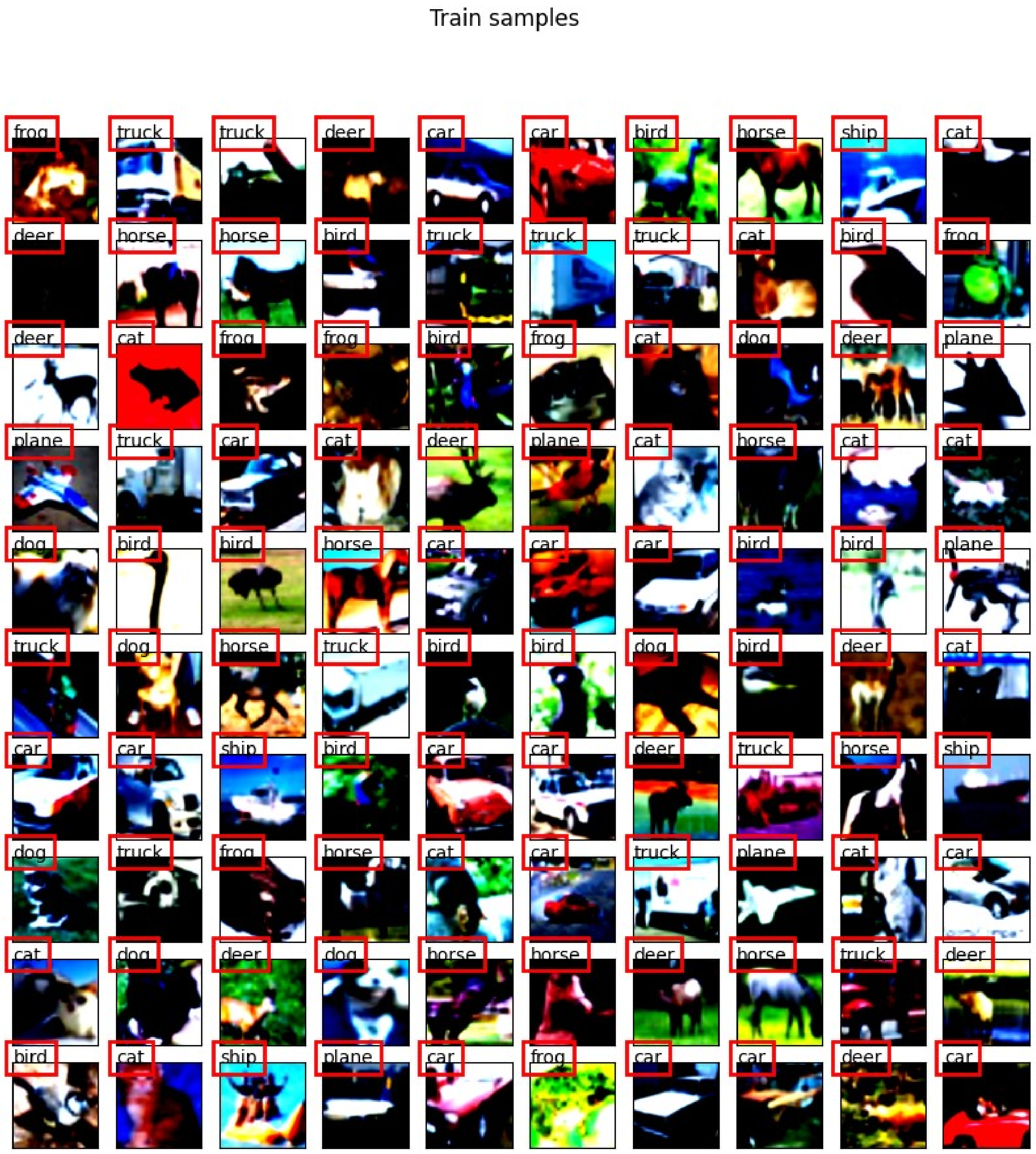
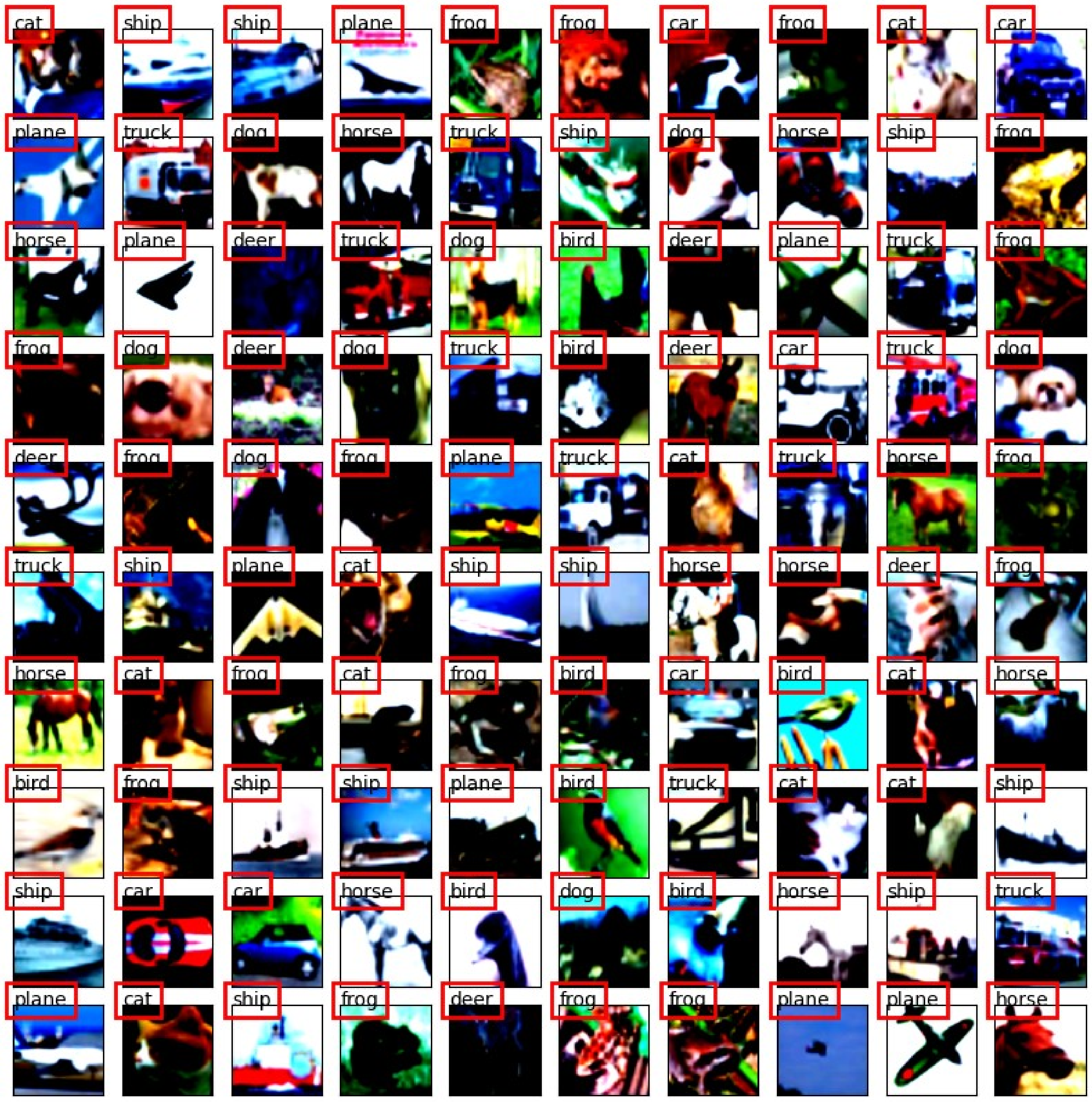
```


Train samples
frog truck truck deer car car bird horse ship cat
deer horse horse bird truck truck truck cat bird frog
deer cat frog frog bird frog cat dog deer plane
plane truck car cat deer plane cat horse cat cat
dog bird bird horse car car car bird bird plane
truck dog horse truck bird bird dog bird deer cat
car car ship bird car car deer truck horse ship
dog truck frog horse cat car truck plane cat car
cat dog deer dog horse horse deer horse truck deer
bird cat ship plane car frog car car deer car

Test samples



