

Кузнецов Антон 20223 Свёрточные нейронные сети: CIFAR10

В этом ноутбуке мы посмотрим, насколько хорошо **CNN** будут предсказывать классы на более сложном датасете картинок -- **CIFAR10**.

Внимание: Рассматривается *задача классификации изображений*.

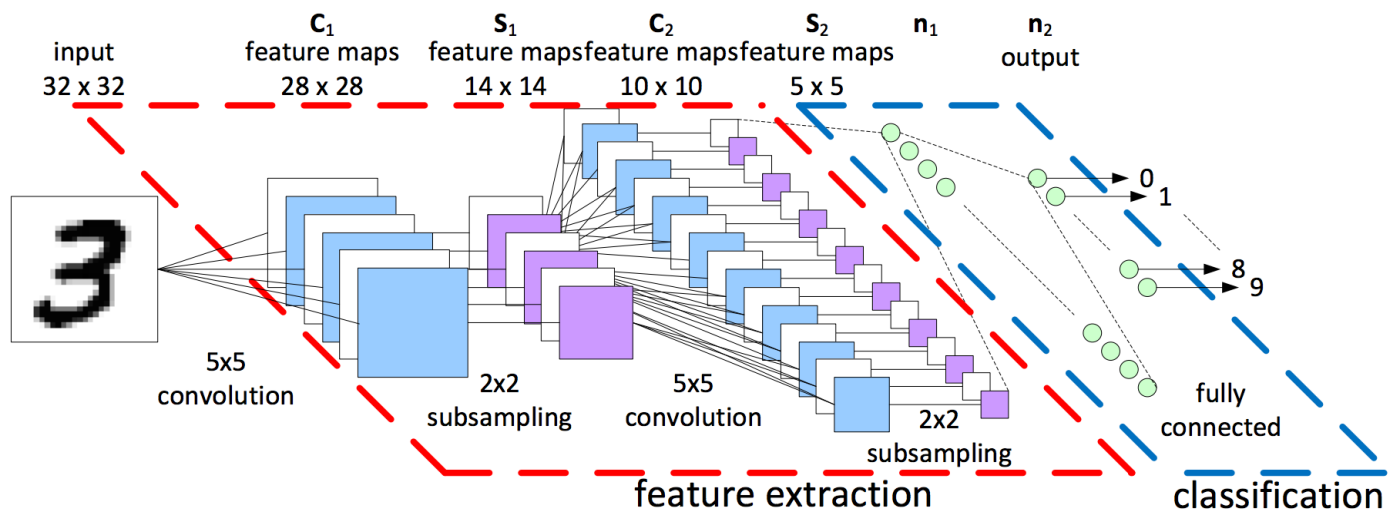
Свёрточная нейросеть (Convolutional Neural Network, CNN) - это многослойная нейросеть, имеющая в своей архитектуре помимо *полносвязных слоёв* (а иногда их может и не быть) ещё и **свёрточные слои (Conv Layers)** и **pooling-слои (Pool Layers)**.

Собственно, название такое эти сети получили потому, что в основе их работы лежит операция **свёртки**.

Сразу же стоит сказать, что свёрточные нейросети **были придуманы прежде всего для задач, связанных с изображениями**, следовательно, на вход они тоже "ожидают" изображение.

- Например, вот так выглядит неглубокая свёрточная нейросеть, имеющая такую архитектуру:

Input -> Conv 5x5 -> Pool 2x2 -> Conv 5x5 -> Pool 2x2 -> FC -> Output



Свёрточные нейросети (простые, есть и намного более продвинутые) почти всегда строятся по следующему правилу:

INPUT -> [[CONV -> RELU]*N -> POOL?]*M -> [FC -> RELU]*L -> FC

то есть:

1). Входной слой: batch картинок -- тензор размера $(batch_size, H, W, C)$ или $(batch_size, C, H, W)$

2). M блоков ($M \geq 0$) из свёрток и **pooling**-ов, причём именно в том порядке, как в формуле выше. Все эти M блоков вместе называют **feature extractor** свёрточной нейросети, потому что эта часть сети отвечает непосредственно за формирование новых, более сложных признаков поверх тех, которые подаются (то есть, по аналогии с **MLP**, мы опять же переходим к новому признаковому пространству, однако здесь оно строится сложнее, чем в обычных многослойных сетях, поскольку используется операция свёртки)

3). L штук FullyConnected-слоёв (с активациями). Эту часть из L FC-слоёв называют **classifier**, поскольку эти слои отвечают непосредственно за предсказание нужного класса (сейчас рассматривается задача

классификации изображений).

Свёрточная нейросеть на PyTorch

Ещё раз напомним про основные компоненты нейросети:

- непосредственно, сама **архитектура** нейросети (сюда входят типы функций активации у каждого нейрона);
- начальная **инициализация** весов каждого слоя;
- метод **оптимизации** нейросети (сюда ещё входит метод изменения `learning_rate`);
- размер **батчей** (`batch_size`);
- количество эпох обучения (`num_epochs`);
- **функция потерь** (`loss`);
- тип **регуляризации** нейросети (`weight_decay`, для каждого слоя можно свой);

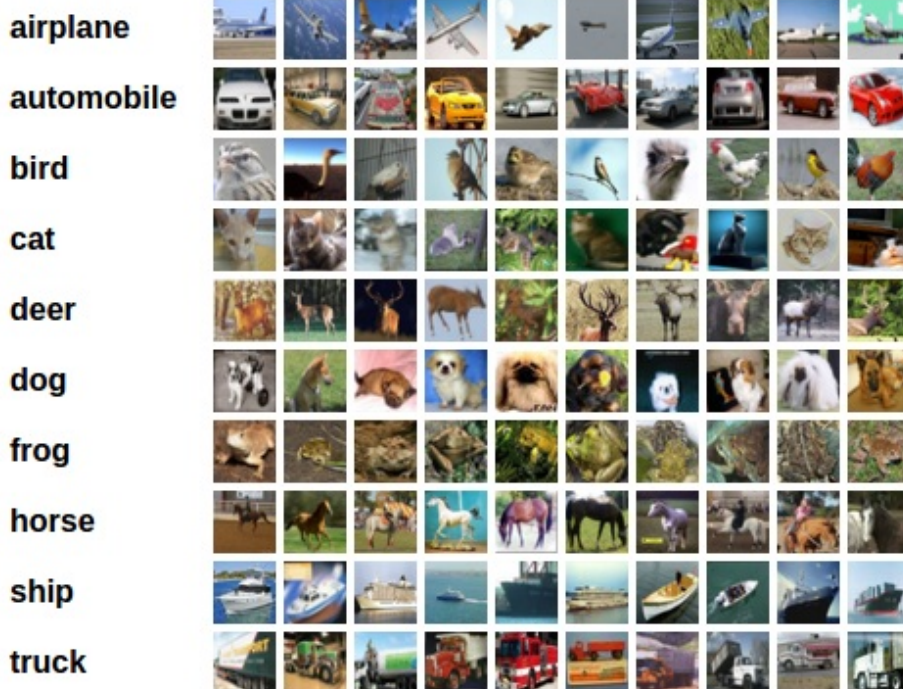
То, что связано с *данными и задачей*:

- само **качество** выборки (непротиворечивость, чистота, корректность постановки задачи);
- **размер** выборки;

Так как мы сейчас рассматриваем **архитектуру CNN**, то, помимо этих компонент, в свёрточной нейросети можно настроить следующие вещи:

- (в каждом **ConvLayer**) размер фильтров (окна свёртки) (`kernel_size`)
- (в каждом **ConvLayer**) количество фильтров (`out_channels`)
- (в каждом **ConvLayer**) размер шага окна свёртки (**stride**) (`stride`)
- (в каждом **ConvLayer**) тип **padding'a** (`padding`)
- (в каждом **PoolLayer**) размер окна **pooling'a** (`kernel_size`)
- (в каждом **PoolLayer**) шаг окна **pooling'a** (`stride`)
- (в каждом **PoolLayer**) тип **pooling'a** (`pool_type`)
- (в каждом **PoolLayer**) тип **padding'a** (`padding`)

CIFAR10



CIFAR10: это набор из **60k** картинок **32x32x3**, **50k** которых составляют обучающую выборку, и оставшиеся **10k** - тестовую. Классов в этом датасете **10**: 'plane', 'car', 'bird', 'cat', 'deer', 'dog', 'frog', 'horse', 'ship', 'truck'.

In [1]:

```
# !pip install torch torchvision
```

In [2]:

```
import torch
import torchvision
from torchvision import transforms

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

In [3]:

```
from tqdm import tqdm_notebook
```

In [4]:

```
transform = transforms.Compose(
    [transforms.ToTensor(),
     transforms.Normalize((0.5, 0.5, 0.5), (0.5, 0.5, 0.5))])

trainset = torchvision.datasets.CIFAR10(root='../pytorch_data', train=True,
                                         download=True, transform=transform)
trainloader = torch.utils.data.DataLoader(trainset, batch_size=4,
                                           shuffle=True, num_workers=2)

testset = torchvision.datasets.CIFAR10(root='../pytorch_data', train=False,
                                         download=True, transform=transform)
testloader = torch.utils.data.DataLoader(testset, batch_size=4,
                                          shuffle=False, num_workers=2)

classes = ('plane', 'car', 'bird', 'cat',
           'deer', 'dog', 'frog', 'horse', 'ship', 'truck')
```

Downloading <https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz> to ../pytorch_data/cifar-10-python.tar.gz

Extracting ../pytorch_data/cifar-10-python.tar.gz to ../pytorch_data
Files already downloaded and verified

In [5]:

```
trainset.data
```

Out[5]:

```
array([[[[ 59,  62,  63],
          [ 43,  46,  45],
          [ 50,  48,  43],
          ...,
          [158, 132, 108],
          [152, 125, 102],
          [148, 124, 103]],

        [[ 16,  20,  20],
          [  0,   0,   0],
          [ 18,   8,   0],
          ...,
          [123,  88,  55],
          [119,  83,  50],
          [122,  87,  57]],

        [[ 25,  24,  21],
          [ 16,   7,   0],
          [ 49,  27,   8],
          ...,
          [118,  84,  50],
          [120,  84,  50],
```

```

[109, 73, 42]],

...,

[[208, 170, 96],
 [201, 153, 34],
 [198, 161, 26],

...,
 [160, 133, 70],
 [ 56, 31, 7],
 [ 53, 34, 20]],

[[180, 139, 96],
 [173, 123, 42],
 [186, 144, 30],

...,
 [184, 148, 94],
 [ 97, 62, 34],
 [ 83, 53, 34]],

[[177, 144, 116],
 [168, 129, 94],
 [179, 142, 87],

...,
 [216, 184, 140],
 [151, 118, 84],
 [123, 92, 72]]],

[[[154, 177, 187],
 [126, 137, 136],
 [105, 104, 95],

...,
 [ 91, 95, 71],
 [ 87, 90, 71],
 [ 79, 81, 70]],

[[140, 160, 169],
 [145, 153, 154],
 [125, 125, 118],

...,
 [ 96, 99, 78],
 [ 77, 80, 62],
 [ 71, 73, 61]],

[[140, 155, 164],
 [139, 146, 149],
 [115, 115, 112],

...,
 [ 79, 82, 64],
 [ 68, 70, 55],
 [ 67, 69, 55]],

...,

[[175, 167, 166],
 [156, 154, 160],
 [154, 160, 170],

...,
 [ 42, 34, 36],
 [ 61, 53, 57],
 [ 93, 83, 91]],

[[165, 154, 128],
 [156, 152, 130],
 [159, 161, 142],

...,
 [103, 93, 96],
 [123, 114, 120],
 [131, 121, 131]],

[[163, 148, 120],

```

```

[158, 148, 122],
[163, 156, 133],
...,
[143, 133, 139],
[143, 134, 142],
[143, 133, 144]]],

[[[255, 255, 255],
  [253, 253, 253],
  [253, 253, 253],
  ...,
  [253, 253, 253],
  [253, 253, 253],
  [253, 253, 253]]],

[[255, 255, 255],
 [255, 255, 255],
 [255, 255, 255],
 ...,
 [255, 255, 255],
 [255, 255, 255],
 [255, 255, 255]]],

[[255, 255, 255],
 [254, 254, 254],
 [254, 254, 254],
 ...,
 [254, 254, 254],
 [254, 254, 254],
 [254, 254, 254]]],

...,

[[[113, 120, 112],
  [111, 118, 111],
  [105, 112, 106],
  ...,
  [ 72,  81,  80],
  [ 72,  80,  79],
  [ 72,  80,  79]]],

[[[111, 118, 110],
  [104, 111, 104],
  [ 99, 106,  98],
  ...,
  [ 68,  75,  73],
  [ 70,  76,  75],
  [ 78,  84,  82]]],

[[[106, 113, 105],
  [ 99, 106,  98],
  [ 95, 102,  94],
  ...,
  [ 78,  85,  83],
  [ 79,  85,  83],
  [ 80,  86,  84]]],

...,

[[[ 35, 178, 235],
  [ 40, 176, 239],
  [ 42, 176, 241],
  ...,
  [ 99, 177, 219],
  [ 79, 147, 197],
  [ 89, 148, 189]]],

[[ 57, 182, 234],
 [ 44, 184, 250],

```

```

[ 50, 183, 240],
...,
[156, 182, 200],
[141, 177, 206],
[116, 149, 175]],

[[ 98, 197, 237],
 [ 64, 189, 252],
 [ 69, 192, 245],
 ...,
 [188, 195, 206],
 [119, 135, 147],
 [ 61,  79,  90]],

...,

[[ 73,  79,  77],
 [ 53,  63,  68],
 [ 54,  68,  80],
 ...,
 [ 17,  40,  64],
 [ 21,  36,  51],
 [ 33,  48,  49]],

[[ 61,  68,  75],
 [ 55,  70,  86],
 [ 57,  79, 103],
 ...,
 [ 24,  48,  72],
 [ 17,  35,  53],
 [  7,  23,  32]],

[[ 44,  56,  73],
 [ 46,  66,  88],
 [ 49,  77, 105],
 ...,
 [ 27,  52,  77],
 [ 21,  43,  66],
 [ 12,  31,  50]]],

[[[189, 211, 240],
  [186, 208, 236],
  [185, 207, 235],
  ...,
  [175, 195, 224],
  [172, 194, 222],
  [169, 194, 220]],

[[194, 210, 239],
 [191, 207, 236],
 [190, 206, 235],
 ...,
 [173, 192, 220],
 [171, 191, 218],
 [167, 190, 216]],

[[208, 219, 244],
 [205, 216, 240],
 [204, 215, 239],
 ...,
 [175, 191, 217],
 [172, 190, 216],
 [169, 191, 215]],

...,

[[207, 199, 181],
 [203, 195, 175],
 [203, 196, 173],
 ...,
 [135, 132, 127],

```

```

        [162, 158, 150],
        [168, 163, 151]],

[[198, 190, 170],
 [189, 181, 159],
 [180, 172, 147],
 ...,
 [178, 171, 160],
 [175, 169, 156],
 [175, 169, 154]],

[[198, 189, 173],
 [189, 181, 162],
 [178, 170, 149],
 ...,
 [195, 184, 169],
 [196, 189, 171],
 [195, 190, 171]]],

[[[229, 229, 239],
   [236, 237, 247],
   [234, 236, 247],
   ...,
   [217, 219, 233],
   [221, 223, 234],
   [222, 223, 233]],

  [[222, 221, 229],
   [239, 239, 249],
   [233, 234, 246],
   ...,
   [223, 223, 236],
   [227, 228, 238],
   [210, 211, 220]],

  [[213, 206, 211],
   [234, 232, 239],
   [231, 233, 244],
   ...,
   [220, 220, 232],
   [220, 219, 232],
   [202, 203, 215]],

  ...,

  [[150, 143, 135],
   [140, 135, 127],
   [132, 127, 120],
   ...,
   [224, 222, 218],
   [230, 228, 225],
   [241, 241, 238]],

  [[137, 132, 126],
   [130, 127, 120],
   [125, 121, 115],
   ...,
   [181, 180, 178],
   [202, 201, 198],
   [212, 211, 207]],

  [[122, 119, 114],
   [118, 116, 110],
   [120, 116, 111],
   ...,
   [179, 177, 173],
   [164, 164, 162],
   [163, 163, 161]]]], dtype=uint8)

```

In [6]:

```
trainloader.dataset.train_list[0]
```

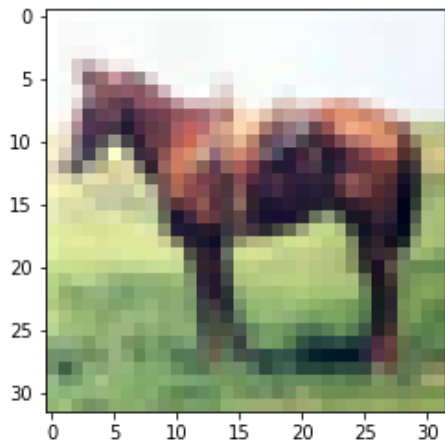
Out[6]:

```
['data_batch_1', 'c99cafc152244af753f735de768cd75f']
```

In [7]:

```
# случайный индекс от 0 до размера тренировочной выборки
i = np.random.randint(low=0, high=50000)

plt.imshow(trainloader.dataset.data[i]);
```



Напишем свёрточную нейросеть для предсказания на **CIFAR10**.

In [8]:

```
import torch.nn as nn
import torch.nn.functional as F
```

In [9]:

```
class SimpleConvNet(torch.nn.Module):
    def __init__(self):
        # вызов конструктора класса nn.Module()
        super(SimpleConvNet, self).__init__()
        # feature extractor
        self.conv1 = nn.Conv2d(in_channels=3, out_channels=6, kernel_size=5)
        self.pool = nn.MaxPool2d(kernel_size=2, stride=2)
        self.conv2 = nn.Conv2d(in_channels=6, out_channels=16, kernel_size=5)
        # classifier
        self.fc1 = nn.Linear(5 * 5 * 16, 120)
        self.fc2 = nn.Linear(120, 84)
        self.fc3 = nn.Linear(84, 10)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        x = self.pool(F.relu(self.conv2(x)))
        # print(x.shape)
        x = x.view(-1, 5 * 5 * 16)
        x = F.relu(self.fc1(x))
        x = F.relu(self.fc2(x))
        x = self.fc3(x)
        return x
```

Обучим:

In [10]:

```
from tqdm import tqdm_notebook
```

In [11]:

```
net = SimpleConvNet()
```



```

loss_fn = torch.nn.CrossEntropyLoss()

learning_rate = 1e-4
optimizer = torch.optim.Adam(net.parameters(), lr=learning_rate)

# итерируемся
for epoch in tqdm_notebook(range(3)):

    running_loss = 0.0
    for i, batch in enumerate(tqdm_notebook(trainloader)):
        # так получаем текущий батч
        X_batch, y_batch = batch