```
learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.fc.parameters(), lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)

Epoch[0]: accuracy = 0.7584599852561951, time = 133.47190737724304
Epoch[1]: accuracy = 0.7836199998855591, time = 134.56931257247925
```

```
Epoch[2]: accuracy = 0.7912200093269348, time = 131.76579809188843
Epoch[3]: accuracy = 0.7971199750900269, time = 132.62603068351746
Epoch[4]: accuracy = 0.7963399887084961, time = 132.72239804267883
Epoch[5]: accuracy = 0.8087999820709229, time = 132.0856158733368
Epoch[6]: accuracy = 0.817799985408783, time = 133.8889524936676
Epoch[7]: accuracy = 0.8195199966430664, time = 133.67858791351318
Epoch[8]: accuracy = 0.8260399699211121, time = 134.11023926734924
Epoch[9]: accuracy = 0.8386799693107605, time = 134.24782919883728
Epoch[10]: accuracy = 0.8505199551582336, time = 133.9661843776703
Epoch[11]: accuracy = 0.8570999503135681, time = 133.6306209564209
Epoch[12]: accuracy = 0.8524199724197388, time = 136.24574303627014
Epoch[13]: accuracy = 0.8709399700164795, time = 133.86288475990295
Epoch[14]: accuracy = 0.8695600032806396, time = 132.84558701515198
Epoch[15]: accuracy = 0.870959997177124, time = 134.21223258972168
Epoch[16]: accuracy = 0.8806599974632263, time = 133.45714831352234
Epoch[17]: accuracy = 0.878879964351654, time = 133.20917320251465
Epoch[18]: accuracy = 0.8874199986457825, time = 133.56253910064697
Epoch[19]: accuracy = 0.8967399597167969, time = 134.24799370765686
train time = 5326.537646770477
```

```
test_model(model, test_dataloader)
```

```
Test accuracy: 0.7937999963760376
```

1. Weights

```
model = torch_model.resnet18(torch_model.ResNet18_Weights.DEFAULT)
```

```
/usr/local/lib/python3.10/dist-packages/torchvision/models/
_utils.py:135: UserWarning: Using 'weights' as positional parameter(s)
is deprecated since 0.13 and may be removed in the future. Please use
keyword parameter(s) instead.
  warnings.warn(
Downloading: "https://download.pytorch.org/models/resnet18-
f37072fd.pth" to /root/.cache/torch/hub/checkpoints/resnet18-
f37072fd.pth
100%|██████████| 44.7M/44.7M [00:00<00:00, 85.8MB/s]
```

```
# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))
```

```
Модель "CNN":
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1           [-1, 64, 16, 16]           9,408
```

```
       BatchNorm2d-2           [-1, 64, 16, 16]             128
              ReLU-3           [-1, 64, 16, 16]               0
         MaxPool2d-4             [-1, 64, 8, 8]               0
            Conv2d-5             [-1, 64, 8, 8]          36,864
       BatchNorm2d-6             [-1, 64, 8, 8]             128
              ReLU-7             [-1, 64, 8, 8]               0
            Conv2d-8             [-1, 64, 8, 8]          36,864
       BatchNorm2d-9             [-1, 64, 8, 8]             128
             ReLU-10             [-1, 64, 8, 8]               0
       BasicBlock-11             [-1, 64, 8, 8]               0
           Conv2d-12             [-1, 64, 8, 8]          36,864
      BatchNorm2d-13             [-1, 64, 8, 8]             128
             ReLU-14             [-1, 64, 8, 8]               0
           Conv2d-15             [-1, 64, 8, 8]          36,864
      BatchNorm2d-16             [-1, 64, 8, 8]             128
             ReLU-17             [-1, 64, 8, 8]               0
       BasicBlock-18             [-1, 64, 8, 8]               0
           Conv2d-19            [-1, 128, 4, 4]          73,728
      BatchNorm2d-20            [-1, 128, 4, 4]             256
             ReLU-21            [-1, 128, 4, 4]               0
           Conv2d-22            [-1, 128, 4, 4]         147,456
      BatchNorm2d-23            [-1, 128, 4, 4]             256
           Conv2d-24            [-1, 128, 4, 4]           8,192
      BatchNorm2d-25            [-1, 128, 4, 4]             256
             ReLU-26            [-1, 128, 4, 4]               0
       BasicBlock-27            [-1, 128, 4, 4]               0
           Conv2d-28            [-1, 128, 4, 4]         147,456
      BatchNorm2d-29            [-1, 128, 4, 4]             256
             ReLU-30            [-1, 128, 4, 4]               0
           Conv2d-31            [-1, 128, 4, 4]         147,456
      BatchNorm2d-32            [-1, 128, 4, 4]             256
             ReLU-33            [-1, 128, 4, 4]               0
       BasicBlock-34            [-1, 128, 4, 4]               0
           Conv2d-35            [-1, 256, 2, 2]         294,912
      BatchNorm2d-36            [-1, 256, 2, 2]             512
             ReLU-37            [-1, 256, 2, 2]               0
           Conv2d-38            [-1, 256, 2, 2]         589,824
      BatchNorm2d-39            [-1, 256, 2, 2]             512
           Conv2d-40            [-1, 256, 2, 2]          32,768
      BatchNorm2d-41            [-1, 256, 2, 2]             512
             ReLU-42            [-1, 256, 2, 2]               0
       BasicBlock-43            [-1, 256, 2, 2]               0
           Conv2d-44            [-1, 256, 2, 2]         589,824
      BatchNorm2d-45            [-1, 256, 2, 2]             512
             ReLU-46            [-1, 256, 2, 2]               0
           Conv2d-47            [-1, 256, 2, 2]         589,824
      BatchNorm2d-48            [-1, 256, 2, 2]             512
             ReLU-49            [-1, 256, 2, 2]               0
       BasicBlock-50            [-1, 256, 2, 2]               0
```

```
          Conv2d-51            [-1, 512, 1, 1]       1,179,648
     BatchNorm2d-52            [-1, 512, 1, 1]           1,024
            ReLU-53            [-1, 512, 1, 1]               0
          Conv2d-54            [-1, 512, 1, 1]       2,359,296
     BatchNorm2d-55            [-1, 512, 1, 1]           1,024
          Conv2d-56            [-1, 512, 1, 1]         131,072
     BatchNorm2d-57            [-1, 512, 1, 1]           1,024
            ReLU-58            [-1, 512, 1, 1]               0
      BasicBlock-59            [-1, 512, 1, 1]               0
          Conv2d-60            [-1, 512, 1, 1]       2,359,296
     BatchNorm2d-61            [-1, 512, 1, 1]           1,024
            ReLU-62            [-1, 512, 1, 1]               0
          Conv2d-63            [-1, 512, 1, 1]       2,359,296
     BatchNorm2d-64            [-1, 512, 1, 1]           1,024
            ReLU-65            [-1, 512, 1, 1]               0
      BasicBlock-66            [-1, 512, 1, 1]               0
AdaptiveAvgPool2d-67           [-1, 512, 1, 1]               0
          Linear-68                 [-1, 1000]         513,000
================================================================
Total params: 11,689,512
Trainable params: 11,689,512
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.01
Forward/backward pass size (MB): 1.29
Params size (MB): 44.59
Estimated Total Size (MB): 45.90
----------------------------------------------------------------
Визуализация модели:
```