        # обнуляем веса
        optimizer.zero_grad()

        # forward + backward + optimize
        y_pred = net(X_batch)
        loss = loss_fn(y_pred, y_batch)
        loss.backward()
        optimizer.step()

    running_loss += loss.item()
    # выводим качество каждые 2000 батчей
    if i % 2000 == 1999:
        print('[%d, %5d] loss: %.3f' %
              (epoch + 1, i + 1, running_loss / 2000))
        running_loss = 0.0

print('Обучение закончено')

```

C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\3477602096.py:9: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for epoch in tqdm_notebook(range(3)):

C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\3477602096.py:12: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```

[1, 2000] loss: 2.042
[1, 4000] loss: 1.812
[1, 6000] loss: 1.725
[1, 8000] loss: 1.656
[1, 10000] loss: 1.630
[1, 12000] loss: 1.590

```

```

[2, 2000] loss: 1.548
[2, 4000] loss: 1.541
[2, 6000] loss: 1.505
[2, 8000] loss: 1.474
[2, 10000] loss: 1.467
[2, 12000] loss: 1.460

```

```

[3, 2000] loss: 1.412
[3, 4000] loss: 1.430
[3, 6000] loss: 1.395
[3, 8000] loss: 1.373
[3, 10000] loss: 1.381
[3, 12000] loss: 1.378

```

Обучение закончено

Посмотрим на **accuracy** на тестовом датасете:

In [12]:

```
class_correct = list(0. for i in range(10))
```

```

class_total = list(0. for i in range(10))

with torch.no_grad():
    for data in testloader:
        images, labels = data
        y_pred = net(images)
        _, predicted = torch.max(y_pred, 1)
        c = (predicted == labels).squeeze()
        for i in range(4):
            label = labels[i]
            class_correct[label] += c[i].item()
            class_total[label] += 1

for i in range(10):
    print('Accuracy of %5s : %2d %%' % (
        classes[i], 100 * class_correct[i] / class_total[i]))

```

```

Accuracy of plane : 50 %
Accuracy of  car : 75 %
Accuracy of  bird : 38 %
Accuracy of  cat : 26 %
Accuracy of  deer : 37 %
Accuracy of  dog : 45 %
Accuracy of  frog : 61 %
Accuracy of horse : 56 %
Accuracy of  ship : 68 %
Accuracy of truck : 56 %

```

Проверим работу нейросети визуально (позапускайте ячейку несколько раз):

In [13]:

```

i = np.random.randint(low=0, high=10000)

def visualize_result(index):
    image = testloader.dataset.data[index]
    plt.imshow(image)

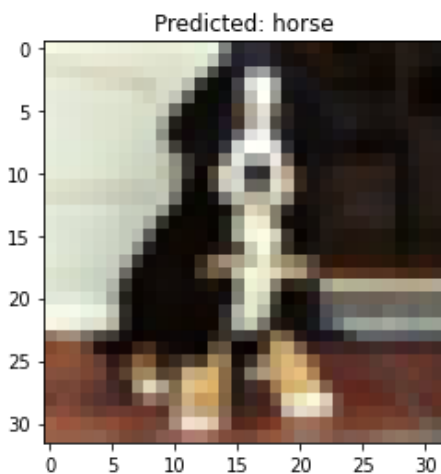
    image = transform(image)  # не забудем отмасштабировать!

    y_pred = net(image.view(1, 3, 32, 32))
    _, predicted = torch.max(y_pred, 1)

    plt.title(f'Predicted: {classes[predicted.numpy()[0]]}')

visualize_result(i)

```



Улучшим свёрточную нейросеть: поэкспериментируем с архитектурой (количество слоёв, порядок слоёв), с гиперпараметрами слоёв (размеры **kernel_size**, размеры **pooling**'а, количество **kernel**'ов в свёрточном слое) и с гиперпараметрами, указанными в "Компоненты нейросети" (см. памятку выше).

In [14]:

```

class BetterConvNet(nn.Module):

```

```

class BetterConvNet(nn.Module):
    def __init__(self):
        # вызов конструктора класса nn.Module()
        super(BetterConvNet, self).__init__()

        self.pool = nn.MaxPool2d(kernel_size=2, stride=2)

        self.conv1 = nn.Conv2d(in_channels=3, out_channels=6, kernel_size=5)
        self.conv2 = nn.Conv2d(in_channels=6, out_channels=16, kernel_size=5)
        self.conv3 = nn.Conv2d(in_channels=16, out_channels=32, kernel_size=5)

        self.fc1 = nn.Linear(3 * 3 * 32, 120)
        self.fc2 = nn.Linear(120, 84)
        self.fc3 = nn.Linear(84, 10)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        x = self.pool(self.conv3(F.relu(self.conv2(x))))
        # print(x.shape)
        x = x.view(-1, 3 * 3 * 32)
        x = F.relu(self.fc1(x))
        x = F.relu(self.fc2(x))
        x = self.fc3(x)
        return x

```

Обучим:

In [15]:

```
from tqdm import tqdm_notebook
```

In [16]:

```

net = BetterConvNet()

loss_fn = torch.nn.CrossEntropyLoss()

learning_rate = 1e-3
optimizer = torch.optim.Adam(net.parameters(), lr=learning_rate)

# итерируемся
for epoch in tqdm_notebook(range(5)):

    running_loss = 0.0
    for i, batch in enumerate(tqdm_notebook(trainloader)):
        # так получаем текущий батч
        X_batch, y_batch = batch

        # обнуляем веса
        optimizer.zero_grad()

        # forward + backward + optimize
        y_pred = net(X_batch)
        loss = loss_fn(y_pred, y_batch)
        loss.backward()
        optimizer.step()

        # выведем текущий loss
        running_loss += loss.item()
        # выведем качество каждые 2000 батчей
        if i % 2000 == 1999:
            print('[%d, %5d] loss: %.3f' %
                  (epoch + 1, i + 1, running_loss / 2000))
            running_loss = 0.0

print('Обучение закончено')

```

C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\4107937569.py:9: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for epoch in tqdm_notebook(range(5)):

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\4107937569.py:12: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
    for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[1, 2000] loss: 1.975
[1, 4000] loss: 1.722
[1, 6000] loss: 1.626
[1, 8000] loss: 1.556
[1, 10000] loss: 1.507
[1, 12000] loss: 1.478
```

```
[2, 2000] loss: 1.440
[2, 4000] loss: 1.428
[2, 6000] loss: 1.402
[2, 8000] loss: 1.373
[2, 10000] loss: 1.396
[2, 12000] loss: 1.383
```

```
[3, 2000] loss: 1.317
[3, 4000] loss: 1.332
[3, 6000] loss: 1.340
[3, 8000] loss: 1.334
[3, 10000] loss: 1.293
[3, 12000] loss: 1.317
```

```
[4, 2000] loss: 1.265
[4, 4000] loss: 1.248
[4, 6000] loss: 1.269
[4, 8000] loss: 1.279
[4, 10000] loss: 1.277
[4, 12000] loss: 1.268
```

```
[5, 2000] loss: 1.219
[5, 4000] loss: 1.226
[5, 6000] loss: 1.225
[5, 8000] loss: 1.257
[5, 10000] loss: 1.216
[5, 12000] loss: 1.242
```

Обучение закончено

In [17]:

```
class_correct = list(0. for i in range(10))
class_total = list(0. for i in range(10))

with torch.no_grad():
    for data in testloader:
        images, labels = data
        y_pred = net(images)
        _, predicted = torch.max(y_pred, 1)
        c = (predicted == labels).squeeze()
        for i in range(4):
            label = labels[i]
            class_correct[label] += c[i].item()
            class_total[label] += 1

for i in range(10):
    print('Accuracy of %5s : %2d %%' % (
        classes[i], 100 * class_correct[i] / class_total[i]))
```

```
Accuracy of plane : 48 %
Accuracy of car : 67 %
Accuracy of bird : 35 %
Accuracy of cat : 26 %
Accuracy of deer : 48 %
Accuracy of dog : 53 %
Accuracy of frog : 71 %
Accuracy of horse : 63 %
```

Accuracy of ship : 63 %
Accuracy of truck : 71 %

Если качество **~70%** в среднем, то текущая нейросеть вполне неплоха (однако на этом датасете известны архитектуры, дающие **95+%** качества).

Посмотрим визуально на работу нейросети:

In [18]:

```
i = np.random.randint(low=0, high=10000)

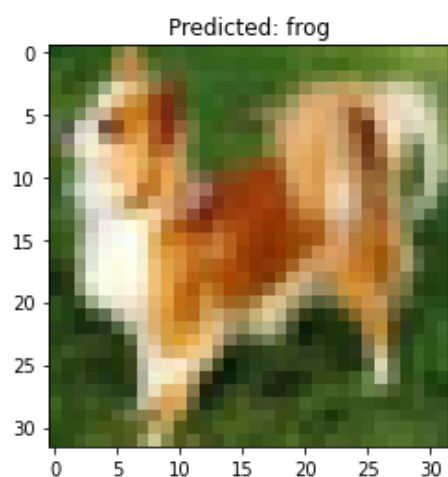
def visualize_result(index):
    image = testloader.dataset.data[index]
    plt.imshow(image)

    image = transform(image)  # не забудем отмасштабировать!

    y_pred = net(image.view(1, 3, 32, 32))
    _, predicted = torch.max(y_pred, 1)

    plt.title(f'Predicted: {classes[predicted.numpy()[0]]}')

visualize_result(i)
```



Попробуем обучить ещё более сильную нейросеть:

In [19]:

```
class StrongConvNet(nn.Module):
    def __init__(self):
        # вызов конструктора класса nn.Module()
        super(StrongConvNet, self).__init__()

        self.pool = nn.MaxPool2d(kernel_size=2, stride=2)

        self.dropout = nn.Dropout(p=0.2)

        self.conv1 = nn.Conv2d(in_channels=3, out_channels=8, kernel_size=5)
        self.bn1 = nn.BatchNorm2d(8)
        self.conv2 = nn.Conv2d(in_channels=8, out_channels=16, kernel_size=1)
        self.bn2 = nn.BatchNorm2d(16)
        self.conv3 = nn.Conv2d(in_channels=16, out_channels=16, kernel_size=3)
        self.bn3 = nn.BatchNorm2d(16)
        self.conv4 = nn.Conv2d(in_channels=16, out_channels=32, kernel_size=1)
        self.bn4 = nn.BatchNorm2d(32)
        self.conv5 = nn.Conv2d(in_channels=32, out_channels=32, kernel_size=3)
        self.bn5 = nn.BatchNorm2d(32)

        self.fc1 = nn.Linear(4 * 4 * 32, 128)
        self.fc2 = nn.Linear(128, 10)
```

```

def forward(self, x):
    x = self.bn1(F.relu(self.conv1(x)))
    x = self.pool(x)
    x = self.bn2(F.relu(self.conv2(x)))
    x = self.bn3(F.relu(self.conv3(x)))
    x = self.pool(x)
    x = self.bn4(F.relu(self.conv4(x)))
    x = self.bn5(F.relu(self.conv5(x)))
#     print(x.shape)
    x = x.view(-1, 4 * 4 * 32)
    x = F.relu(self.fc1(x))
    x = self.dropout(x)
    x = self.fc2(x)
    return x

```

Обучим:

In [20]:

```
from tqdm import tqdm_notebook
```

In [21]:

```
from torch.optim import lr_scheduler
```

In [22]:

```

net = StrongConvNet()

loss_fn = torch.nn.CrossEntropyLoss()

num_epochs = 5

optimizer = torch.optim.Adam(net.parameters(), lr=learning_rate)
learning_rate = 1e-3
# новая фишка -- динамически изменяем LR
scheduler = lr_scheduler.CosineAnnealingLR(optimizer, T_max=num_epochs)

for epoch in tqdm_notebook(range(num_epochs)):

    scheduler.step()

    running_loss = 0.0
    for i, batch in enumerate(tqdm_notebook(trainloader)):
        X_batch, y_batch = batch

        optimizer.zero_grad()

        y_pred = net(X_batch)
        loss = loss_fn(y_pred, y_batch)
        loss.backward()
        optimizer.step()

        running_loss += loss.item()
        if i % 2000 == 1999:
            print('[%d, %5d] loss: %.3f' %
                  (epoch + 1, i + 1, running_loss / 2000))
            running_loss = 0.0

print('Обучение закончено')

```

C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\3687784610.py:12: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for epoch in tqdm_notebook(range(num_epochs)):

C:\Users\koshi8bit\anaconda3\lib\site-packages\torch\optim\lr_scheduler.py:129: UserWarning: Detected call of `lr_scheduler.step()` before `optimizer.step()`. In PyTorch 1.1.0 and later, you should call them in the opposite order: `optimizer.step()` before `lr_scheduler.step()`. Failure to do this will result in PyTorch skipping the first value of the learning rate schedule. See more details at <https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate>

```
earning rate schedule. See more details at https://pytorch.org/docs/stable/optim.html#how-to-adjust-learning-rate
warnings.warn("Detected call of `lr_scheduler.step()` before `optimizer.step()`. "
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\3687784610.py:17: TqdmDeprecationWar
ning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[1, 2000] loss: 1.862
[1, 4000] loss: 1.660
[1, 6000] loss: 1.575
[1, 8000] loss: 1.500
[1, 10000] loss: 1.426
[1, 12000] loss: 1.407
```

```
[2, 2000] loss: 1.299
[2, 4000] loss: 1.242
[2, 6000] loss: 1.218
[2, 8000] loss: 1.236
[2, 10000] loss: 1.224
[2, 12000] loss: 1.156
```

```
[3, 2000] loss: 1.080
[3, 4000] loss: 1.079
[3, 6000] loss: 1.072
[3, 8000] loss: 1.079
[3, 10000] loss: 1.047
[3, 12000] loss: 1.051
```

```
[4, 2000] loss: 0.972
[4, 4000] loss: 0.961
[4, 6000] loss: 0.962
[4, 8000] loss: 0.980
[4, 10000] loss: 0.966
[4, 12000] loss: 0.957
```

```
[5, 2000] loss: 0.933
[5, 4000] loss: 0.901
[5, 6000] loss: 0.918
[5, 8000] loss: 0.960
[5, 10000] loss: 0.958
[5, 12000] loss: 0.924
```

Обучение закончено

In [23]:

```
class_correct = list(0. for i in range(10))
class_total = list(0. for i in range(10))

with torch.no_grad():
    for data in testloader:
        images, labels = data
        y_pred = net(images)
        _, predicted = torch.max(y_pred, 1)
        c = (predicted == labels).squeeze()
        for i in range(4):
            label = labels[i]
            class_correct[label] += c[i].item()
            class_total[label] += 1

for i in range(10):
    print('Accuracy of %5s : %2d %%' % (
        classes[i], 100 * class_correct[i] / class_total[i]))
```

```
Accuracy of plane : 70 %
Accuracy of car : 76 %
Accuracy of bird : 48 %
Accuracy of cat : 42 %
Accuracy of deer : 58 %
Accuracy of dog : 51 %
```

Accuracy of frog : 69 %
Accuracy of horse : 67 %
Accuracy of ship : 74 %
Accuracy of truck : 72 %

Посмотрим визуально на работу нейросети:

In [24]:

```
i = np.random.randint(low=0, high=10000)

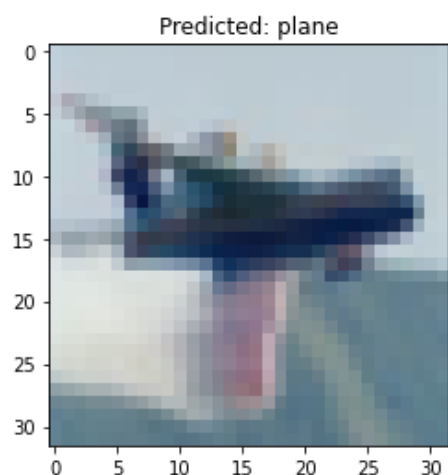
def visualize_result(index):
    image = testloader.dataset.data[index]
    plt.imshow(image)

    image = transform(image)  # не забудем отмасштабировать!

    y_pred = net(image.view(1, 3, 32, 32))
    _, predicted = torch.max(y_pred, 1)

    plt.title(f'Predicted: {classes[predicted.numpy()[0]]}')

visualize_result(i)
```



Даже обучив более глубокую и прокаченную (**BatchNorm**, **Dropout**) нейросеть на этих данных мы видим, что качество нас всё ещё не устраивает, в реальной жизни необходимо ошибаться не больше, чем на **5%**, а часто и это уже много. Как же быть, ведь свёрточные нейросети должны хорошо классифицировать изображения?

К сожалению, обучение нейросети с нуля на не очень большой выборке (а здесь она именно такая) часто приводит к переобучению, что плохо сказывается на тестовом качестве.

Для того, чтобы получить более качественную модель, часто дообучают сильную нейросеть, обученную на **ImageNet**, то есть используют технику **Transfer Learning**. О ней речь пойдёт далее в нашем курсе.

Полезные ссылки

1). Примеры написания нейросетей на **PyTorch** (официальные туториалы) (на английском):

https://pytorch.org/tutorials/beginner/pytorch_with_examples.html#examples

https://pytorch.org/tutorials/beginner/blitz/cifar10_tutorial.html

2). Курс Стэнфорда: <http://cs231n.github.io/>

3). Практически исчерпывающая информация по основам свёрточных нейросетей (из **cs231n**) (на английском):

<http://cs231n.github.io/convolutional-networks/>

<http://cs231n.github.io/understanding-cnn/>

<http://cs231n.github.io/transfer-learning/>

4). Видео о Computer Vision от Andrei Karpathy: <https://www.youtube.com/watch?v=u6aFVumt0M>

Пробую лучшую конфигурацию из **MNIST**

In [25]:

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

In [26]:

```
def check_network(net):
    class_correct = list(0. for i in range(10))
    class_total = list(0. for i in range(10))

    with torch.no_grad():
        for data in testloader:
            images, labels = data
            y_pred = net(images)
            _, predicted = torch.max(y_pred, 1)
            c = (predicted == labels).squeeze()
            for i in range(4):
                label = labels[i]
                class_correct[label] += c[i].item()
                class_total[label] += 1

    for i in range(10):
        print('Accuracy of %2s : %2d %%' % (
            classes[i], 100 * class_correct[i] / class_total[i]))

    class_correct_t = sum(class_correct)
    class_total_t = sum(class_total)

    print('Средняя точность:', (100. * class_correct_t / class_total_t))
```

In [37]:

```
def check_network(net):
    class_correct = list(0. for i in range(10))
    class_total = list(0. for i in range(10))

    with torch.no_grad():
        for data in testloader:
            images, labels = data
            y_pred = net(images)
            _, predicted = torch.max(y_pred, 1)
            c = (predicted == labels).squeeze()
            for i in range(4):
                label = labels[i]
                class_correct[label] += c[i].item()
                class_total[label] += 1

    for i in range(10):
        print('Accuracy of %5s : %2d %%' % (
            classes[i], 100 * class_correct[i] / class_total[i]))
    class_correct_t = sum(class_correct)
    class_total_t = sum(class_total)

    print('Средняя точность:', (100. * class_correct_t / class_total_t))
```

In [27]:

```
def train(net, learning_rate = 1e-4, num_epochs = 3):
    loss_fn = torch.nn.CrossEntropyLoss()
    tmp = []
    optimizer = torch.optim.Adam(net.parameters(), lr=learning_rate)
    # итерируется
```

```

for epoch in tqdm_notebook(range(num_epochs)):
    running_loss = 0.0
    for i, batch in enumerate(tqdm_notebook(trainloader)):
        # так получаем текущий батч
        X_batch, y_batch = batch

        # обнуляем веса
        optimizer.zero_grad()

        # forward + backward + optimize
        y_pred = nett(X_batch)
        loss = loss_fn(y_pred, y_batch)
        loss.backward()
        optimizer.step()

        # выведем текущий loss
        running_loss += loss.item()
        # выведем качество каждые 2000 батчей
        if i % 2000 == 1999:
            tmp.append(running_loss / 2000)
            print('[%d, %5d] loss: %.3f' %
                  (epoch + 1, i + 1, running_loss / 2000))
            running_loss = 0.0

    x = np.array(range(len(tmp)))
    y = np.array(tmp)
    print(x, y)
    plt.plot(x, y)
    plt.show()
print('OK')

```

In [33]:

```

class SimpleConvNet2(nn.Module):
    def __init__(self, channels1, channels2, kernel_size1, kernel_size2, fc1, fc2, is_max_pool = True):
        # вызов конструктора предка
        super(SimpleConvNet2, self).__init__()
        # необходимо заранее знать, сколько каналов у картинки (сейчас = 1),
        # которую будем подавать в сеть, больше ничего
        # про входящие картинки знать не нужно
        self.conv1 = nn.Conv2d(in_channels=3, out_channels=channels1, kernel_size=kernel_size1)
        new_size = 32 - kernel_size1 + 1
        if is_max_pool:
            self.pool = nn.MaxPool2d(kernel_size=2, stride=2)
        else:
            self.pool = nn.AvgPool2d(kernel_size=2, stride=2)
        new_size = new_size // 2
        self.conv2 = nn.Conv2d(in_channels=channels1, out_channels=channels2, kernel_size=kernel_size2)
        new_size = new_size - kernel_size2 + 1
        new_size = new_size // 2

        self.fc1_size = new_size * new_size * channels2

        self.fc1 = nn.Linear(new_size * new_size * channels2, fc1) # !!!
        self.fc2 = nn.Linear(fc1, fc2)
        self.fc3 = nn.Linear(fc2, 10)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        #print(x.shape)
        x = self.pool(F.relu(self.conv2(x)))
        #print(x.shape)
        x = x.view(-1, self.fc1_size) # !!!
        x = F.relu(self.fc1(x))
        x = F.relu(self.fc2(x))
        x = self.fc3(x)
        return x

```

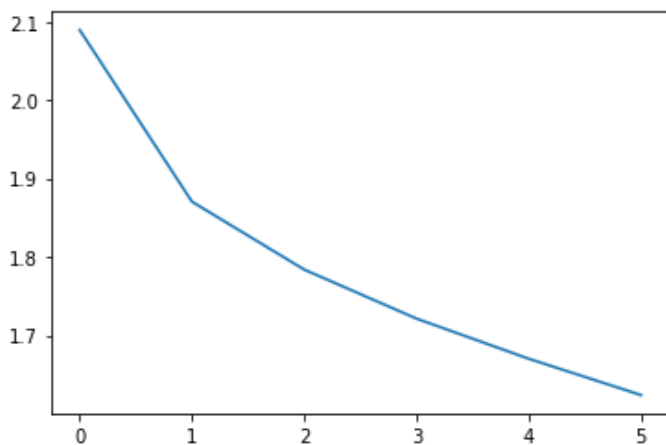
```
in [41]:
```

```
net = SimpleConvNet2(6, 16, 7, 3, 128, 64, True)
train(net, num_epochs=16)
check_network(net)
```

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:6: TqdmDeprecationWarn
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
    for epoch in tqdm_notebook(range(num_epochs)):
```

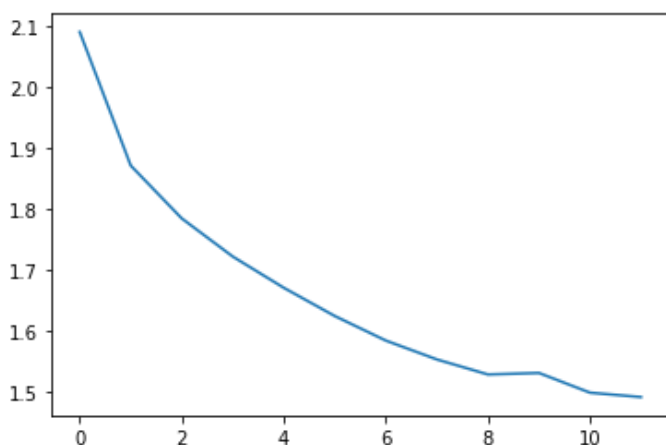
```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
    for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[1, 2000] loss: 2.089
[1, 4000] loss: 1.870
[1, 6000] loss: 1.784
[1, 8000] loss: 1.721
[1, 10000] loss: 1.670
[1, 12000] loss: 1.624
[0 1 2 3 4 5] [2.0892696 1.87029987 1.78373925 1.72123038 1.670055 1.62377672]
```



```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
    for i, batch in enumerate(tqdm_notebook(trainloader)):
```

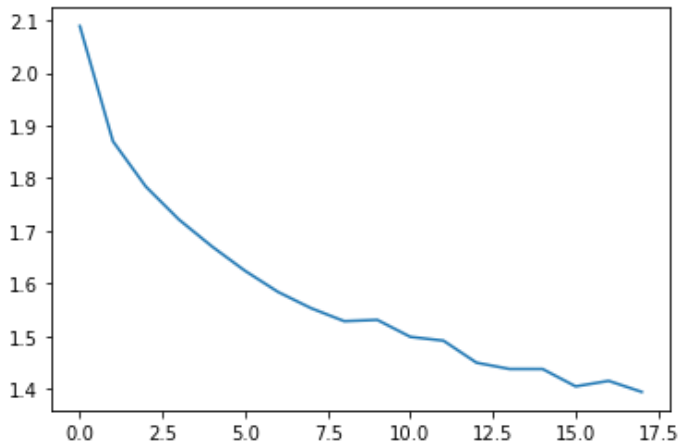
```
[2, 2000] loss: 1.584
[2, 4000] loss: 1.553
[2, 6000] loss: 1.528
[2, 8000] loss: 1.531
[2, 10000] loss: 1.498
[2, 12000] loss: 1.491
[0 1 2 3 4 5 6 7 8 9 10 11] [2.0892696 1.87029987 1.78373925 1.72123038 1.670
055 1.62377672
1.58358612 1.55268693 1.5280911 1.53055249 1.49823898 1.49108258]
```



```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn
ing: This function will be removed in tadm==5.0.0
```

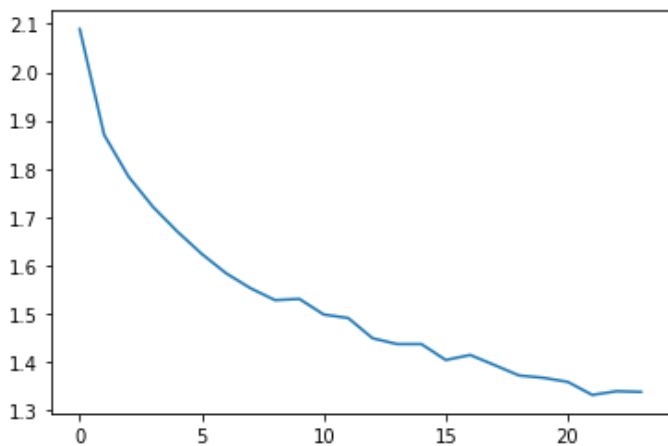
```
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[3, 2000] loss: 1.449  
[3, 4000] loss: 1.437  
[3, 6000] loss: 1.437  
[3, 8000] loss: 1.404  
[3, 10000] loss: 1.415  
[3, 12000] loss: 1.394  
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17] [2.0892696  1.87029987 1.78373925  
1.72123038 1.670055 1.62377672  
1.58358612 1.55268693 1.5280911 1.53055249 1.49823898 1.49108258  
1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451]
```



```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn  
ing: This function will be removed in tqdm==5.0.0  
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

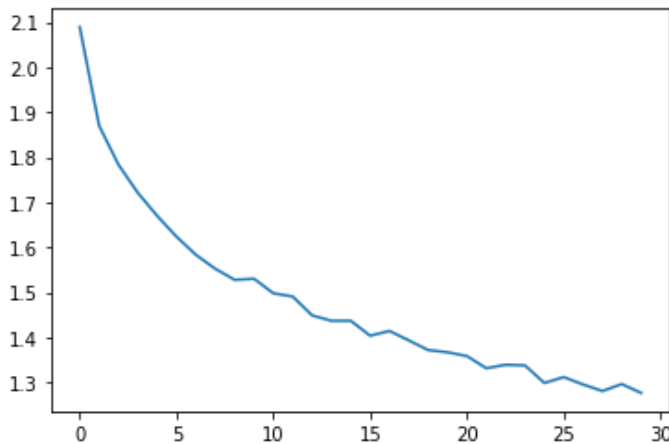
```
[4, 2000] loss: 1.372  
[4, 4000] loss: 1.367  
[4, 6000] loss: 1.359  
[4, 8000] loss: 1.332  
[4, 10000] loss: 1.340  
[4, 12000] loss: 1.338  
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23] [2.0892696  1.8  
7029987 1.78373925 1.72123038 1.670055 1.62377672  
1.58358612 1.55268693 1.5280911 1.53055249 1.49823898 1.49108258  
1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451  
1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885]
```



```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn  
ing: This function will be removed in tqdm==5.0.0  
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

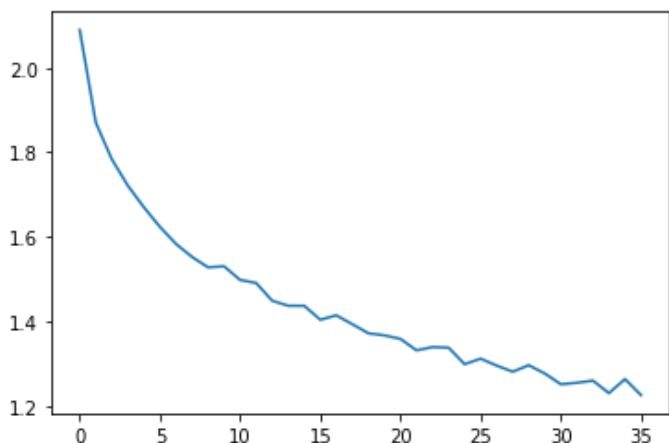
```
[5, 2000] loss: 1.299  
[5, 4000] loss: 1.312  
[5, 6000] loss: 1.296  
[5, 8000] loss: 1.281
```

```
[5, 10000] loss: 1.297
[5, 12000] loss: 1.277
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29] [2.0892696  1.87029987 1.78373925 1.72123038 1.670055  1.62377672
 1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
 1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
 1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
 1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

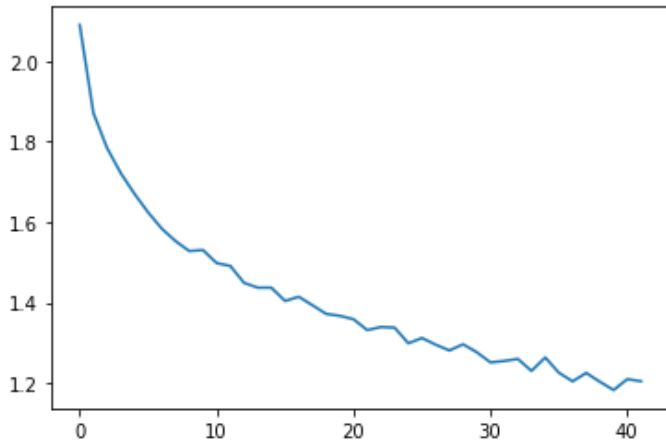
```
[6, 2000] loss: 1.252
[6, 4000] loss: 1.255
[6, 6000] loss: 1.260
[6, 8000] loss: 1.231
[6, 10000] loss: 1.264
[6, 12000] loss: 1.226
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35] [2.0892696  1.87029987 1.78373925 1.72123038 1.670055
 1.62377672
 1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
 1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
 1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
 1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
 1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

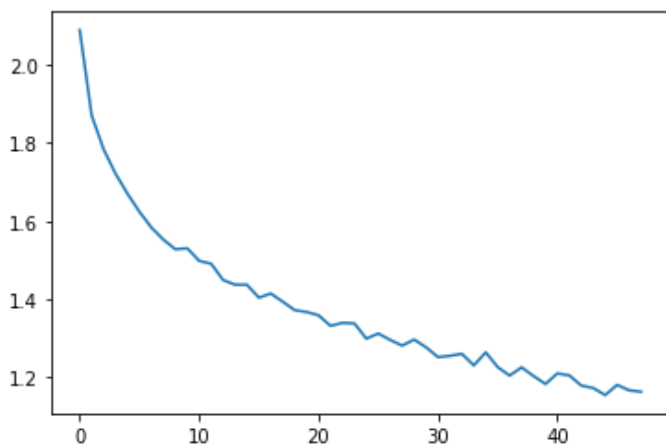
```
[7, 2000] loss: 1.205
[7, 4000] loss: 1.226
[7, 6000] loss: 1.203
[7, 8000] loss: 1.183
[7, 10000] loss: 1.210
[7, 12000] loss: 1.205
```

```
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41] [2.0892696  1.87029987 1.78373925
1.72123038 1.670055  1.62377672
1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[8, 2000] loss: 1.179
[8, 4000] loss: 1.173
[8, 6000] loss: 1.155
[8, 8000] loss: 1.181
[8, 10000] loss: 1.167
[8, 12000] loss: 1.163
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47] [2.0892696  1.87029987 1.78373925 1.72123038 1.670055  1.62377672
1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619
1.17890116 1.17265078 1.15469224 1.18070836 1.16677022 1.16323808]
```



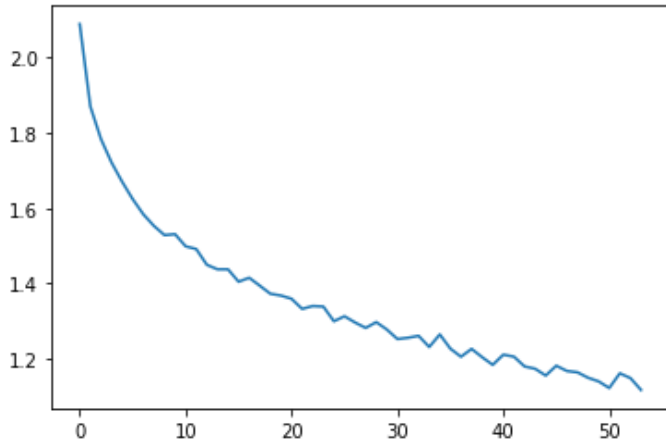
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[9, 2000] loss: 1.149
[9, 4000] loss: 1.139
[9, 6000] loss: 1.122
[9, 8000] loss: 1.161
```

```

[9, 8000] loss: 1.161
[9, 10000] loss: 1.148
[9, 12000] loss: 1.116
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53] [2.0892696  1.87029987 1.78373925 1.72123038 1.670055  1.62377672
 1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
 1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
 1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
 1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
 1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
 1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619
 1.17890116 1.17265078 1.15469224 1.18070836 1.16677022 1.16323808
 1.14878619 1.13905321 1.12150312 1.16061834 1.14782672 1.11644591]

```

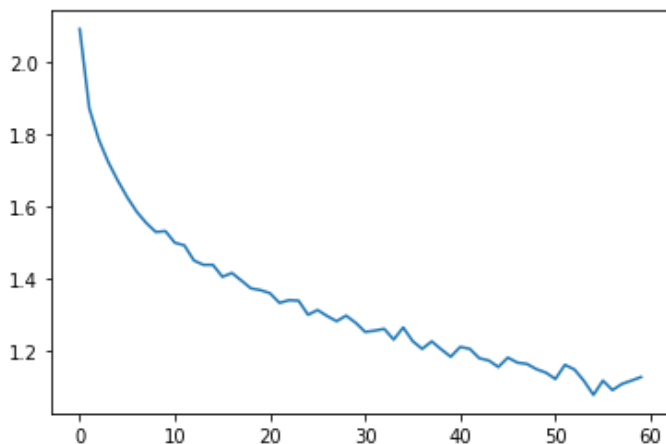


C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```

[10, 2000] loss: 1.077
[10, 4000] loss: 1.117
[10, 6000] loss: 1.091
[10, 8000] loss: 1.108
[10, 10000] loss: 1.117
[10, 12000] loss: 1.127
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59] [2.0892696  1.87029987 1.78373925 1.72123038 1.670055
 5  1.62377672
 1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
 1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
 1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
 1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
 1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
 1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619
 1.17890116 1.17265078 1.15469224 1.18070836 1.16677022 1.16323808
 1.14878619 1.13905321 1.12150312 1.16061834 1.14782672 1.11644591
 1.07747355 1.11698416 1.09076086 1.10785238 1.11710217 1.12678882]

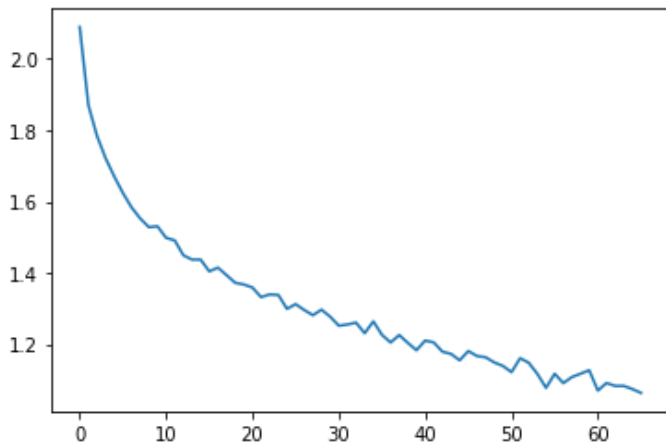
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

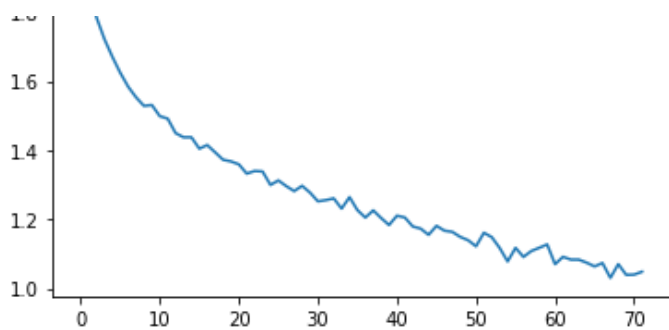
```
[11, 2000] loss: 1.070
[11, 4000] loss: 1.091
[11, 6000] loss: 1.083
[11, 8000] loss: 1.083
[11, 10000] loss: 1.074
[11, 12000] loss: 1.063
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65] [2.0892696  1.87029987 1.78373925
1.72123038 1.670055  1.62377672
1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619
1.17890116 1.17265078 1.15469224 1.18070836 1.16677022 1.16323808
1.14878619 1.13905321 1.12150312 1.16061834 1.14782672 1.11644591
1.07747355 1.11698416 1.09076086 1.10785238 1.11710217 1.12678882
1.06980582 1.09102106 1.08293311 1.08286585 1.07402457 1.06328142]
```