```
for param in model.parameters():
    param.requires_grad = False
model.fc = last_layer(512)
model.fc.apply(init_weights)
model = model.to(device)
```

```
Linear(in_features=512, out_features=10, bias=True)
Parameter containing:
tensor([[-0.1054,  0.0083, -0.1061,  ...,  0.0543, -0.0405,  0.0225],
        [ 0.0455,  0.0606,  0.0152,  ...,  0.0355, -0.0918, -0.0505],
        [ 0.0220, -0.0252,  0.0451,  ..., -0.0400, -0.0598,  0.0342],
        ...,
        [-0.0165,  0.0279, -0.0334,  ...,  0.0920, -0.0008, -0.1010],
        [ 0.0982, -0.0545,  0.0046,  ...,  0.0712, -0.0628,  0.0117],
        [ 0.0011,  0.0164,  0.0395,  ...,  0.0753, -0.1057,  0.0034]],
       requires_grad=True)
```

```
transforms = torch_model.ResNet18_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)
```

```
Downloading https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz to
/content/cifar-10-python.tar.gz

100%|██████████| 170498071/170498071 [00:05<00:00, 31237559.94it/s]

Extracting /content/cifar-10-python.tar.gz to /content
Files already downloaded and verified
Number of train samples: 50000

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Number of test samples: 10000

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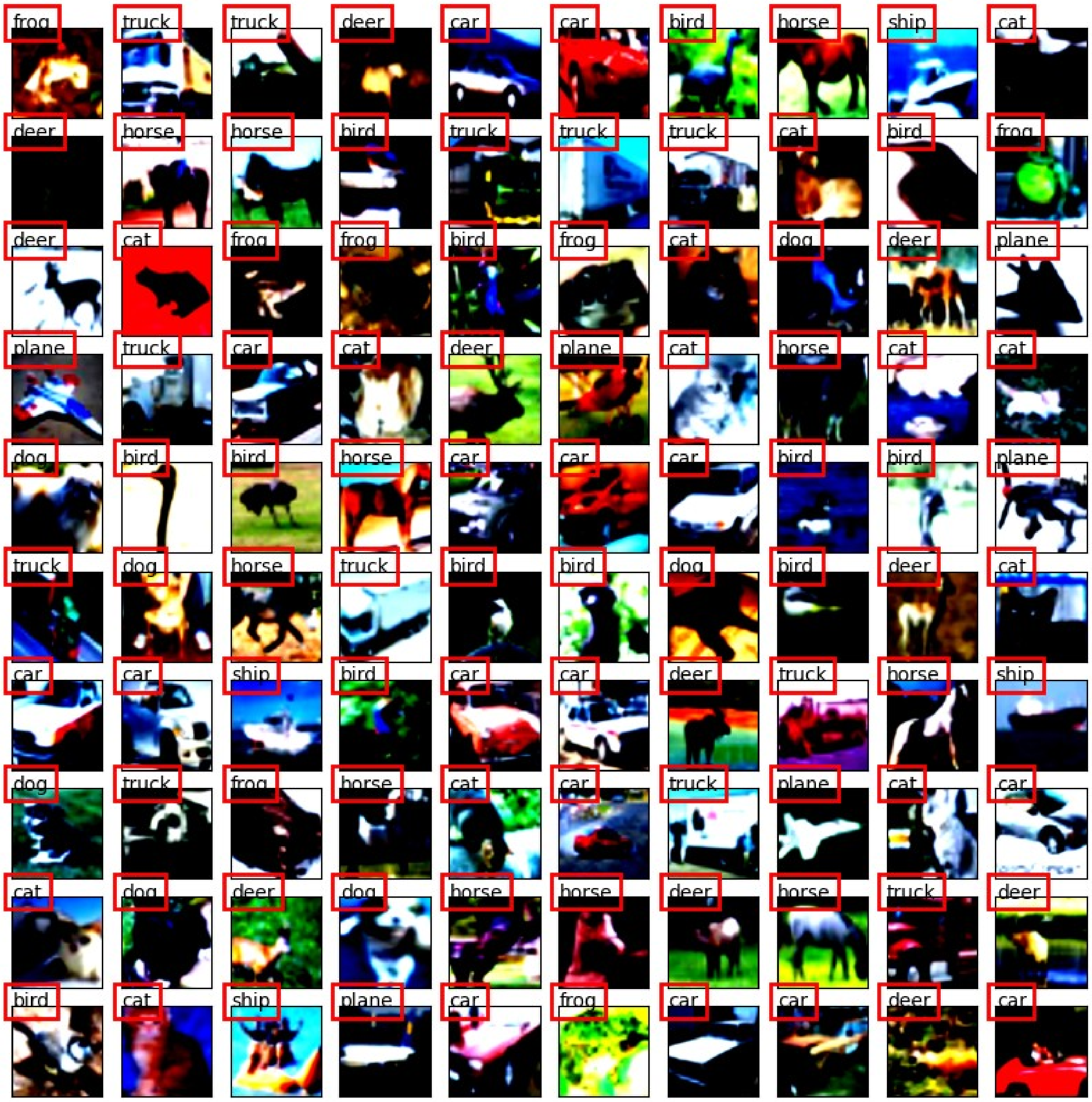
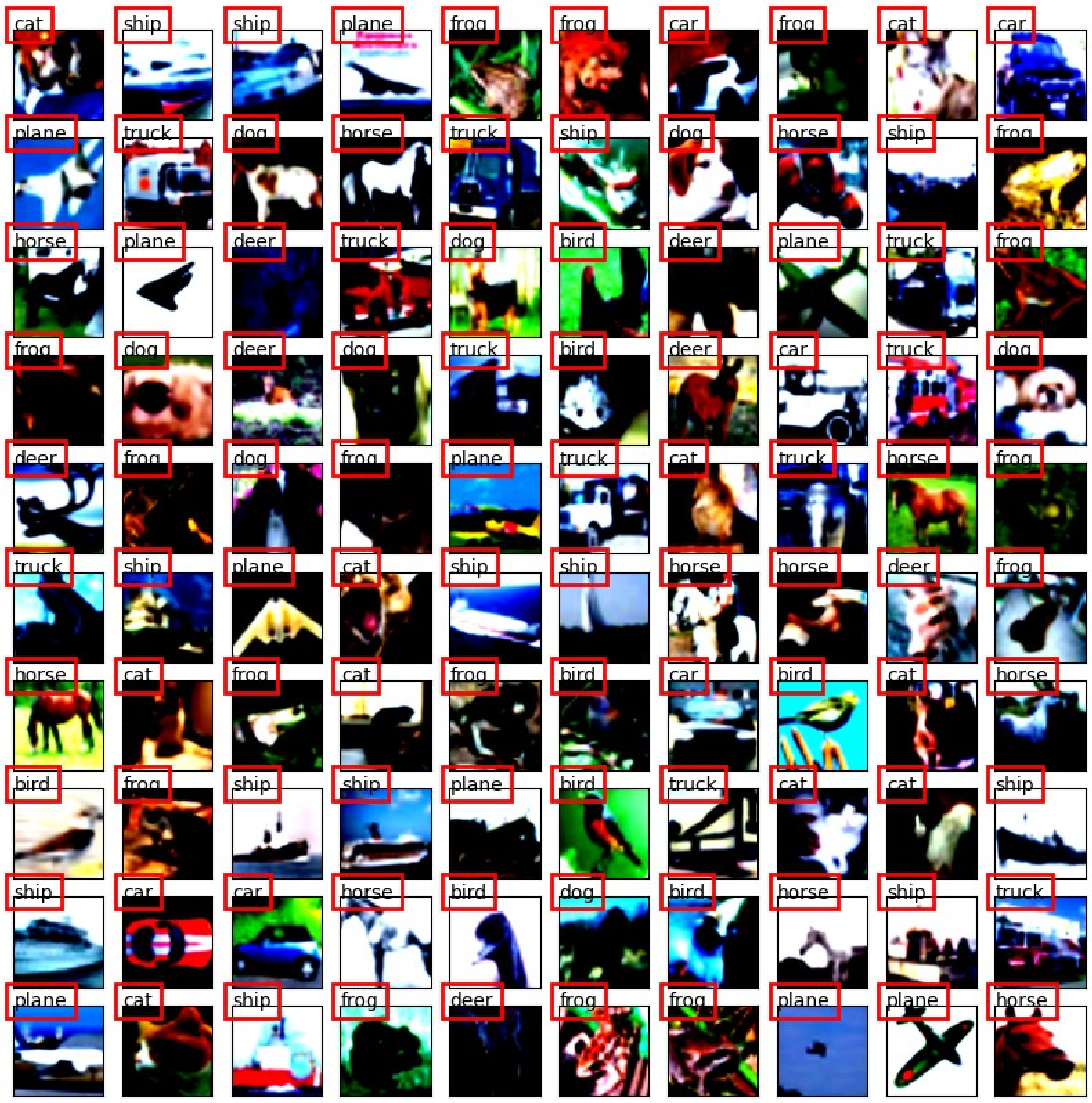
Train samples