```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

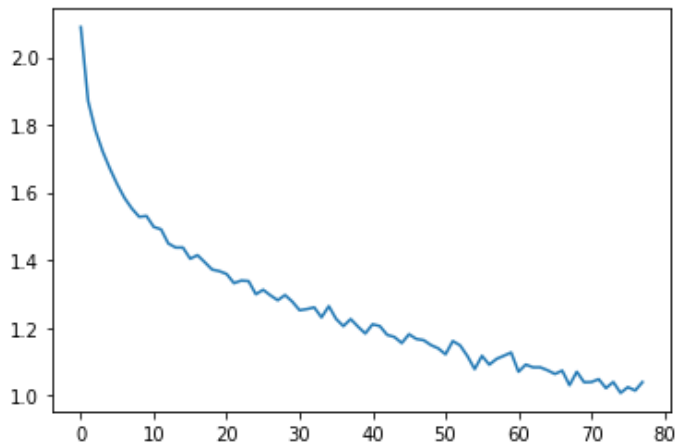
```
[12, 2000] loss: 1.073
[12, 4000] loss: 1.030
[12, 6000] loss: 1.070
[12, 8000] loss: 1.039
[12, 10000] loss: 1.039
[12, 12000] loss: 1.048
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71] [2.0892696  1.87
029987 1.78373925 1.72123038 1.670055  1.62377672
1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619
1.17890116 1.17265078 1.15469224 1.18070836 1.16677022 1.16323808
1.14878619 1.13905321 1.12150312 1.16061834 1.14782672 1.11644591
1.07747355 1.11698416 1.09076086 1.10785238 1.11710217 1.12678882
1.06980582 1.09102106 1.08293311 1.08286585 1.07402457 1.06328142
1.0730544  1.0299423  1.06984808 1.03876956 1.03940007 1.04785426]
```





C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[13, 2000] loss: 1.021
[13, 4000] loss: 1.039
[13, 6000] loss: 1.007
[13, 8000] loss: 1.024
[13, 10000] loss: 1.014
[13, 12000] loss: 1.039
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
 72 73 74 75 76 77] [2.0892696  1.87029987 1.78373925 1.72123038 1.670055  1.62377672
 1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
 1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
 1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
 1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
 1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
 1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619
 1.17890116 1.17265078 1.15469224 1.18070836 1.16677022 1.16323808
 1.14878619 1.13905321 1.12150312 1.16061834 1.14782672 1.11644591
 1.07747355 1.11698416 1.09076086 1.10785238 1.11710217 1.12678882
 1.06980582 1.09102106 1.08293311 1.08286585 1.07402457 1.06328142
 1.0730544  1.0299423  1.06984808 1.03876956 1.03940007 1.04785426
 1.02139827 1.03940176 1.0072442  1.0243159  1.01427089 1.03915798]
```



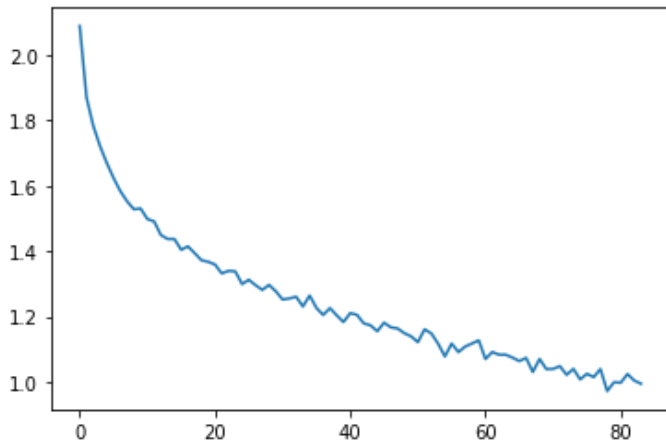
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[14, 2000] loss: 0.972
[14, 4000] loss: 0.998
[14, 6000] loss: 0.997
[14, 8000] loss: 1.024
[14, 10000] loss: 1.004
[14, 12000] loss: 0.994
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
 72 73 74 75 76 77 78 79 80 81 82 83] [2.0892696  1.87029987 1.78373925 1.72123038 1.670055  1.62377672
 1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
 1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
 1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
 1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
 1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
 1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619
 1.17890116 1.17265078 1.15469224 1.18070836 1.16677022 1.16323808
 1.14878619 1.13905321 1.12150312 1.16061834 1.14782672 1.11644591
 1.07747355 1.11698416 1.09076086 1.10785238 1.11710217 1.12678882
 1.06980582 1.09102106 1.08293311 1.08286585 1.07402457 1.06328142
 1.0730544  1.0299423  1.06984808 1.03876956 1.03940007 1.04785426
 1.02139827 1.03940176 1.0072442  1.0243159  1.01427089 1.03915798]
```

```

1.58358612 1.55268693 1.5280911 1.53055249 1.49823898 1.49108258
1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619
1.17890116 1.17265078 1.15469224 1.18070836 1.16677022 1.16323808
1.14878619 1.13905321 1.12150312 1.16061834 1.14782672 1.11644591
1.07747355 1.11698416 1.09076086 1.10785238 1.11710217 1.12678882
1.06980582 1.09102106 1.08293311 1.08286585 1.07402457 1.06328142
1.0730544 1.0299423 1.06984808 1.03876956 1.03940007 1.04785426
1.02139827 1.03940176 1.0072442 1.0243159 1.01427089 1.03915798
0.97159083 0.99840684 0.99711362 1.02356767 1.00390686 0.99385623]

```

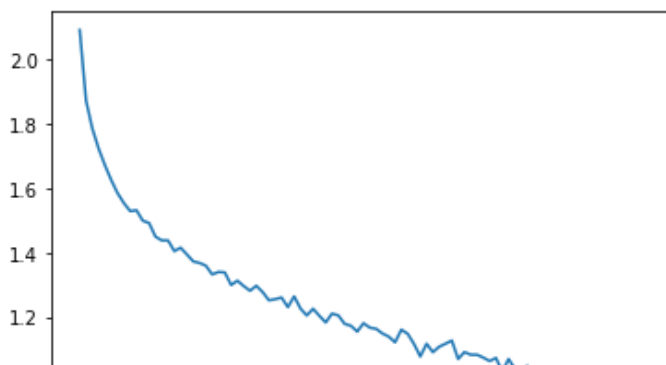


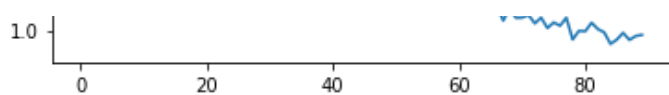
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```

[15, 2000] loss: 0.958
[15, 4000] loss: 0.971
[15, 6000] loss: 0.992
[15, 8000] loss: 0.970
[15, 10000] loss: 0.982
[15, 12000] loss: 0.986
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89] [2.0892696  1.87029987 1.78373925
1.72123038 1.670055  1.62377672
1.58358612 1.55268693 1.5280911  1.53055249 1.49823898 1.49108258
1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619
1.17890116 1.17265078 1.15469224 1.18070836 1.16677022 1.16323808
1.14878619 1.13905321 1.12150312 1.16061834 1.14782672 1.11644591
1.07747355 1.11698416 1.09076086 1.10785238 1.11710217 1.12678882
1.06980582 1.09102106 1.08293311 1.08286585 1.07402457 1.06328142
1.0730544 1.0299423 1.06984808 1.03876956 1.03940007 1.04785426
1.02139827 1.03940176 1.0072442 1.0243159 1.01427089 1.03915798
0.97159083 0.99840684 0.99711362 1.02356767 1.00390686 0.99385623
0.95801587 0.9710532  0.9922554  0.97038159 0.98236516 0.98603356]

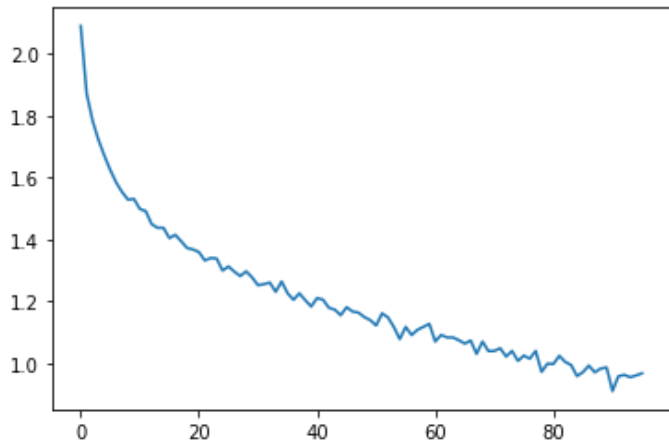
```





C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[16, 2000] loss: 0.910
[16, 4000] loss: 0.958
[16, 6000] loss: 0.962
[16, 8000] loss: 0.954
[16, 10000] loss: 0.960
[16, 12000] loss: 0.967
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95] [2.0892696  1.87
0.29987 1.78373925 1.72123038 1.670055 1.62377672
 1.58358612 1.55268693 1.5280911 1.53055249 1.49823898 1.49108258
 1.44917333 1.43718538 1.43713752 1.40411636 1.41459291 1.39359451
 1.37210221 1.36731272 1.35882572 1.33187698 1.33950992 1.33807885
 1.29907786 1.31220637 1.29568087 1.28131518 1.29662122 1.27706143
 1.25168835 1.25514818 1.26021972 1.23055347 1.26392971 1.22610636
 1.20466561 1.22552601 1.20337416 1.18304331 1.21015504 1.20486619
 1.17890116 1.17265078 1.15469224 1.18070836 1.16677022 1.16323808
 1.14878619 1.13905321 1.12150312 1.16061834 1.14782672 1.11644591
 1.07747355 1.11698416 1.09076086 1.10785238 1.11710217 1.12678882
 1.06980582 1.09102106 1.08293311 1.08286585 1.07402457 1.06328142
 1.0730544 1.0299423 1.06984808 1.03876956 1.03940007 1.04785426
 1.02139827 1.03940176 1.0072442 1.0243159 1.01427089 1.03915798
 0.97159083 0.99840684 0.99711362 1.02356767 1.00390686 0.99385623
 0.95801587 0.9710532 0.9922554 0.97038159 0.98236516 0.98603356
 0.90980207 0.95765962 0.96200769 0.95447356 0.96026989 0.96697766]
```



OK
Accuracy of plane : 61 %
Accuracy of car : 63 %
Accuracy of bird : 43 %
Accuracy of cat : 46 %
Accuracy of deer : 50 %
Accuracy of dog : 48 %
Accuracy of frog : 75 %
Accuracy of horse : 67 %
Accuracy of ship : 78 %
Accuracy of truck : 74 %
Средняя точность: 60.76

In [43]:

```
check_network(net)
```

Accuracy of plane : 72 %
Accuracy of car : 62 %
Accuracy of bird : 55 %
Accuracy of cat : 42 %

```
Accuracy of cat : 42 %  
Accuracy of deer : 49 %  
Accuracy of dog : 50 %  
Accuracy of frog : 73 %  
Accuracy of horse : 62 %  
Accuracy of ship : 68 %  
Accuracy of truck : 75 %  
Средняя точность: 61.0
```

Ура! С самого начала получилось получить **61%** применяя сетку из **MNIST**

Попробую дообучить

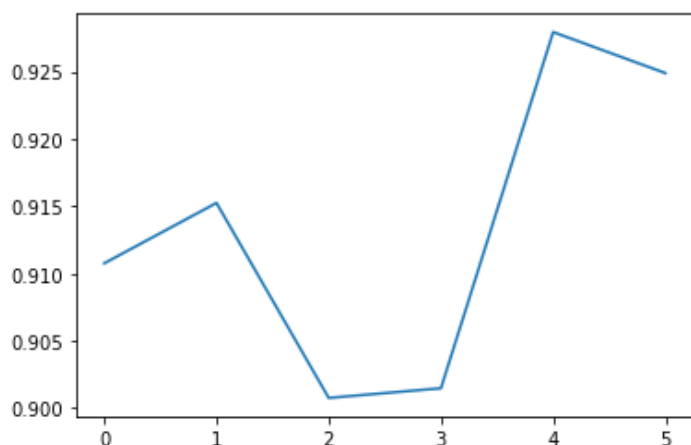
In [44]:

```
train(net, num_epochs=16)  
check_network(net)
```

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:6: TqdmDeprecationWarn  
ing: This function will be removed in tqdm==5.0.0  
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
    for epoch in tqdm_notebook(range(num_epochs)):
```

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn  
ing: This function will be removed in tqdm==5.0.0  
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
    for i, batch in enumerate(tqdm_notebook(trainloader)):
```

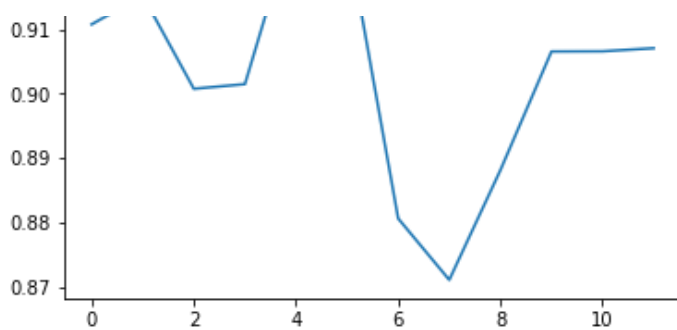
```
[1, 2000] loss: 0.911  
[1, 4000] loss: 0.915  
[1, 6000] loss: 0.901  
[1, 8000] loss: 0.901  
[1, 10000] loss: 0.928  
[1, 12000] loss: 0.925  
[0 1 2 3 4 5] [0.91076048 0.91524454 0.90076564 0.90148068 0.92793281 0.92488344]
```



```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn  
ing: This function will be removed in tqdm==5.0.0  
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
    for i, batch in enumerate(tqdm_notebook(trainloader)):
```

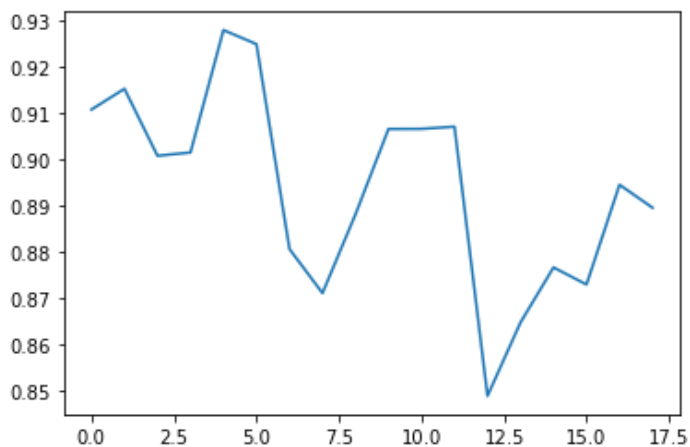
```
[2, 2000] loss: 0.881  
[2, 4000] loss: 0.871  
[2, 6000] loss: 0.888  
[2, 8000] loss: 0.907  
[2, 10000] loss: 0.907  
[2, 12000] loss: 0.907  
[ 0 1 2 3 4 5 6 7 8 9 10 11] [0.91076048 0.91524454 0.90076564 0.90148068 0.927  
93281 0.92488344  
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086]
```





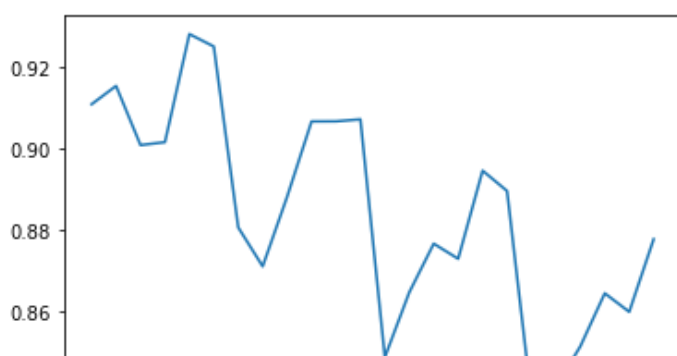
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

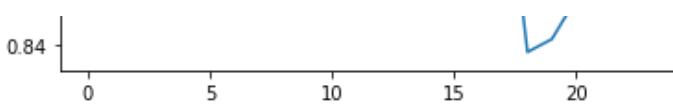
```
[3, 2000] loss: 0.849
[3, 4000] loss: 0.865
[3, 6000] loss: 0.877
[3, 8000] loss: 0.873
[3, 10000] loss: 0.895
[3, 12000] loss: 0.890
[ 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17] [0.91076048 0.91524454 0.90076564
0.90148068 0.92793281 0.92488344
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

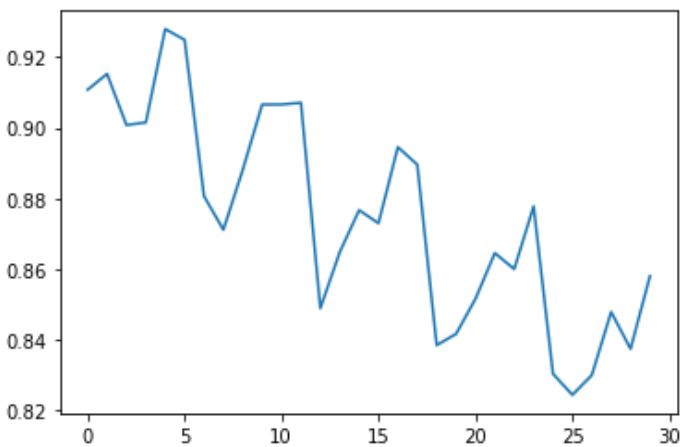
```
[4, 2000] loss: 0.838
[4, 4000] loss: 0.842
[4, 6000] loss: 0.852
[4, 8000] loss: 0.865
[4, 10000] loss: 0.860
[4, 12000] loss: 0.878
[ 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23] [0.91076048 0.9
1524454 0.90076564 0.90148068 0.92793281 0.92488344
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416]
```





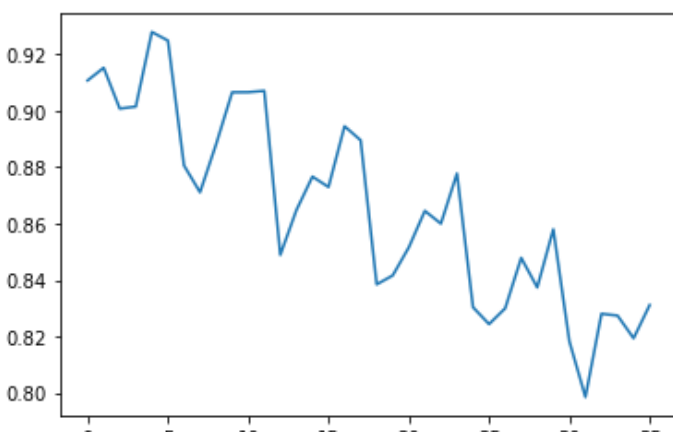
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[5, 2000] loss: 0.830
[5, 4000] loss: 0.824
[5, 6000] loss: 0.830
[5, 8000] loss: 0.848
[5, 10000] loss: 0.837
[5, 12000] loss: 0.858
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29] [0.91076048 0.91524454 0.90076564 0.90148068 0.92793281 0.92488344
 0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
 0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
 0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
 0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869]
```



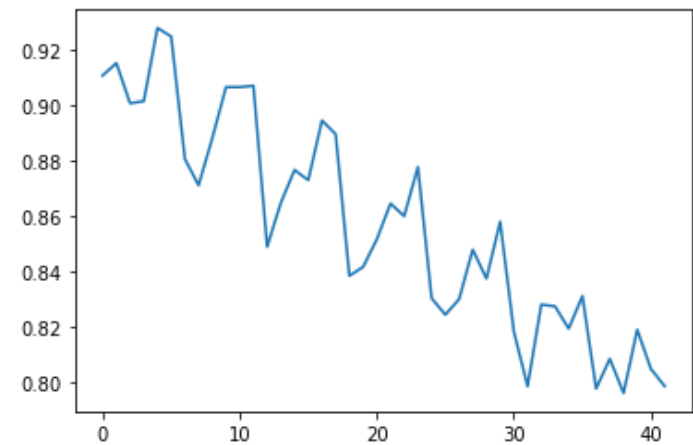
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[6, 2000] loss: 0.818
[6, 4000] loss: 0.798
[6, 6000] loss: 0.828
[6, 8000] loss: 0.827
[6, 10000] loss: 0.819
[6, 12000] loss: 0.831
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35] [0.91076048 0.91524454 0.90076564 0.90148068 0.92793281 0.92488344
 0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
 0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
 0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
 0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
 0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042]
```



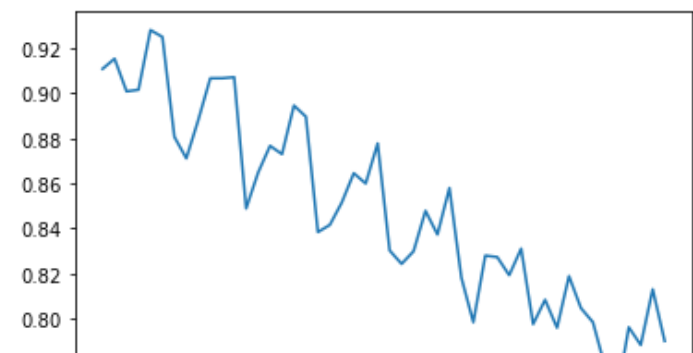
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

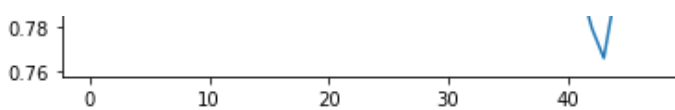
```
[7, 2000] loss: 0.798
[7, 4000] loss: 0.808
[7, 6000] loss: 0.796
[7, 8000] loss: 0.819
[7, 10000] loss: 0.805
[7, 12000] loss: 0.799
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41] [0.91076048 0.91524454 0.90076564
0.90148068 0.92793281 0.92488344
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042
0.79765403 0.80842902 0.79604328 0.81891201 0.80474002 0.79852631]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

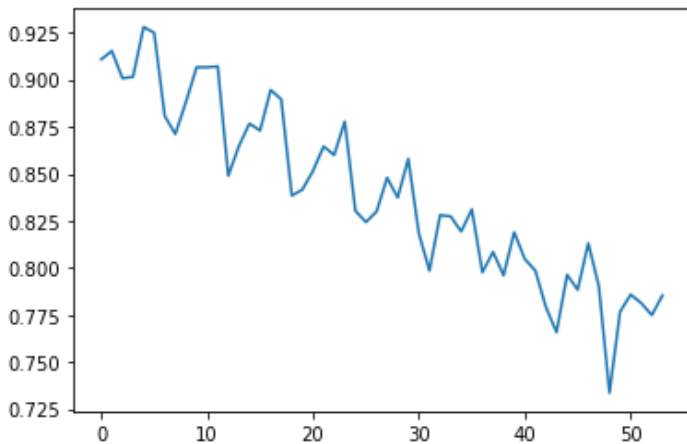
```
[8, 2000] loss: 0.779
[8, 4000] loss: 0.766
[8, 6000] loss: 0.796
[8, 8000] loss: 0.788
[8, 10000] loss: 0.813
[8, 12000] loss: 0.790
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47] [0.91076048 0.91
524454 0.90076564 0.90148068 0.92793281 0.92488344
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042
0.79765403 0.80842902 0.79604328 0.81891201 0.80474002 0.79852631
0.77912054 0.765854 0.79626778 0.78842402 0.81308925 0.79019344]
```





C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

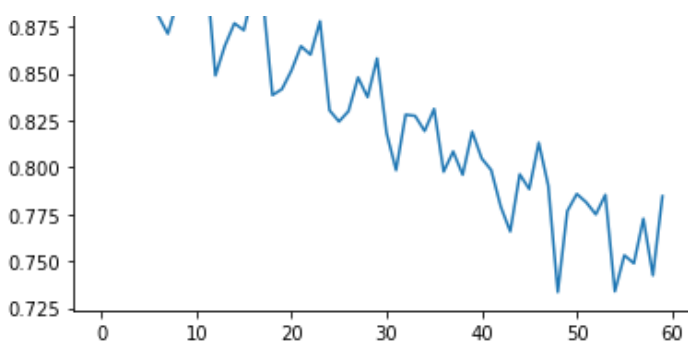
```
[9, 2000] loss: 0.734
[9, 4000] loss: 0.777
[9, 6000] loss: 0.786
[9, 8000] loss: 0.781
[9, 10000] loss: 0.775
[9, 12000] loss: 0.785
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53] [0.91076048 0.91524454 0.90076564 0.90148068 0.92793281 0.92488344
 0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
 0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
 0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
 0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
 0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042
 0.79765403 0.80842902 0.79604328 0.81891201 0.80474002 0.79852631
 0.77912054 0.765854 0.79626778 0.78842402 0.81308925 0.79019344
 0.7335861 0.77670211 0.78580668 0.78132338 0.77490727 0.7853479 ]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

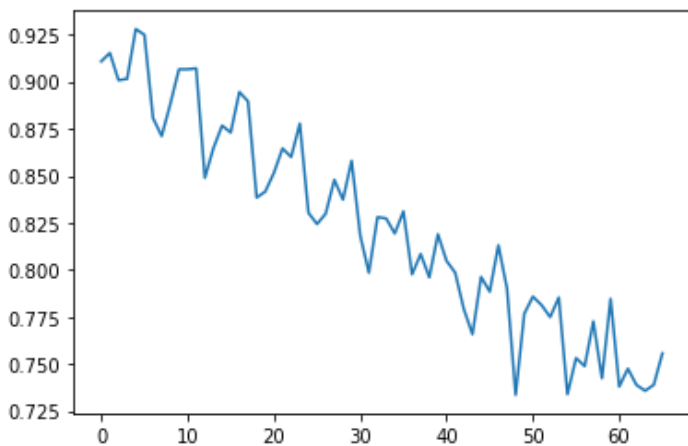
```
[10, 2000] loss: 0.734
[10, 4000] loss: 0.753
[10, 6000] loss: 0.749
[10, 8000] loss: 0.773
[10, 10000] loss: 0.742
[10, 12000] loss: 0.785
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59] [0.91076048 0.91524454 0.90076564 0.90148068 0.92793281 0.92488344
 0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
 0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
 0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
 0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
 0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042
 0.79765403 0.80842902 0.79604328 0.81891201 0.80474002 0.79852631
 0.77912054 0.765854 0.79626778 0.78842402 0.81308925 0.79019344
 0.7335861 0.77670211 0.78580668 0.78132338 0.77490727 0.7853479
 0.73396329 0.75315651 0.74885806 0.77266318 0.74246174 0.78460778]
```





C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[11, 2000] loss: 0.738
[11, 4000] loss: 0.748
[11, 6000] loss: 0.739
[11, 8000] loss: 0.736
[11, 10000] loss: 0.739
[11, 12000] loss: 0.756
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65] [0.91076048 0.91524454 0.90076564
0.90148068 0.92793281 0.92488344
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042
0.79765403 0.80842902 0.79604328 0.81891201 0.80474002 0.79852631
0.77912054 0.765854 0.79626778 0.78842402 0.81308925 0.79019344
0.7335861 0.77670211 0.78580668 0.78132338 0.77490727 0.7853479
0.73396329 0.75315651 0.74885806 0.77266318 0.74246174 0.78460778
0.73799708 0.74752441 0.73884806 0.7357746 0.73894033 0.75566989]
```



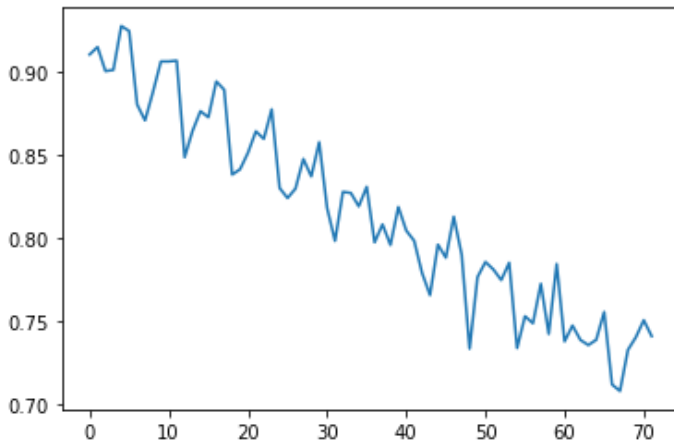
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[12, 2000] loss: 0.712
[12, 4000] loss: 0.708
[12, 6000] loss: 0.733
[12, 8000] loss: 0.740
[12, 10000] loss: 0.751
[12, 12000] loss: 0.741
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71] [0.91076048 0.91
524454 0.90076564 0.90148068 0.92793281 0.92488344
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416]
```

```

0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042
0.79765403 0.80842902 0.79604328 0.81891201 0.80474002 0.79852631
0.77912054 0.765854 0.79626778 0.78842402 0.81308925 0.79019344
0.7335861 0.77670211 0.78580668 0.78132338 0.77490727 0.7853479
0.73396329 0.75315651 0.74885806 0.77266318 0.74246174 0.78460778
0.73799708 0.74752441 0.73884806 0.7357746 0.73894033 0.75566989
0.71199349 0.70807784 0.73287387 0.7404387 0.75075087 0.74114599]

```

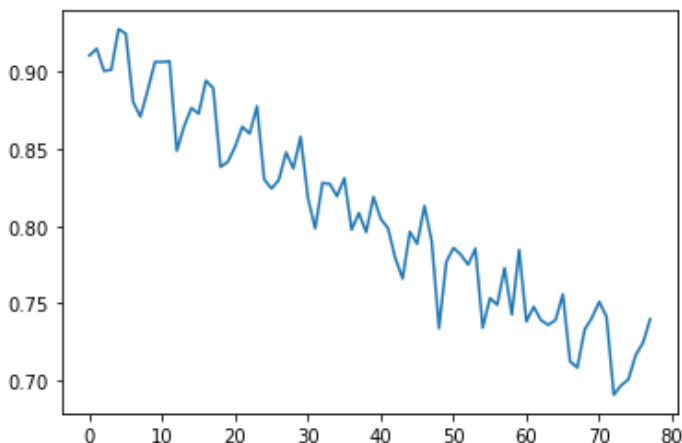


C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```

[13, 2000] loss: 0.690
[13, 4000] loss: 0.697
[13, 6000] loss: 0.700
[13, 8000] loss: 0.716
[13, 10000] loss: 0.724
[13, 12000] loss: 0.740
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
72 73 74 75 76 77] [0.91076048 0.91524454 0.90076564 0.90148068 0.92793281 0.92488344
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042
0.79765403 0.80842902 0.79604328 0.81891201 0.80474002 0.79852631
0.77912054 0.765854 0.79626778 0.78842402 0.81308925 0.79019344
0.7335861 0.77670211 0.78580668 0.78132338 0.77490727 0.7853479
0.73396329 0.75315651 0.74885806 0.77266318 0.74246174 0.78460778
0.73799708 0.74752441 0.73884806 0.7357746 0.73894033 0.75566989
0.71199349 0.70807784 0.73287387 0.7404387 0.75075087 0.74114599
0.69032109 0.6965586 0.70035303 0.71615571 0.72406578 0.73955277]

```

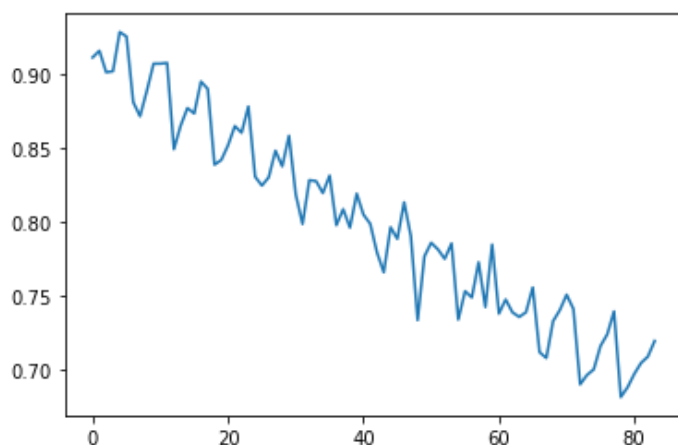


C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```

[14, 2000] loss: 0.682
[14, 4000] loss: 0.688
[14, 6000] loss: 0.697
[14, 8000] loss: 0.705
[14, 10000] loss: 0.709
[14, 12000] loss: 0.720
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
 72 73 74 75 76 77 78 79 80 81 82 83] [0.91076048 0.91524454 0.90076564 0.90148068 0.92793
281 0.92488344
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042
0.79765403 0.80842902 0.79604328 0.81891201 0.80474002 0.79852631
0.77912054 0.765854 0.79626778 0.78842402 0.81308925 0.79019344
0.7335861 0.77670211 0.78580668 0.78132338 0.77490727 0.7853479
0.73396329 0.75315651 0.74885806 0.77266318 0.74246174 0.78460778
0.73799708 0.74752441 0.73884806 0.7357746 0.73894033 0.75566989
0.71199349 0.70807784 0.73287387 0.7404387 0.75075087 0.74114599
0.69032109 0.6965586 0.70035303 0.71615571 0.72406578 0.73955277
0.68174013 0.68832635 0.69742198 0.70478073 0.70905197 0.71957125]

```

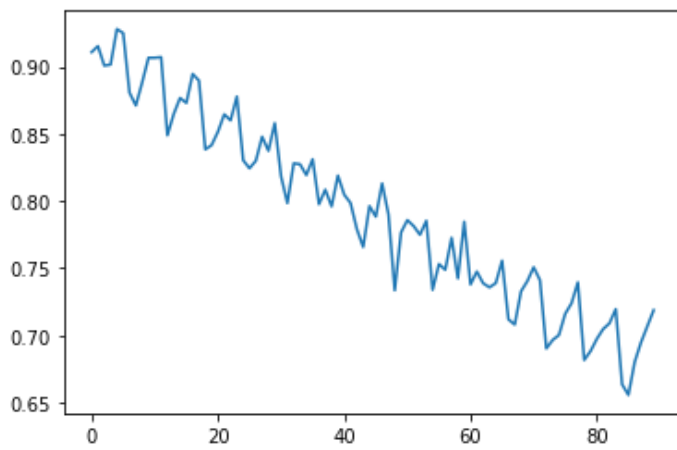


C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```

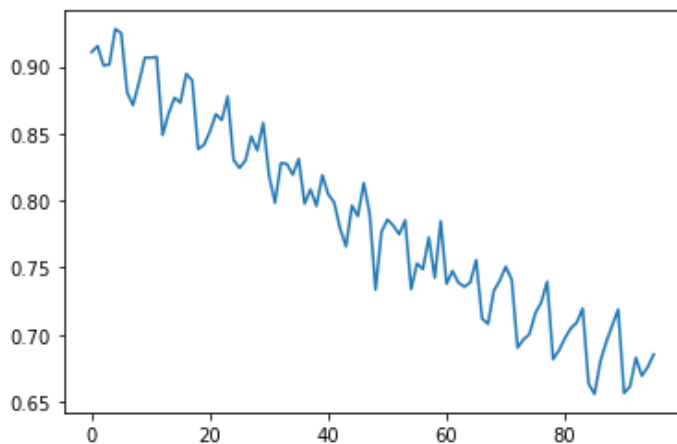
[15, 2000] loss: 0.664
[15, 4000] loss: 0.656
[15, 6000] loss: 0.680
[15, 8000] loss: 0.695
[15, 10000] loss: 0.707
[15, 12000] loss: 0.719
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89] [0.91076048 0.91524454 0.90076564
0.90148068 0.92793281 0.92488344
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042
0.79765403 0.80842902 0.79604328 0.81891201 0.80474002 0.79852631
0.77912054 0.765854 0.79626778 0.78842402 0.81308925 0.79019344
0.7335861 0.77670211 0.78580668 0.78132338 0.77490727 0.7853479
0.73396329 0.75315651 0.74885806 0.77266318 0.74246174 0.78460778
0.73799708 0.74752441 0.73884806 0.7357746 0.73894033 0.75566989
0.71199349 0.70807784 0.73287387 0.7404387 0.75075087 0.74114599
0.69032109 0.6965586 0.70035303 0.71615571 0.72406578 0.73955277
0.68174013 0.68832635 0.69742198 0.70478073 0.70905197 0.71957125
0.66367953 0.65579041 0.68032207 0.69491124 0.70689355 0.71882059]

```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[16, 2000] loss: 0.656
[16, 4000] loss: 0.661
[16, 6000] loss: 0.683
[16, 8000] loss: 0.669
[16, 10000] loss: 0.676
[16, 12000] loss: 0.685
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71
 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95] [0.91076048 0.91
524454 0.90076564 0.90148068 0.92793281 0.92488344
0.88062244 0.87109414 0.88812511 0.90655529 0.90658403 0.90706086
0.84888357 0.86475236 0.87664611 0.87295389 0.89451164 0.88955182
0.83842172 0.84160589 0.8515423 0.86450631 0.85996865 0.87774416
0.83031412 0.82434349 0.82992129 0.84784578 0.83736682 0.85796869
0.81826026 0.79848322 0.82801767 0.82737456 0.81932659 0.83109042
0.79765403 0.80842902 0.79604328 0.81891201 0.80474002 0.79852631
0.77912054 0.765854 0.79626778 0.78842402 0.81308925 0.79019344
0.7335861 0.77670211 0.78580668 0.78132338 0.77490727 0.7853479
0.73396329 0.75315651 0.74885806 0.77266318 0.74246174 0.78460778
0.73799708 0.74752441 0.73884806 0.7357746 0.73894033 0.75566989
0.71199349 0.70807784 0.73287387 0.7404387 0.75075087 0.74114599
0.69032109 0.6965586 0.70035303 0.71615571 0.72406578 0.73955277
0.68174013 0.68832635 0.69742198 0.70478073 0.70905197 0.71957125
0.66367953 0.65579041 0.68032207 0.69491124 0.70689355 0.71882059
0.6564276 0.66142815 0.68292711 0.66939013 0.67588274 0.68533777]
```



OK
Accuracy of plane : 65 %
Accuracy of car : 65 %
Accuracy of bird : 54 %
Accuracy of cat : 37 %
Accuracy of deer : 52 %
Accuracy of dog : 52 %
Accuracy of frog : 71 %