Test samples



```
learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.fc.parameters(), lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)

Epoch[0]: accuracy = 0.7274599671363831, time = 134.01403093338013
Epoch[1]: accuracy = 0.7578799724578857, time = 134.17937111854553
```

```
Epoch[2]: accuracy = 0.7758399844169617, time = 136.39211130142212
Epoch[3]: accuracy = 0.7821199893951416, time = 133.69815516471863
Epoch[4]: accuracy = 0.7752799987792969, time = 136.0906012058258
Epoch[5]: accuracy = 0.7862199544906616, time = 136.01660108566284
Epoch[6]: accuracy = 0.7900999784469604, time = 133.74976420402527
Epoch[7]: accuracy = 0.7939800024032593, time = 134.50200629234314
Epoch[8]: accuracy = 0.7942599654197693, time = 134.31048798561096
Epoch[9]: accuracy = 0.7878999710083008, time = 135.3505744934082
Epoch[10]: accuracy = 0.7988199591636658, time = 135.93762755393982
Epoch[11]: accuracy = 0.79367995262146, time = 134.0378932952881
Epoch[12]: accuracy = 0.7895799875259399, time = 130.2157006263733
Epoch[13]: accuracy = 0.7952799797058105, time = 128.0634801387787
Epoch[14]: accuracy = 0.7955399751663208, time = 129.41853523254395
Epoch[15]: accuracy = 0.7999799847602844, time = 128.6872215270996
Epoch[16]: accuracy = 0.7971599698066711, time = 127.93745112419128
Epoch[17]: accuracy = 0.794160008430481, time = 129.3034646511078
Epoch[18]: accuracy = 0.7957800030708313, time = 129.42212867736816
Epoch[19]: accuracy = 0.7978799939155579, time = 129.11809086799622
train time = 5302.444882154465
```

```
test_model(model, test_dataloader)
```

```
Test accuracy: 0.7870999574661255
```

3*. Weights + Sequental

```
model = torch_model.resnet18(torch_model.ResNet18_Weights.DEFAULT)
```

```
/usr/local/lib/python3.10/dist-packages/torchvision/models/
_utils.py:135: UserWarning: Using 'weights' as positional parameter(s)
is deprecated since 0.13 and may be removed in the future. Please use
keyword parameter(s) instead.
  warnings.warn(
Downloading: "https://download.pytorch.org/models/resnet18-
f37072fd.pth" to /root/.cache/torch/hub/checkpoints/resnet18-
f37072fd.pth
100%|██████████| 44.7M/44.7M [00:00<00:00, 142MB/s]
```

```
# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))
```

```
Модель "CNN":
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1           [-1, 64, 16, 16]           9,408
       BatchNorm2d-2           [-1, 64, 16, 16]             128
              ReLU-3           [-1, 64, 16, 16]               0
         MaxPool2d-4             [-1, 64, 8, 8]               0
            Conv2d-5             [-1, 64, 8, 8]          36,864
       BatchNorm2d-6             [-1, 64, 8, 8]             128
              ReLU-7             [-1, 64, 8, 8]               0
            Conv2d-8             [-1, 64, 8, 8]          36,864
       BatchNorm2d-9             [-1, 64, 8, 8]             128
             ReLU-10             [-1, 64, 8, 8]               0
       BasicBlock-11             [-1, 64, 8, 8]               0
           Conv2d-12             [-1, 64, 8, 8]          36,864
      BatchNorm2d-13             [-1, 64, 8, 8]             128
             ReLU-14             [-1, 64, 8, 8]               0
           Conv2d-15             [-1, 64, 8, 8]          36,864
      BatchNorm2d-16             [-1, 64, 8, 8]             128
             ReLU-17             [-1, 64, 8, 8]               0
       BasicBlock-18             [-1, 64, 8, 8]               0
           Conv2d-19            [-1, 128, 4, 4]          73,728
      BatchNorm2d-20            [-1, 128, 4, 4]             256
             ReLU-21            [-1, 128, 4, 4]               0
           Conv2d-22            [-1, 128, 4, 4]         147,456
      BatchNorm2d-23            [-1, 128, 4, 4]             256
           Conv2d-24            [-1, 128, 4, 4]           8,192
      BatchNorm2d-25            [-1, 128, 4, 4]             256
             ReLU-26            [-1, 128, 4, 4]               0
       BasicBlock-27            [-1, 128, 4, 4]               0
           Conv2d-28            [-1, 128, 4, 4]         147,456
      BatchNorm2d-29            [-1, 128, 4, 4]             256
             ReLU-30            [-1, 128, 4, 4]               0
           Conv2d-31            [-1, 128, 4, 4]         147,456
      BatchNorm2d-32            [-1, 128, 4, 4]             256
             ReLU-33            [-1, 128, 4, 4]               0
       BasicBlock-34            [-1, 128, 4, 4]               0
           Conv2d-35            [-1, 256, 2, 2]         294,912
      BatchNorm2d-36            [-1, 256, 2, 2]             512
             ReLU-37            [-1, 256, 2, 2]               0
           Conv2d-38            [-1, 256, 2, 2]         589,824
      BatchNorm2d-39            [-1, 256, 2, 2]             512
           Conv2d-40            [-1, 256, 2, 2]          32,768
      BatchNorm2d-41            [-1, 256, 2, 2]             512
             ReLU-42            [-1, 256, 2, 2]               0
       BasicBlock-43            [-1, 256, 2, 2]               0
           Conv2d-44            [-1, 256, 2, 2]         589,824
      BatchNorm2d-45            [-1, 256, 2, 2]             512
             ReLU-46            [-1, 256, 2, 2]               0
           Conv2d-47            [-1, 256, 2, 2]         589,824
      BatchNorm2d-48            [-1, 256, 2, 2]             512
             ReLU-49            [-1, 256, 2, 2]               0
```

```
       BasicBlock-50            [-1, 256, 2, 2]               0
           Conv2d-51            [-1, 512, 1, 1]       1,179,648
      BatchNorm2d-52            [-1, 512, 1, 1]           1,024
             ReLU-53            [-1, 512, 1, 1]               0
           Conv2d-54            [-1, 512, 1, 1]       2,359,296
      BatchNorm2d-55            [-1, 512, 1, 1]           1,024
           Conv2d-56            [-1, 512, 1, 1]         131,072
      BatchNorm2d-57            [-1, 512, 1, 1]           1,024
             ReLU-58            [-1, 512, 1, 1]               0
       BasicBlock-59            [-1, 512, 1, 1]               0
           Conv2d-60            [-1, 512, 1, 1]       2,359,296
      BatchNorm2d-61            [-1, 512, 1, 1]           1,024
             ReLU-62            [-1, 512, 1, 1]               0
           Conv2d-63            [-1, 512, 1, 1]       2,359,296
      BatchNorm2d-64            [-1, 512, 1, 1]           1,024
             ReLU-65            [-1, 512, 1, 1]               0
       BasicBlock-66            [-1, 512, 1, 1]               0
AdaptiveAvgPool2d-67            [-1, 512, 1, 1]               0
           Linear-68                 [-1, 1000]         513,000
================================================================
Total params: 11,689,512
Trainable params: 11,689,512
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.01
Forward/backward pass size (MB): 1.29
Params size (MB): 44.59
Estimated Total Size (MB): 45.90
----------------------------------------------------------------
Визуализация модели:
```

```
for param in model.parameters():
    param.requires_grad = False
model.fc = last_sequental_layer(512)
model.fc.apply(init_weights)
model = model.to(device)
```

```
Linear(in_features=512, out_features=256, bias=True)
Parameter containing:
tensor([[ 0.0720, -0.0701, -0.0681,  ...,  0.0198,  0.0107, -0.0812],
        [-0.0230,  0.0588,  0.0868,  ...,  0.0526, -0.0306, -0.0151],
        [ 0.0261, -0.0610, -0.0360,  ...,  0.0334, -0.0109,  0.0788],
        ...,
        [-0.0444, -0.0580, -0.0670,  ...,  0.0031,  0.0498, -0.0756],
        [-0.0387,  0.0448, -0.0629,  ..., -0.0607,  0.0527,  0.0145],
        [-0.0198, -0.0583,  0.0566,  ...,  0.0535,  0.0018, -0.0780]],
       requires_grad=True)
ReLU()
Linear(in_features=256, out_features=10, bias=True)
Parameter containing:
tensor([[ 0.0628,  0.1211, -0.1041,  ..., -0.0775, -0.1007,  0.1224],
        [ 0.0815, -0.0602, -0.1055,  ...,  0.0397, -0.0264,  0.0204],
        [ 0.0301, -0.0678,  0.0719,  ..., -0.1130,  0.1392, -0.1355],
        ...,
        [-0.1405,  0.0262,  0.1393,  ...,  0.1376, -0.0812,  0.0704],
        [ 0.0861,  0.0051, -0.0794,  ..., -0.0544,  0.0112,  0.1229],
        [ 0.1047, -0.0255,  0.1043,  ..., -0.0666, -0.1122,  0.1334]],
       requires_grad=True)
Sequential(
  (0): Linear(in_features=512, out_features=256, bias=True)
  (1): ReLU()
  (2): Linear(in_features=256, out_features=10, bias=True)
)
```

```
print(model)
```

```
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): Sequential(
    (0): Linear(in_features=512, out_features=256, bias=True)
    (1): ReLU()
    (2): Linear(in_features=256, out_features=10, bias=True)
  )
)
```

```
transforms = torch_model.ResNet18_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)
```

```
Downloading https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz to
/content/cifar-10-python.tar.gz

100%|██████████| 170498071/170498071 [00:08<00:00, 20688473.72it/s]

Extracting /content/cifar-10-python.tar.gz to /content
Files already downloaded and verified
Number of train samples: 50000

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Number of test samples: 10000

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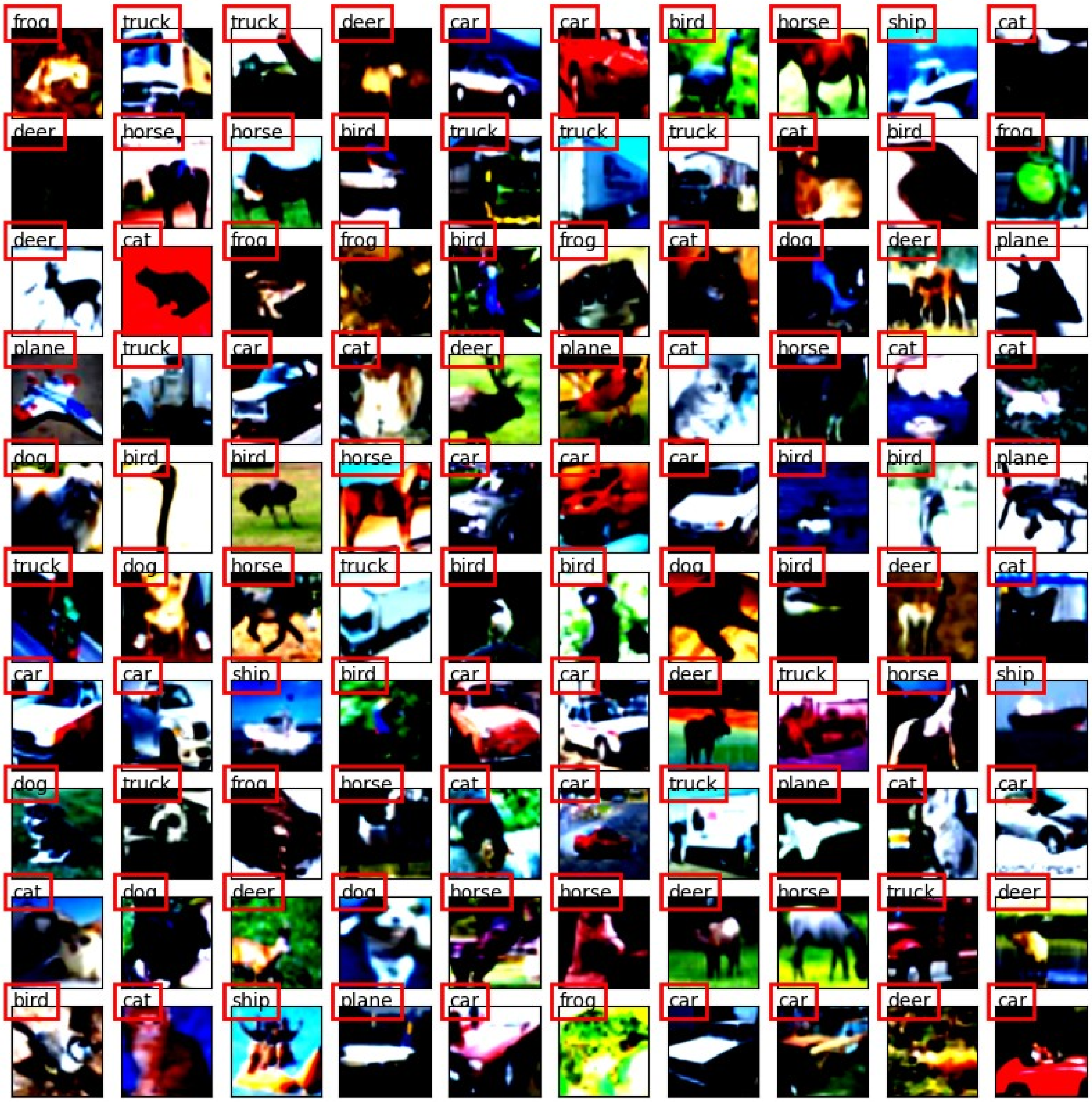
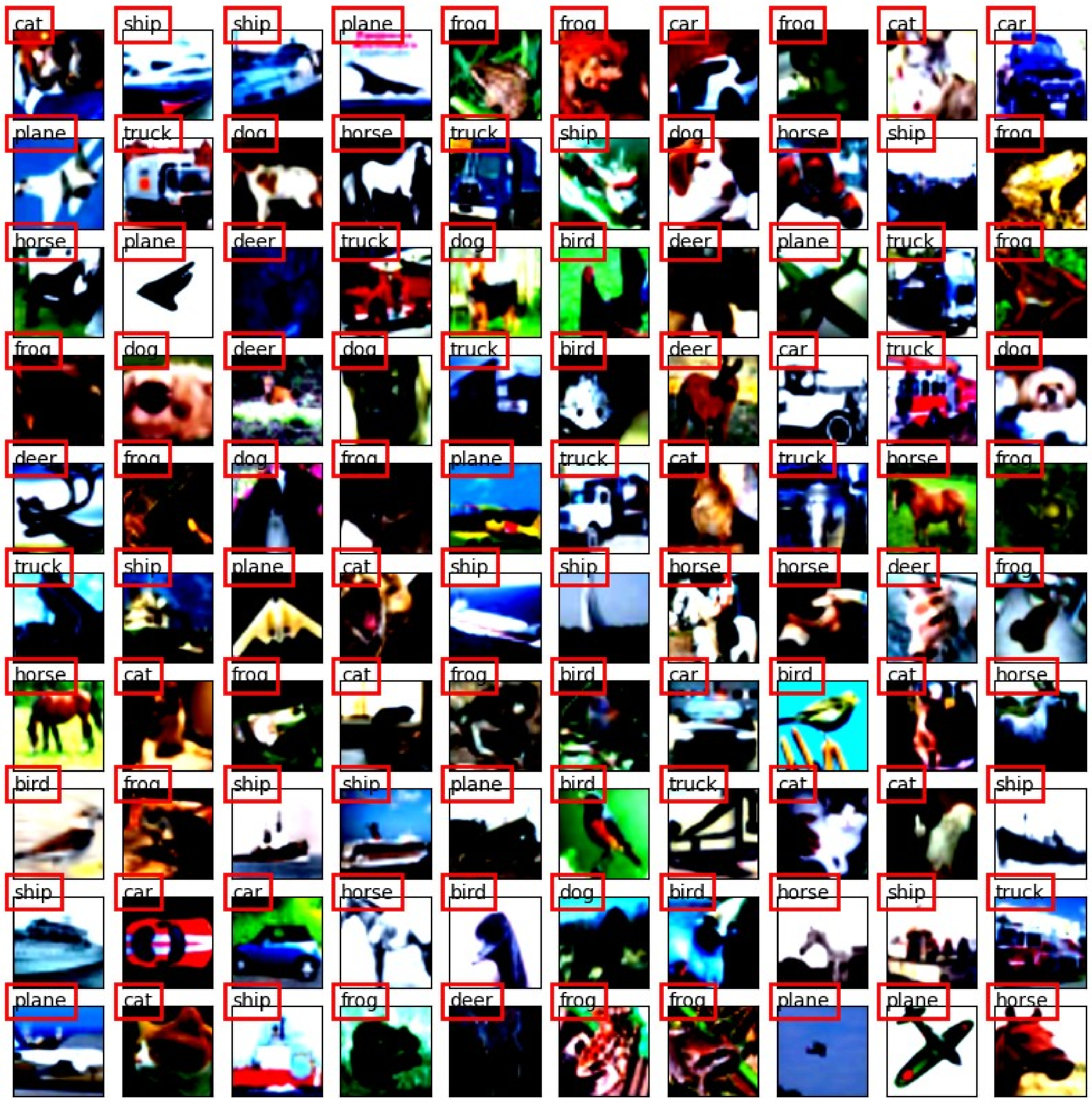
```