```
Accuracy of 1109 : 71 %
Accuracy of horse : 72 %
Accuracy of ship : 78 %
Accuracy of truck : 69 %
Средняя точность: 62.18
```

In [45]:

```
check_network(net)
```

```
Accuracy of plane : 65 %
Accuracy of car : 65 %
Accuracy of bird : 54 %
Accuracy of cat : 37 %
Accuracy of deer : 52 %
Accuracy of dog : 52 %
Accuracy of frog : 71 %
Accuracy of horse : 72 %
Accuracy of ship : 78 %
Accuracy of truck : 69 %
Средняя точность: 62.18
```

In []:

Дообучение сильно не помогло.

Пробую добиться такого же результата, но за меньшее кол-во эпох засчет добавления pool слоя и подбора параметров

In [46]:

```
class ConvNet1(nn.Module):
    def __init__(self, channels1, channels2, channels3, kernel_size1, kernel_size2, kernel_size3, fc1, fc2, is_max_pool = True):
        # вызов конструктора класса nn.Module()
        super(ConvNet1, self).__init__()

        if is_max_pool:
            self.pool = nn.MaxPool2d(kernel_size=2, stride=2)
        else:
            self.pool = nn.AvgPool2d(kernel_size=2, stride=2)

        self.conv1 = nn.Conv2d(in_channels=3, out_channels=channels1, kernel_size=kernel_size1)
        new_size = 32 - kernel_size1 + 1
        new_size = new_size // 2

        self.conv2 = nn.Conv2d(in_channels=channels1, out_channels=channels2, kernel_size=kernel_size2)
        new_size = new_size - kernel_size2 + 1
        #new_size = new_size // 2 #тут нет пулинга

        self.conv3 = nn.Conv2d(in_channels=channels2, out_channels=channels3, kernel_size=kernel_size3)
        new_size = new_size - kernel_size3 + 1
        new_size = new_size // 2

        print(new_size)

        self.fc1_size = new_size * new_size * channels3

        self.fc1 = nn.Linear(self.fc1_size, fc1)
        self.fc2 = nn.Linear(fc1, fc2)
        self.fc3 = nn.Linear(fc2, 10)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        x = self.pool(self.conv3(F.relu(self.conv2(x))))
        # print(x.shape)
        x = x.view(-1, self.fc1_size)
        x = F.relu(self.fc1(x))
        x = F.relu(self.fc2(x))
        x = self.fc3(x)
```

```
return x
```

```
In [47]:
```

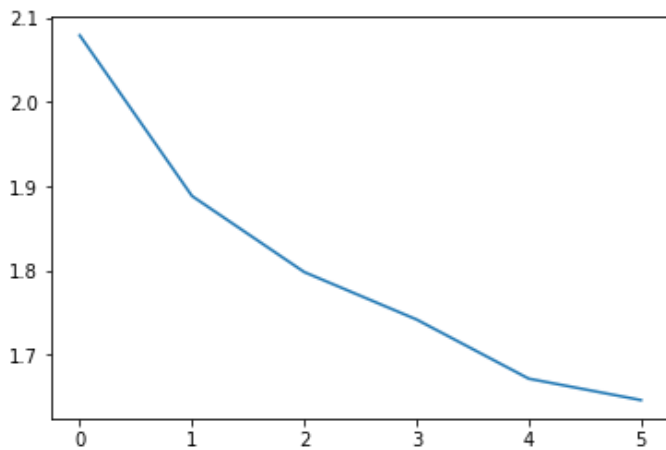
```
net = ConvNet1(6, 16, 32, 5, 5, 5, 128, 64, True)
train(net)
```

```
3
```

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:6: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
  for epoch in tqdm_notebook(range(num_epochs)):
```

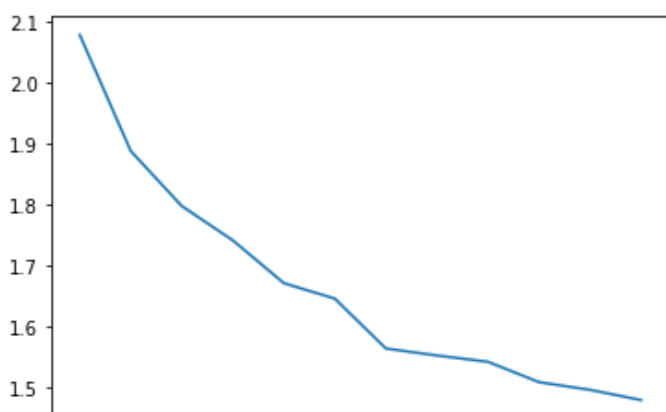
```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
  for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[1, 2000] loss: 2.079
[1, 4000] loss: 1.888
[1, 6000] loss: 1.798
[1, 8000] loss: 1.742
[1, 10000] loss: 1.672
[1, 12000] loss: 1.647
[0 1 2 3 4 5] [2.07883386 1.88842796 1.79827675 1.74209487 1.6719412 1.6465397 ]
```



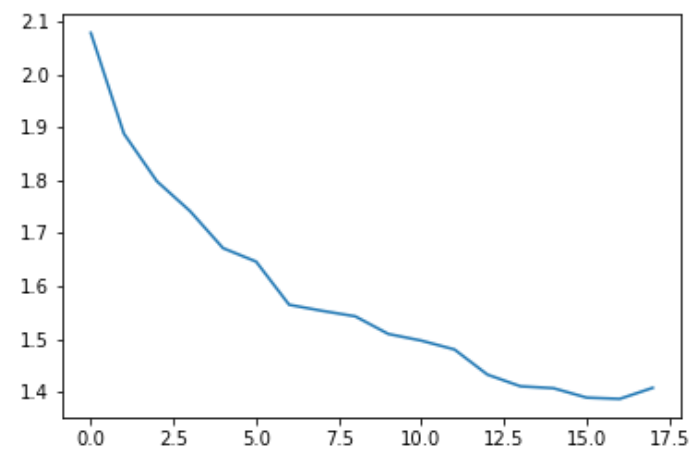
```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
  for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[2, 2000] loss: 1.565
[2, 4000] loss: 1.553
[2, 6000] loss: 1.543
[2, 8000] loss: 1.510
[2, 10000] loss: 1.497
[2, 12000] loss: 1.480
[0 1 2 3 4 5 6 7 8 9 10 11] [2.07883386 1.88842796 1.79827675 1.74209487 1.671
9412 1.6465397
1.5648766 1.55340699 1.54305344 1.5097178 1.49711242 1.48041827]
```



```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[3, 2000] loss: 1.433
[3, 4000] loss: 1.411
[3, 6000] loss: 1.407
[3, 8000] loss: 1.389
[3, 10000] loss: 1.387
[3, 12000] loss: 1.408
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17] [2.07883386 1.88842796 1.79827675
1.74209487 1.6719412 1.6465397
1.5648766 1.55340699 1.54305344 1.5097178 1.49711242 1.48041827
1.43280019 1.41078342 1.40711129 1.38938427 1.38695624 1.40785099]
```



OK

In [48]:

```
check_network(net)
```

```
Accuracy of plane : 57 %
Accuracy of car : 67 %
Accuracy of bird : 41 %
Accuracy of cat : 21 %
Accuracy of deer : 32 %
Accuracy of dog : 40 %
Accuracy of frog : 62 %
Accuracy of horse : 50 %
Accuracy of ship : 65 %
Accuracy of truck : 54 %
Средняя точность: 49.52
```

In [49]:

```
net = ConvNet1(6, 16, 32, 7, 5, 3, 128, 64, True)
train(net)
```

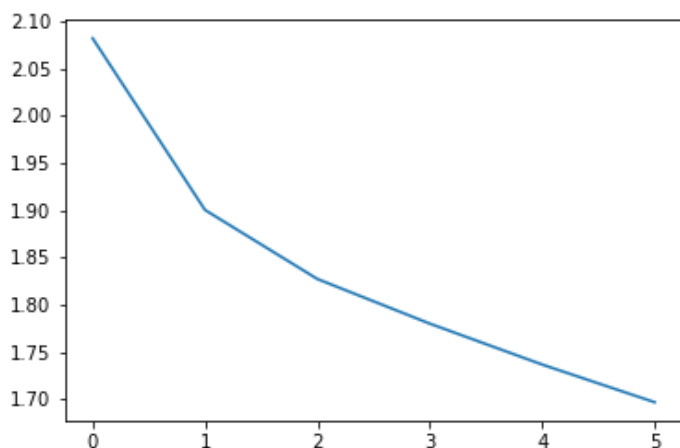
3

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:6: TqdmDeprecationWarn
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for epoch in tqdm_notebook(range(num_epochs)):
```

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

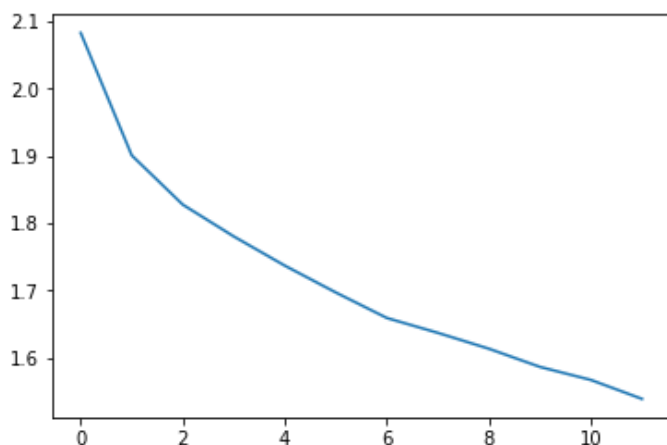
```
[1, 2000] loss: 2.082
[1, 4000] loss: 1.900
[1, 6000] loss: 1.887
```

```
[1, 6000] loss: 1.827
[1, 8000] loss: 1.780
[1, 10000] loss: 1.737
[1, 12000] loss: 1.697
[0 1 2 3 4 5] [2.08229958 1.9003437 1.82719947 1.77991779 1.73654272 1.6966441 ]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

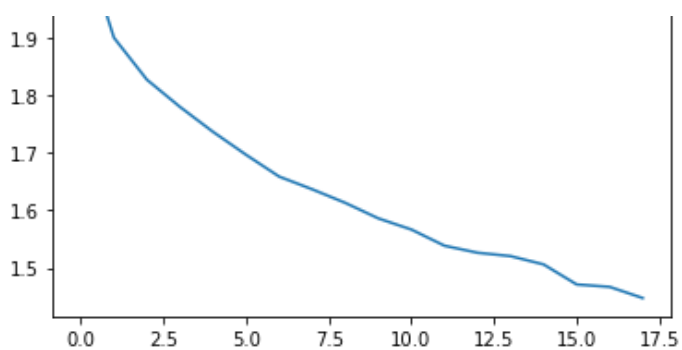
```
[2, 2000] loss: 1.659
[2, 4000] loss: 1.637
[2, 6000] loss: 1.613
[2, 8000] loss: 1.586
[2, 10000] loss: 1.567
[2, 12000] loss: 1.539
[ 0 1 2 3 4 5 6 7 8 9 10 11] [2.08229958 1.9003437 1.82719947 1.77991779 1.736
54272 1.6966441
1.65877789 1.63669244 1.6131053 1.58611365 1.56671694 1.53860124]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[3, 2000] loss: 1.526
[3, 4000] loss: 1.520
[3, 6000] loss: 1.506
[3, 8000] loss: 1.471
[3, 10000] loss: 1.467
[3, 12000] loss: 1.448
[ 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17] [2.08229958 1.9003437 1.82719947
1.77991779 1.73654272 1.6966441
1.65877789 1.63669244 1.6131053 1.58611365 1.56671694 1.53860124
1.52638185 1.52048987 1.5060766 1.47124329 1.46700002 1.44758481]
```





OK

In [50]:

```
check_network(net)
```

```
Accuracy of plane : 52 %
Accuracy of   car : 53 %
Accuracy of  bird : 25 %
Accuracy of   cat : 19 %
Accuracy of  deer : 29 %
Accuracy of   dog : 56 %
Accuracy of  frog : 58 %
Accuracy of horse : 64 %
Accuracy of  ship : 46 %
Accuracy of truck : 64 %
Средняя точность: 46.99
```

In [51]:

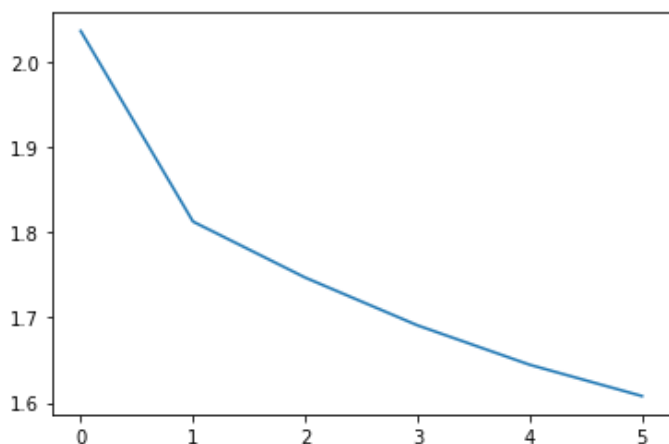
```
net = ConvNet1(6, 16, 32, 7, 5, 3, 256, 128, True)
train(net)
```

3

C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:6: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for epoch in tqdm_notebook(range(num_epochs)):

C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

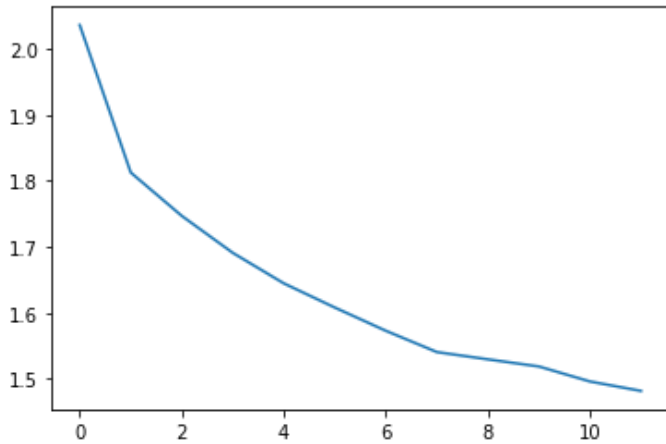
```
[1, 2000] loss: 2.036
[1, 4000] loss: 1.812
[1, 6000] loss: 1.747
[1, 8000] loss: 1.691
[1, 10000] loss: 1.645
[1, 12000] loss: 1.608
[0 1 2 3 4 5] [2.03584557 1.81245903 1.74679641 1.69080995 1.64461128 1.60795135]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0

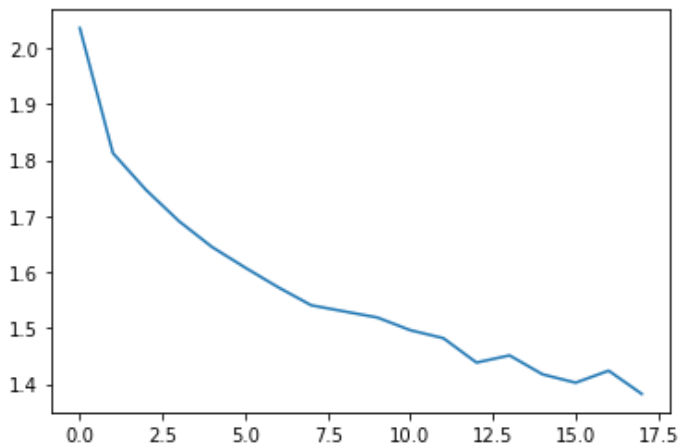
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[2, 2000] loss: 1.573
[2, 4000] loss: 1.541
[2, 6000] loss: 1.530
[2, 8000] loss: 1.519
[2, 10000] loss: 1.496
[2, 12000] loss: 1.482
[ 0  1  2  3  4  5  6  7  8  9 10 11] [2.03584557 1.81245903 1.74679641 1.69080995 1.644
61128 1.60795135
1.57277273 1.54056793 1.52954438 1.5187268 1.49600475 1.48174514]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[3, 2000] loss: 1.438
[3, 4000] loss: 1.451
[3, 6000] loss: 1.417
[3, 8000] loss: 1.402
[3, 10000] loss: 1.424
[3, 12000] loss: 1.382
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17] [2.03584557 1.81245903 1.74679641
1.69080995 1.64461128 1.60795135
1.57277273 1.54056793 1.52954438 1.5187268 1.49600475 1.48174514
1.43813818 1.45097959 1.41711159 1.40220599 1.42364957 1.38217519]
```



OK

In [52]:

```
check_network(net)
```

```
Accuracy of plane : 47 %
Accuracy of car : 64 %
Accuracy of bird : 36 %
Accuracy of cat : 31 %
Accuracy of dog : 28 %
```

Accuracy of deer : 28 %
Accuracy of dog : 35 %
Accuracy of frog : 70 %
Accuracy of horse : 69 %
Accuracy of ship : 55 %
Accuracy of truck : 59 %
Средняя точность: 49.82

In [53]:

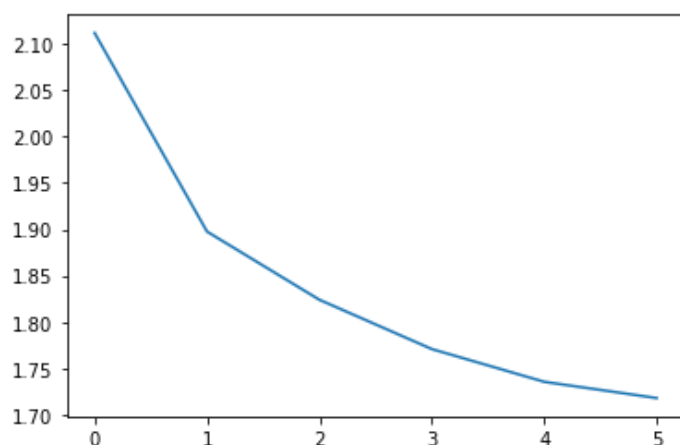
```
net = ConvNet1(6, 16, 32, 7, 5, 3, 64, 32, True)
train(net)
```

3

C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:6: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for epoch in tqdm_notebook(range(num_epochs)):