Train samples



Test samples



```
learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.fc.parameters(), lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)
```

```
Epoch[0]: accuracy = 0.7594799995422363, time = 133.73124742507935
Epoch[1]: accuracy = 0.7796799540519714, time = 133.07196974754333
```

```
Epoch[2]: accuracy = 0.7849000096321106, time = 131.48094820976257
Epoch[3]: accuracy = 0.7990399599075317, time = 133.5985472202301
Epoch[4]: accuracy = 0.8082799911499023, time = 133.9399676322937
Epoch[5]: accuracy = 0.8157399892807007, time = 131.6291744709015
Epoch[6]: accuracy = 0.8211399912834167, time = 130.24699783325195
Epoch[7]: accuracy = 0.8364599943161011, time = 133.8600754737854
Epoch[8]: accuracy = 0.8285399675369263, time = 133.16687679290771
Epoch[9]: accuracy = 0.8524399995803833, time = 131.25341796875
Epoch[10]: accuracy = 0.8587200045585632, time = 133.86997056007385
Epoch[11]: accuracy = 0.8580799698829651, time = 133.42539286613464
Epoch[12]: accuracy = 0.8598399758338928, time = 133.3869035243988
Epoch[13]: accuracy = 0.8741199970245361, time = 134.33729028701782
Epoch[14]: accuracy = 0.8752399682998657, time = 132.73814916610718
Epoch[15]: accuracy = 0.8773799538612366, time = 132.74400520324707
Epoch[16]: accuracy = 0.8805599808692932, time = 134.41021251678467
Epoch[17]: accuracy = 0.8913599848747253, time = 135.32344675064087
Epoch[18]: accuracy = 0.8877599835395813, time = 133.90785479545593
Epoch[19]: accuracy = 0.8972399830818176, time = 132.90964651107788
train time = 5322.203461408615

test_model(model, test_dataloader)

Test accuracy: 0.7958999872207642
```

Densenet121

1. Single layer

```
model =
torch_model.densenet121(torch_model.DenseNet121_Weights.DEFAULT)

/usr/local/lib/python3.10/dist-packages/torchvision/models/
_utils.py:135: UserWarning: Using 'weights' as positional parameter(s)
is deprecated since 0.13 and may be removed in the future. Please use
keyword parameter(s) instead.
  warnings.warn(
Downloading: "https://download.pytorch.org/models/densenet121-
a639ec97.pth" to /root/.cache/torch/hub/checkpoints/densenet121-
a639ec97.pth
100%|██████████| 30.8M/30.8M [00:00<00:00, 132MB/s]

print(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)
```

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      )
      (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)
      )
    )
    (transition3): _Transition(
      (norm): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1),
bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock4): _DenseBlock(
      (denselayer1): _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)
      )
      (denselayer2): _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)
      )
      (denselayer3): _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)
      )
      (denselayer4): _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)
      )
      (denselayer5): _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)
      )
      (denselayer6): _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)
      )
      (denselayer7): _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)
      )
      (denselayer8): _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)
      )
      (denselayer9): _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)
      )
      (denselayer10): _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)
      )
      (denselayer11): _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)
      )
      (denselayer12): _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)
      )
      (denselayer13): _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)
      )
      (denselayer14): _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)
      )
      (denselayer15): _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)
      )
      (denselayer16): _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)
      )
    )
    (norm5): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  )
  (classifier): Linear(in_features=1024, out_features=1000, bias=True)
)

for param in model.parameters():
    param.requires_grad = False
```

```
model.classifier = last_layer(1024)
model = model.to(device)

print(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)
      )
    )
    (transition3): _Transition(
      (norm): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
      (conv): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1),
bias=False)
      (pool): AvgPool2d(kernel_size=2, stride=2, padding=0)
    )
    (denseblock4): _DenseBlock(
      (denselayer1): _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)
      )
      (denselayer2): _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)
      )
      (denselayer3): _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)
      )
      (denselayer4): _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)
      )
      (denselayer5): _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)
      )
      (denselayer6): _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)
      )
      (denselayer7): _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)
      )
      (denselayer8): _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)
      )
      (denselayer9): _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)
      )
      (denselayer10): _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)
      )
      (denselayer11): _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)
      )
      (denselayer12): _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)
      )
      (denselayer13): _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)
      )
      (denselayer14): _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)
      )
      (denselayer15): _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)
      )
      (denselayer16): _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)
      )
    )
    (norm5): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
  )
  (classifier): Linear(in_features=1024, out_features=10, bias=True)
)
```

```
transforms = torch_model.DenseNet121_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)
```

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Files already downloaded and verified
Files already downloaded and verified
Number of train samples: 50000
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Number of test samples: 10000

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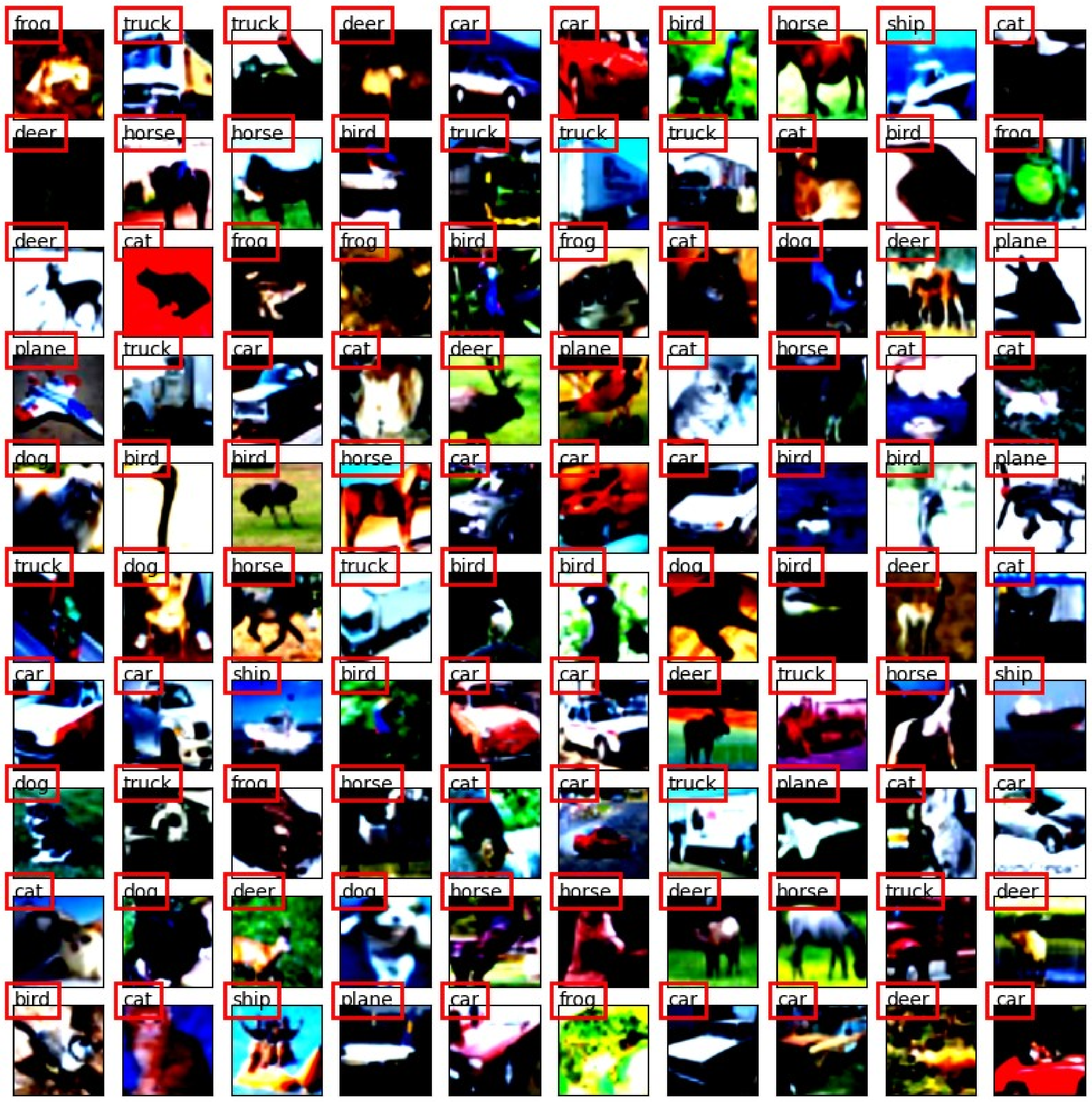
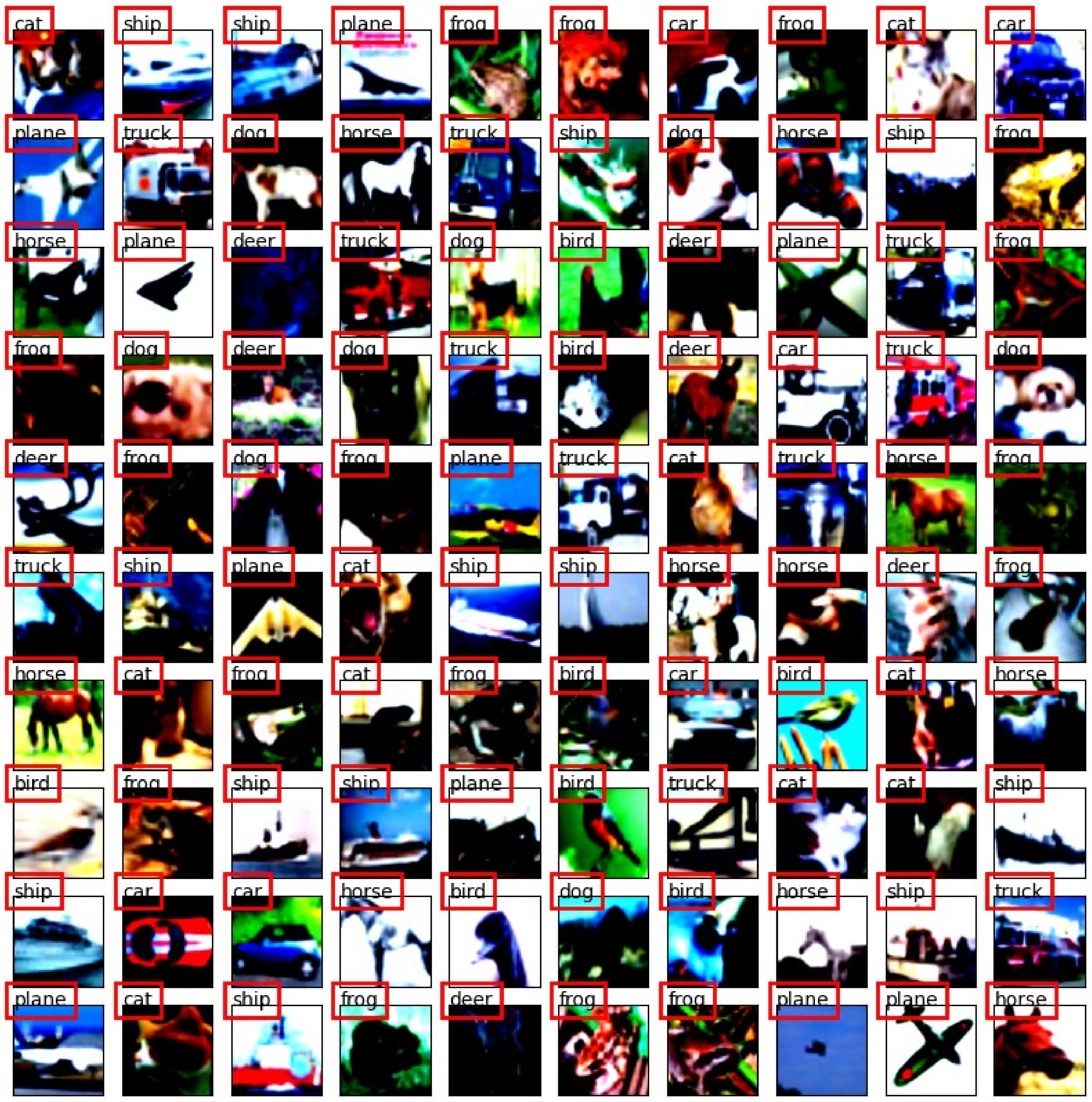
WARNING:matplotlib.image:Clipping input data to the valid range for
imshow with RGB data ([0..1] for floats or [0..255] for integers).
```