C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

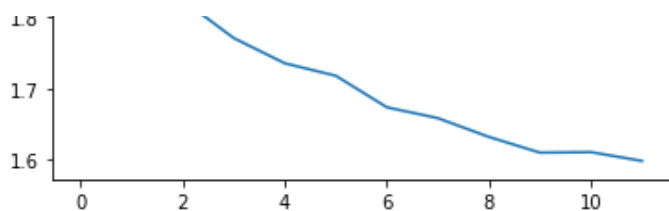
```
[1, 2000] loss: 2.112
[1, 4000] loss: 1.898
[1, 6000] loss: 1.824
[1, 8000] loss: 1.771
[1, 10000] loss: 1.735
[1, 12000] loss: 1.718
[0 1 2 3 4 5] [2.11196123 1.89750843 1.82387792 1.77064574 1.73529681 1.71776291]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

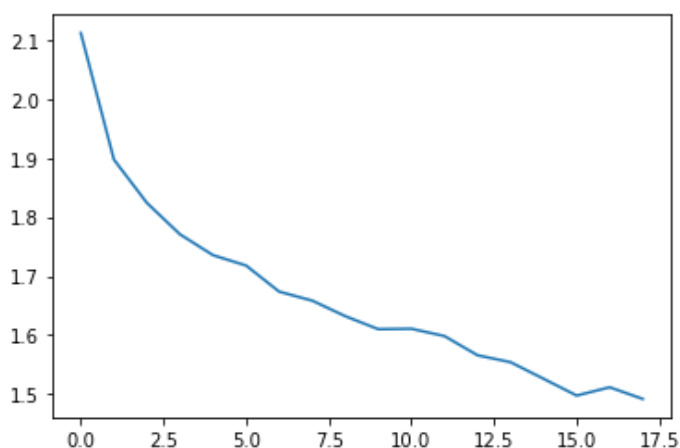
```
[2, 2000] loss: 1.673
[2, 4000] loss: 1.658
[2, 6000] loss: 1.632
[2, 8000] loss: 1.610
[2, 10000] loss: 1.611
[2, 12000] loss: 1.598
[0 1 2 3 4 5 6 7 8 9 10 11] [2.11196123 1.89750843 1.82387792 1.77064574 1.73529681 1.71776291
1.67349972 1.65824699 1.63189842 1.60982219 1.61054249 1.59821609]
```





```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[3, 2000] loss: 1.566
[3, 4000] loss: 1.554
[3, 6000] loss: 1.526
[3, 8000] loss: 1.497
[3, 10000] loss: 1.511
[3, 12000] loss: 1.492
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17] [2.11196123 1.89750843 1.82387792
1.77064574 1.73529681 1.71776291
 1.67349972 1.65824699 1.63189842 1.60982219 1.61054249 1.59821609
 1.56560454 1.55389611 1.52571633 1.49727982 1.51128671 1.49157999]
```



OK

In [54]:

```
check_network(net)
```

```
Accuracy of plane : 36 %
Accuracy of  car : 58 %
Accuracy of  bird : 15 %
Accuracy of  cat : 15 %
Accuracy of  deer : 32 %
Accuracy of  dog : 56 %
Accuracy of  frog : 59 %
Accuracy of horse : 59 %
Accuracy of  ship : 48 %
Accuracy of truck : 63 %
Средняя точность: 44.62
```

результат плохой, **49,5%** в лучшем случае Попробую дообучить

In []:

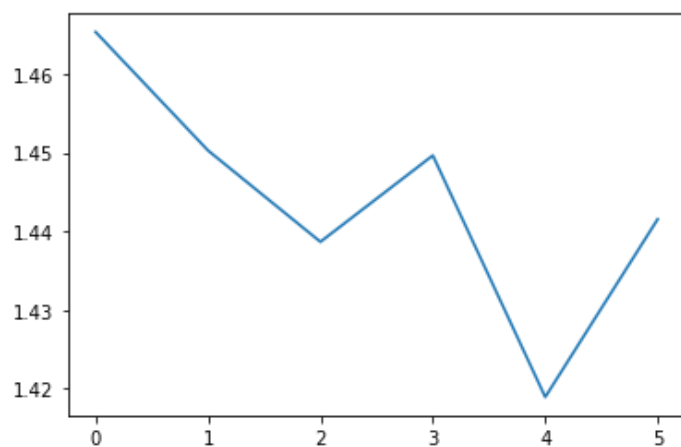
```
train(net, num_epochs=10)
```

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:6: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for epoch in tqdm_notebook(range(num_epochs)):
```

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
```

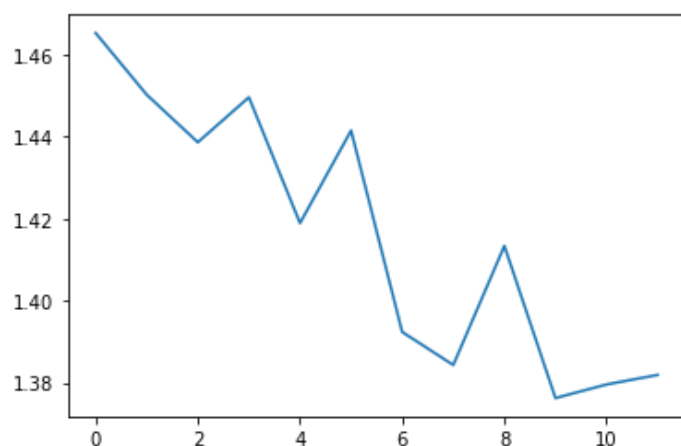
```
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[1, 2000] loss: 1.465  
[1, 4000] loss: 1.450  
[1, 6000] loss: 1.439  
[1, 8000] loss: 1.450  
[1, 10000] loss: 1.419  
[1, 12000] loss: 1.442  
[0 1 2 3 4 5] [1.46532488 1.45026886 1.43866629 1.44963789 1.41894068 1.44153695]
```



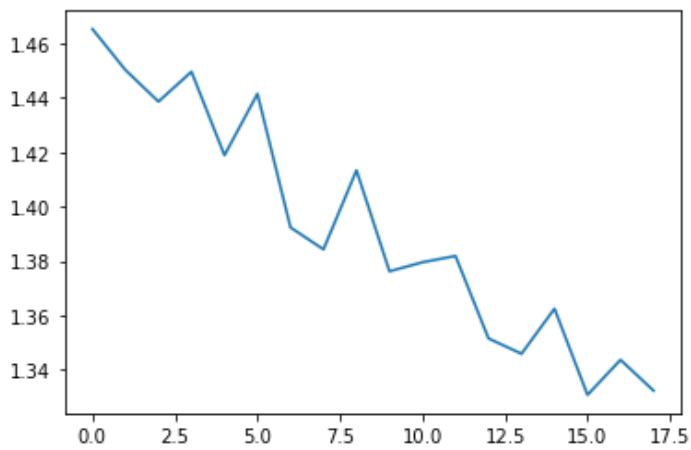
```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn  
ing: This function will be removed in tqdm==5.0.0  
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[2, 2000] loss: 1.392  
[2, 4000] loss: 1.384  
[2, 6000] loss: 1.413  
[2, 8000] loss: 1.376  
[2, 10000] loss: 1.380  
[2, 12000] loss: 1.382  
[ 0 1 2 3 4 5 6 7 8 9 10 11] [1.46532488 1.45026886 1.43866629 1.44963789 1.418  
94068 1.44153695  
1.39239297 1.38433211 1.41339064 1.37626947 1.37958225 1.38190863]
```



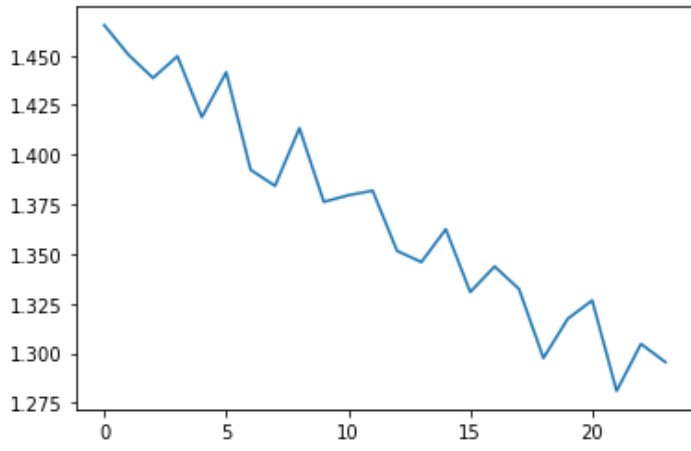
```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn  
ing: This function will be removed in tqdm==5.0.0  
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[3, 2000] loss: 1.352  
[3, 4000] loss: 1.346  
[3, 6000] loss: 1.363  
[3, 8000] loss: 1.331  
[3, 10000] loss: 1.344  
[3, 12000] loss: 1.332  
[ 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17] [1.46532488 1.45026886 1.43866629  
1.44963789 1.41894068 1.44153695  
1.39239297 1.38433211 1.41339064 1.37626947 1.37958225 1.38190863  
1 35150101 1 3450375 1 3625316 1 33082251 1 34371870 1 332404481]
```



```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

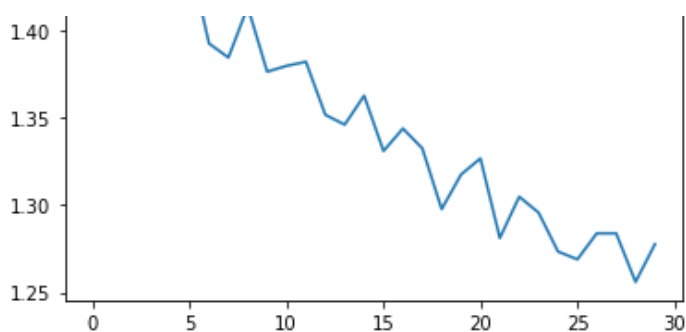
```
[4, 2000] loss: 1.298
[4, 4000] loss: 1.317
[4, 6000] loss: 1.327
[4, 8000] loss: 1.281
[4, 10000] loss: 1.305
[4, 12000] loss: 1.296
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23] [1.46532488 1.4
5026886 1.43866629 1.44963789 1.41894068 1.44153695
 1.39239297 1.38433211 1.41339064 1.37626947 1.37958225 1.38190863
 1.35159191 1.3459375 1.3625316 1.33082251 1.34371879 1.33240448
 1.29760223 1.31740545 1.32662986 1.28104783 1.30470344 1.29555808]
```



```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn
ing: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

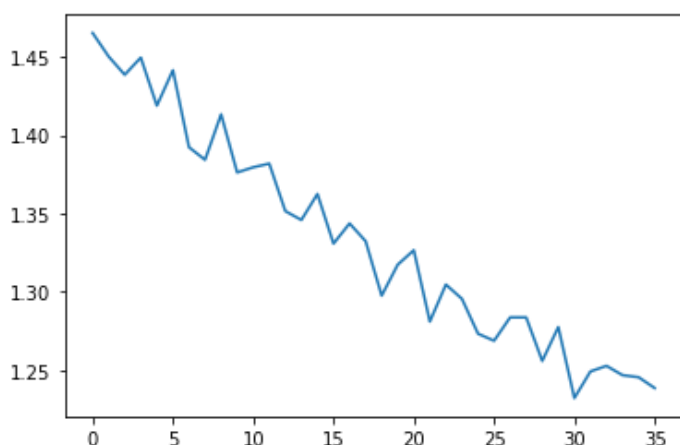
```
[5, 2000] loss: 1.273
[5, 4000] loss: 1.269
[5, 6000] loss: 1.284
[5, 8000] loss: 1.284
[5, 10000] loss: 1.256
[5, 12000] loss: 1.278
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29] [1.46532488 1.45026886 1.43866629 1.44963789 1.41894068 1.44153695
 1.39239297 1.38433211 1.41339064 1.37626947 1.37958225 1.38190863
 1.35159191 1.3459375 1.3625316 1.33082251 1.34371879 1.33240448
 1.29760223 1.31740545 1.32662986 1.28104783 1.30470344 1.29555808
 1.2733213 1.26882 1.28373463 1.28372326 1.25593356 1.27754872]
```





C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

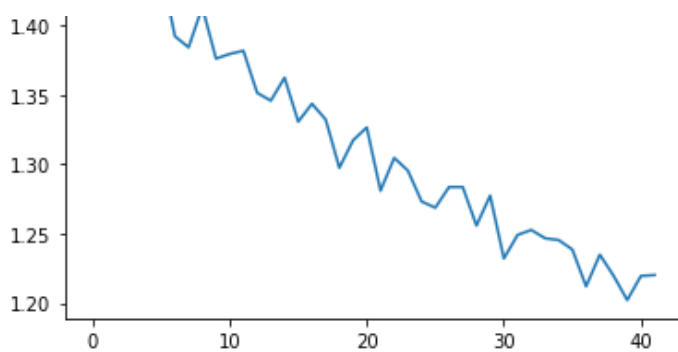
```
[6, 2000] loss: 1.232
[6, 4000] loss: 1.249
[6, 6000] loss: 1.253
[6, 8000] loss: 1.247
[6, 10000] loss: 1.246
[6, 12000] loss: 1.239
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35] [1.46532488 1.45026886 1.43866629 1.44963789 1.41894
068 1.44153695
 1.39239297 1.38433211 1.41339064 1.37626947 1.37958225 1.38190863
 1.35159191 1.3459375 1.3625316 1.33082251 1.34371879 1.33240448
 1.29760223 1.31740545 1.32662986 1.28104783 1.30470344 1.29555808
 1.2733213 1.26882 1.28373463 1.28372326 1.25593356 1.27754872
 1.23223358 1.24921135 1.25278714 1.24683369 1.2455284 1.23862421]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

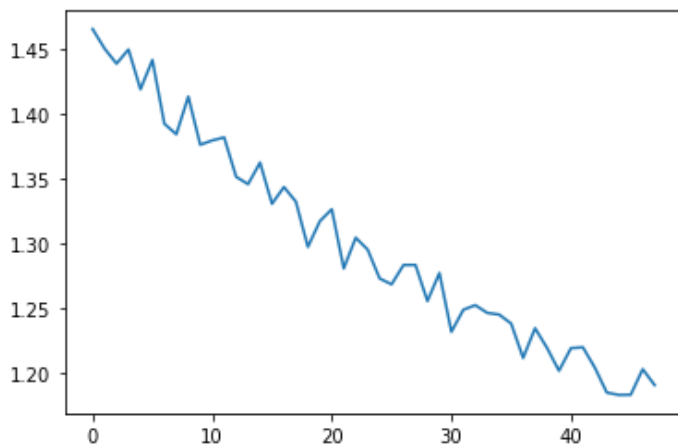
```
[7, 2000] loss: 1.212
[7, 4000] loss: 1.235
[7, 6000] loss: 1.220
[7, 8000] loss: 1.202
[7, 10000] loss: 1.220
[7, 12000] loss: 1.220
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41] [1.46532488 1.45026886 1.43866629
1.44963789 1.41894068 1.44153695
 1.39239297 1.38433211 1.41339064 1.37626947 1.37958225 1.38190863
 1.35159191 1.3459375 1.3625316 1.33082251 1.34371879 1.33240448
 1.29760223 1.31740545 1.32662986 1.28104783 1.30470344 1.29555808
 1.2733213 1.26882 1.28373463 1.28372326 1.25593356 1.27754872
 1.23223358 1.24921135 1.25278714 1.24683369 1.2455284 1.23862421
 1.21215765 1.23500921 1.21982846 1.20229538 1.21969032 1.22031982]
```





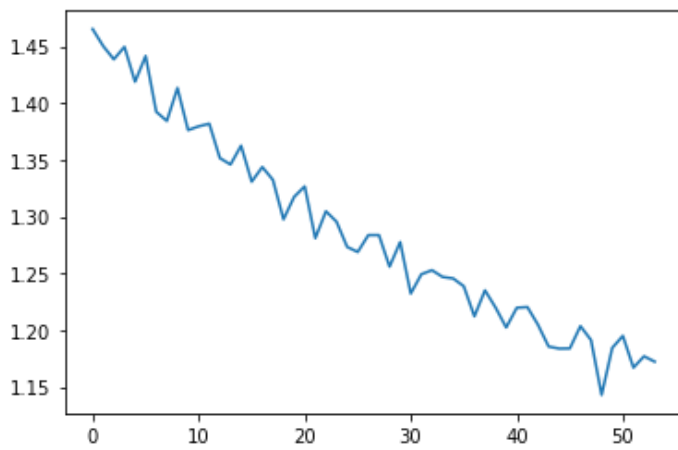
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[8, 2000] loss: 1.205
[8, 4000] loss: 1.185
[8, 6000] loss: 1.184
[8, 8000] loss: 1.184
[8, 10000] loss: 1.203
[8, 12000] loss: 1.191
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47] [1.46532488 1.45026886
0.26886 1.43866629 1.44963789 1.41894068 1.44153695
 1.39239297 1.38433211 1.41339064 1.37626947 1.37958225 1.38190863
 1.35159191 1.3459375 1.3625316 1.33082251 1.34371879 1.33240448
 1.29760223 1.31740545 1.32662986 1.28104783 1.30470344 1.29555808
 1.2733213 1.26882 1.28373463 1.28372326 1.25593356 1.27754872
 1.23223358 1.24921135 1.25278714 1.24683369 1.2455284 1.23862421
 1.21215765 1.23500921 1.21982846 1.20229538 1.21969032 1.22031982
 1.20464413 1.18547646 1.1836825 1.18383228 1.20349793 1.19123147]
```



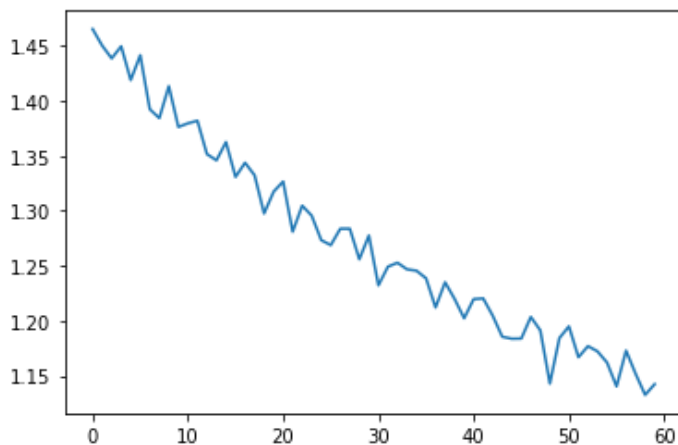
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[9, 2000] loss: 1.143
[9, 4000] loss: 1.184
[9, 6000] loss: 1.195
[9, 8000] loss: 1.167
[9, 10000] loss: 1.177
[9, 12000] loss: 1.172
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53] [1.46532488 1.45026886 1.43866629 1.44963789 1.41894068 1.44153695
 1.39239297 1.38433211 1.41339064 1.37626947 1.37958225 1.38190863
 1.35159191 1.3459375 1.3625316 1.33082251 1.34371879 1.33240448
 1.29760223 1.31740545 1.32662986 1.28104783 1.30470344 1.29555808
 1.2733213 1.26882 1.28373463 1.28372326 1.25593356 1.27754872
 1.23223358 1.24921135 1.25278714 1.24683369 1.2455284 1.23862421
 1.21215765 1.23500921 1.21982846 1.20229538 1.21969032 1.22031982
 1.20464413 1.18547646 1.1836825 1.18383228 1.20349793 1.19123147
 1.14287019 1.18428482 1.19493859 1.16687479 1.17691562 1.17218077]
```