Train samples



Test samples



```
learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.classifier.parameters(),
lr=learning_rate)
model = model.to(device)

train_loop(model, train_dataloader, optimizer, loss_function)
```

```
Epoch[0]: accuracy = 0.7708999514579773, time = 172.45439887046814
Epoch[1]: accuracy = 0.7917199730873108, time = 173.8807408809662
Epoch[2]: accuracy = 0.8006599545478821, time = 173.64650082588196
Epoch[3]: accuracy = 0.796999990940094, time = 173.86425352096558
Epoch[4]: accuracy = 0.8100199699401855, time = 173.65966701507568
Epoch[5]: accuracy = 0.8076399564743042, time = 174.50546216964722
Epoch[6]: accuracy = 0.8104000091552734, time = 173.82365036010742
Epoch[7]: accuracy = 0.8085799813270569, time = 173.53456020355225
Epoch[8]: accuracy = 0.811739981174469, time = 173.1445758342743
Epoch[9]: accuracy = 0.811199963092804, time = 174.12666630744934
Epoch[10]: accuracy = 0.8151999711990356, time = 173.08181023597717
Epoch[11]: accuracy = 0.8173199892044067, time = 173.460134267807
Epoch[12]: accuracy = 0.8162199854850769, time = 173.07563638687134
Epoch[13]: accuracy = 0.814300000667572, time = 173.4216662216187
Epoch[14]: accuracy = 0.8192600011825562, time = 174.47900819778442
Epoch[15]: accuracy = 0.8169800043106079, time = 171.43979167938232
Epoch[16]: accuracy = 0.8141999840736389, time = 171.9295723438263
Epoch[17]: accuracy = 0.8133400082588196, time = 172.0942211151123
Epoch[18]: accuracy = 0.8139399886131287, time = 172.2222945690155
Epoch[19]: accuracy = 0.8186999559402466, time = 172.34216904640198
train time = 6931.575216054916

test_model(model, test_dataloader)

Test accuracy: 0.8026999831199646
```

1. Sequental layer

```
model =
torch_model.densenet121(torch_model.DenseNet121_Weights.DEFAULT)

# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))

for param in model.parameters():
    param.requires_grad = False
model.classifier = last_sequential_layer(1024)
model = model.to(device)

print(model)

transforms = torch_model.DenseNet121_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)
```

```
learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.classifier.parameters(),
lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)

test_model(model, test_dataloader)
```

1. Weights

```
model =
torch_model.densenet121(torch_model.DenseNet121_Weights.DEFAULT)

# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))

for param in model.parameters():
    param.requires_grad = False
model.classifier = last_layer(1024)
model.classifier.apply(init_weights)
model = model.to(device)

print(model)

transforms = torch_model.DenseNet121_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)

learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.fc.parameters(), lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)

test_model(model, test_dataloader)
```

Resnext50_32x4d

1. Single layer

```
model =
torch_model.resnext50_32x4d(torch_model.ResNeXt50_32X4D_Weights.DEFAUL
T)
```

```
# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))

for param in model.parameters():
    param.requires_grad = False
model.fc = last_layer(2048)
model = model.to(device)

print(model)

transforms = torch_model.ResNeXt50_32X4D_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)

learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.fc.parameters(), lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)

test_model(model, test_dataloader)
```

1. Sequental layer

```
model =
torch_model.resnext50_32x4d(torch_model.ResNeXt50_32X4D_Weights.DEFAUL
T)

# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))

for param in model.parameters():
    param.requires_grad = False
model.fc = last_sequental_layer(2048)
model = model.to(device)

print(model)

transforms = torch_model.ResNeXt50_32X4D_Weights.DEFAULT.transforms()
batch_size = 128
```

```
train_dataloader, test_dataloader = download_data(transforms,
batch_size)

learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.fc.parameters(), lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)

test_model(model, test_dataloader)
```

1. Weights

```
model =
torch_model.resnext50_32x4d(torch_model.ResNeXt50_32X4D_Weights.DEFAUL
T)

# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))

for param in model.parameters():
    param.requires_grad = False
model.fc = last_layer(2048)
model.fc.apply(init_weights)
model = model.to(device)

print(model)

transforms = torch_model.ResNeXt50_32X4D_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)

learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.fc.parameters(), lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)

test_model(model, test_dataloader)
```

ViT_B_16

1. Single layer

```
model = torch_model.vit_b_16(torch_model.ViT_B_16_Weights.DEFAULT)
```

```
# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))

for param in model.parameters():
    param.requires_grad = False
model.heads = last_layer(768)
model = model.to(device)

print(model)

transforms = torch_model.ViT_B_16_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)

learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.heads.parameters(),
lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)

test_model(model, test_dataloader)
```

1. Sequental layer

```
model = torch_model.vit_b_16(torch_model.ViT_B_16_Weights.DEFAULT)

# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))

for param in model.parameters():
    param.requires_grad = False
model.heads = last_sequental_layer(768)
model = model.to(device)

print(model)

transforms = torch_model.ViT_B_16_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)
```

```
learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.heads.parameters(),
lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)

test_model(model, test_dataloader)
```

1. Weights

```
model = torch_model.vit_b_16(torch_model.ViT_B_16_Weights.DEFAULT)

# Информация об архитектуре и визуализация сети
print("Модель \"CNN\":")
summary(model.to(device), input_size=(3, 32, 32))

print("Визуализация модели:")
display(make_dot(model(torch.randn(16, 3, 32, 32).to(device)),
params=dict(model.named_parameters())))

for param in model.parameters():
    param.requires_grad = False
model.heads = last_layer(768)
model.heads.apply(init_weights)
model = model.to(device)

print(model)

transforms = torch_model.ViT_B_16_Weights.DEFAULT.transforms()
batch_size = 128
train_dataloader, test_dataloader = download_data(transforms,
batch_size)

learning_rate = 0.001
loss_function = torch.nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.heads.parameters(),
lr=learning_rate)

train_loop(model, train_dataloader, optimizer, loss_function)

test_model(model, test_dataloader)
```