C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[10, 2000] loss: 1.162
[10, 4000] loss: 1.140
[10, 6000] loss: 1.173
[10, 8000] loss: 1.152
[10, 10000] loss: 1.133
[10, 12000] loss: 1.142
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47
 48 49 50 51 52 53 54 55 56 57 58 59] [1.46532488 1.45026886 1.43866629 1.44963789 1.41894
068 1.44153695
 1.39239297 1.38433211 1.41339064 1.37626947 1.37958225 1.38190863
 1.35159191 1.3459375 1.3625316 1.33082251 1.34371879 1.33240448
 1.29760223 1.31740545 1.32662986 1.28104783 1.30470344 1.29555808
 1.2733213 1.26882 1.28373463 1.28372326 1.25593356 1.27754872
 1.23223358 1.24921135 1.25278714 1.24683369 1.2455284 1.23862421
 1.21215765 1.23500921 1.21982846 1.20229538 1.21969032 1.22031982
 1.20464413 1.18547646 1.1836825 1.18383228 1.20349793 1.19123147
 1.14287019 1.18428482 1.19493859 1.16687479 1.17691562 1.17218077
 1.16200115 1.14036679 1.17282756 1.15179194 1.13257471 1.14233073]
```



OK

```
[10, 2000] loss: 1.162
[10, 4000] loss: 1.140
[10, 6000] loss: 1.173
[10, 8000] loss: 1.152
[10, 2000] loss: 1.162
[10, 4000] loss: 1.140
[10, 6000] loss: 1.173
[10, 2000] loss: 1.162
[10, 4000] loss: 1.140
[10, 2000] loss: 1.162
[9, 2000] loss: 1.143
[9, 4000] loss: 1.184
[9, 2000] loss: 1.143
[8, 2000] loss: 1.205
```

```
[8, 2000] loss: 1.205
[8, 4000] loss: 1.185
[8, 2000] loss: 1.205
[7, 2000] loss: 1.212
[7, 4000] loss: 1.235
[7, 2000] loss: 1.212
[6, 2000] loss: 1.232
[6, 4000] loss: 1.249
[6, 2000] loss: 1.232
[5, 2000] loss: 1.273
[5, 4000] loss: 1.269
[5, 2000] loss: 1.273
[4, 2000] loss: 1.298
[4, 4000] loss: 1.317
[4, 2000] loss: 1.298
[3, 2000] loss: 1.352
[3, 4000] loss: 1.346
[3, 2000] loss: 1.352
[2, 2000] loss: 1.392
[2, 4000] loss: 1.384
[2, 2000] loss: 1.392
[1, 2000] loss: 1.465
[1, 4000] loss: 1.450
[1, 2000] loss: 1.465
```

In [57]:

```
check_network(net)
```

```
Accuracy of plane : 48 %
Accuracy of   car : 71 %
Accuracy of  bird : 55 %
Accuracy of   cat : 35 %
Accuracy of  deer : 32 %
Accuracy of   dog : 43 %
Accuracy of  frog : 76 %
Accuracy of horse : 63 %
Accuracy of  ship : 78 %
Accuracy of truck : 59 %
Средняя точность: 56.61
```

Не большой прирост. Попробую добавить дропаут и сделать **4 conv** слоя. Так же убегу один слой **fc** слой.
Пробую ф-ю **leaky_relu**

In [61]:

```
from torch.nn import Dropout
```

In [67]:

```
class ConvNet3(nn.Module):
    def __init__(self, channels1, channels2, channels3, channels4, kernel_size1, kernel_size2, kernel_size3, kernel_size4, fcl, dropout, is_max_pool = True):
        # ВЫЗОВ КОНСТРУКТОРА КЛАССА nn.Module()
        super(ConvNet3, self).__init__()

        if is_max_pool:
            self.pool = nn.MaxPool2d(kernel_size=2, stride=2)
        else:
            self.pool = nn.AvgPool2d(kernel_size=2, stride=2)

        self.conv1 = nn.Conv2d(in_channels=3, out_channels=channels1, kernel_size=kernel_size1)
        new_size = 32 - kernel_size1 + 1
        #new_size = new_size // 2

        self.conv2 = nn.Conv2d(in_channels=channels1, out_channels=channels2, kernel_size=kernel_size2)
        new_size = new_size - kernel_size2 + 1
        new_size = new_size // 2 #тут нет пулинга
```

```

        self.conv3 = nn.Conv2d(in_channels=channels2, out_channels=channels3, kernel_size=kernel_size3)
        new_size = new_size - kernel_size3 + 1
        #new_size = new_size // 2

        self.conv4 = nn.Conv2d(in_channels=channels3, out_channels=channels4, kernel_size=kernel_size4)
        new_size = new_size - kernel_size4 + 1
        new_size = new_size // 2

        #print(new_size)

        self.fc1_size = new_size * new_size * channels4

        self.fc1 = nn.Linear(self.fc1_size, fc1)
        self.fc3 = nn.Linear(fc1, 10)

        self.dropout1 = Dropout(dropout)

    def forward(self, x):
        x = self.pool(F.leaky_relu(self.conv2(F.leaky_relu(self.conv1(x)))))
        x = self.pool(self.conv4(F.leaky_relu(self.conv3(x))))
        x = x.view(-1, self.fc1_size)
        x = self.dropout1(F.leaky_relu(self.fc1(x)))
        #x = self.dropout2(F.leaky_relu(self.fc2(x)))
        x = self.fc3(x)

    return x

```

In [68]:

```

net = ConvNet3(20, 30, 40, 50, 3, 3, 3, 3, 100, 0.3, True)
train(net)

```

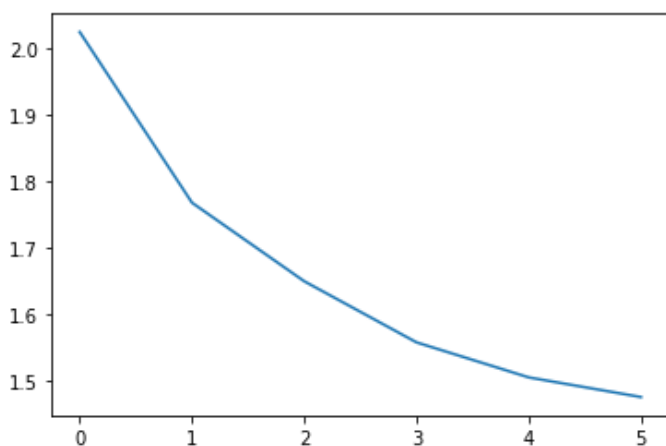
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:6: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for epoch in tqdm_notebook(range(num_epochs)):

C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```

[1, 2000] loss: 2.024
[1, 4000] loss: 1.768
[1, 6000] loss: 1.650
[1, 8000] loss: 1.559
[1, 10000] loss: 1.506
[1, 12000] loss: 1.477
[0 1 2 3 4 5] [2.0239138 1.76797981 1.65015887 1.55854467 1.50601794 1.4765551 ]

```

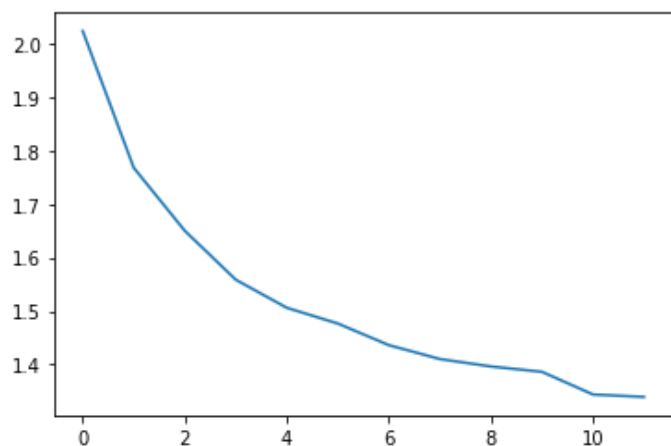


C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```

[2, 2000] loss: 1.436
[2, 4000] loss: 1.410
[2, 6000] loss: 1.396
[2, 8000] loss: 1.386
[2, 10000] loss: 1.344
[2, 12000] loss: 1.339
[ 0  1  2  3  4  5  6  7  8  9 10 11] [2.0239138  1.76797981 1.65015887 1.55854467 1.506
01794 1.4765551
 1.43611546 1.41008717 1.3962357  1.3862364  1.3437943  1.33926131]

```

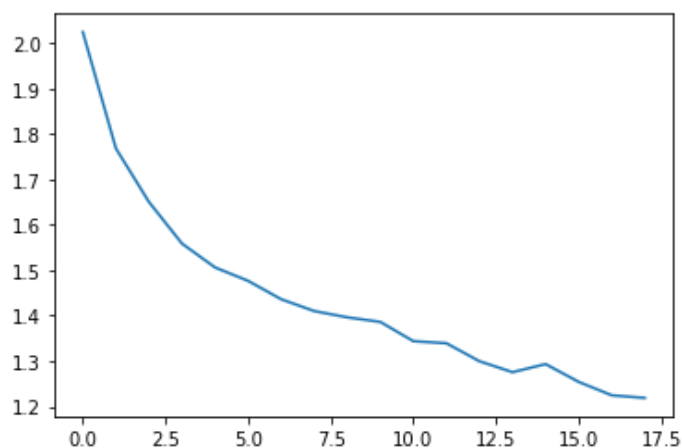


C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```

[3, 2000] loss: 1.300
[3, 4000] loss: 1.276
[3, 6000] loss: 1.293
[3, 8000] loss: 1.254
[3, 10000] loss: 1.225
[3, 12000] loss: 1.219
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17] [2.0239138  1.76797981 1.65015887
1.55854467 1.50601794 1.4765551
 1.43611546 1.41008717 1.3962357  1.3862364  1.3437943  1.33926131
 1.29965873 1.27560783 1.29338666 1.25431288 1.22474511 1.21899149]

```



OK

In [69]:

```
check_network(net)
```

```

Accuracy of plane : 59 %
Accuracy of car : 70 %
Accuracy of bird : 35 %
Accuracy of cat : 34 %
Accuracy of deer : 48 %
Accuracy of dog : 50 %
Accuracy of frog : 63 %

```

Accuracy of horse : 66 %
Accuracy of ship : 75 %
Accuracy of truck : 65 %
Средняя точность: 56.85

пробую дообучить

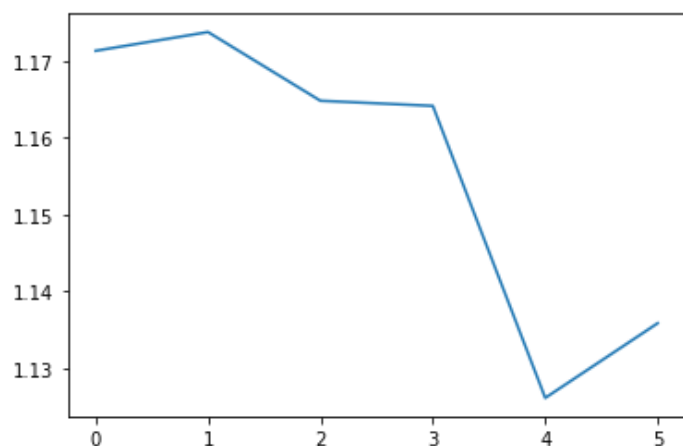
In [70]:

```
train(net, num_epochs=5)
```

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:6: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
  for epoch in tqdm_notebook(range(num_epochs)):
```

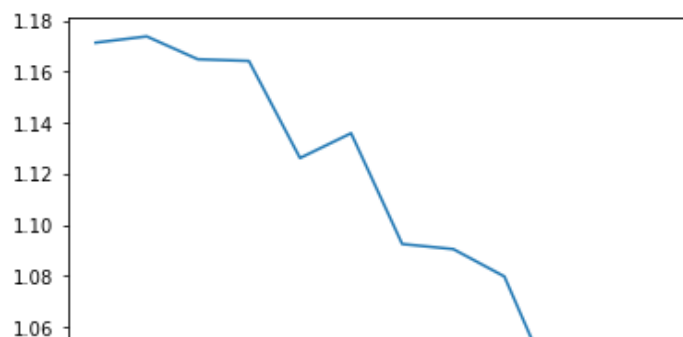
```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
  for i, batch in enumerate(tqdm_notebook(trainloader)):
```

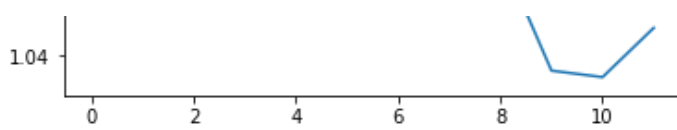
```
[1, 2000] loss: 1.171
[1, 4000] loss: 1.174
[1, 6000] loss: 1.165
[1, 8000] loss: 1.164
[1, 10000] loss: 1.126
[1, 12000] loss: 1.136
[0 1 2 3 4 5] [1.17127604 1.17371257 1.1647741 1.16410802 1.12611357 1.13583032]
```



```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
  for i, batch in enumerate(tqdm_notebook(trainloader)):
```

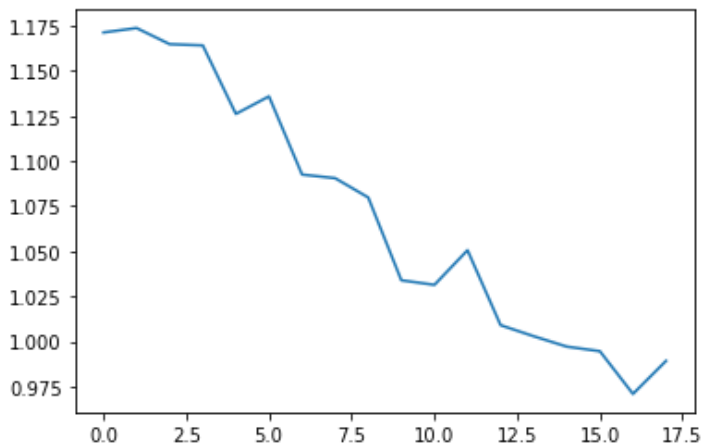
```
[2, 2000] loss: 1.092
[2, 4000] loss: 1.090
[2, 6000] loss: 1.080
[2, 8000] loss: 1.034
[2, 10000] loss: 1.031
[2, 12000] loss: 1.051
[ 0 1 2 3 4 5 6 7 8 9 10 11] [1.17127604 1.17371257 1.1647741 1.16410802 1.12611357 1.13583032
1.09247145 1.09047894 1.07977357 1.0338574 1.03132914 1.05053512]
```





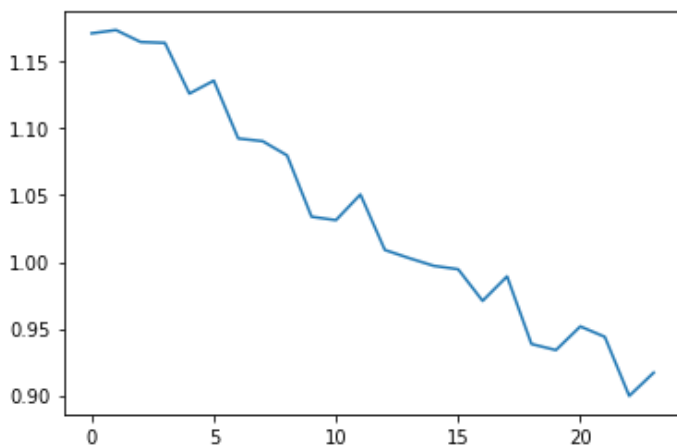
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[3, 2000] loss: 1.009
[3, 4000] loss: 1.003
[3, 6000] loss: 0.997
[3, 8000] loss: 0.995
[3, 10000] loss: 0.971
[3, 12000] loss: 0.989
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17] [1.17127604 1.17371257 1.1647741
1.16410802 1.12611357 1.13583032
1.09247145 1.09047894 1.07977357 1.0338574 1.03132914 1.05053512
1.00897552 1.002837 0.99707789 0.99454213 0.97086063 0.98917668]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

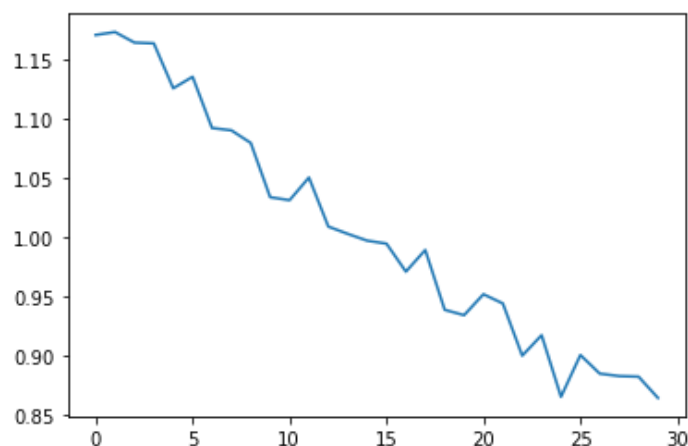
```
[4, 2000] loss: 0.939
[4, 4000] loss: 0.934
[4, 6000] loss: 0.952
[4, 8000] loss: 0.944
[4, 10000] loss: 0.900
[4, 12000] loss: 0.917
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23] [1.17127604 1.1
7371257 1.1647741 1.16410802 1.12611357 1.13583032
1.09247145 1.09047894 1.07977357 1.0338574 1.03132914 1.05053512
1.00897552 1.002837 0.99707789 0.99454213 0.97086063 0.98917668
0.93851364 0.93397242 0.95169484 0.94389371 0.89964296 0.91703935]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`

```
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[5, 2000] loss: 0.865  
[5, 4000] loss: 0.900  
[5, 6000] loss: 0.884  
[5, 8000] loss: 0.882  
[5, 10000] loss: 0.882  
[5, 12000] loss: 0.864  
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23  
24 25 26 27 28 29] [1.17127604 1.17371257 1.1647741  1.16410802 1.12611357 1.13583032  
1.09247145 1.09047894 1.07977357 1.0338574  1.03132914 1.05053512  
1.00897552 1.002837  0.99707789 0.99454213 0.97086063 0.98917668  
0.93851364 0.93397242 0.95169484 0.94389371 0.89964296 0.91703935  
0.86486911 0.90022938 0.88446714 0.88238486 0.8818972  0.86390722]
```



OK

In [71]:

```
check_network(net)
```

```
Accuracy of plane : 73 %  
Accuracy of car : 86 %  
Accuracy of bird : 48 %  
Accuracy of cat : 40 %  
Accuracy of deer : 57 %  
Accuracy of dog : 54 %  
Accuracy of frog : 77 %  
Accuracy of horse : 72 %  
Accuracy of ship : 71 %  
Accuracy of truck : 78 %  
Средняя точность: 66.2
```

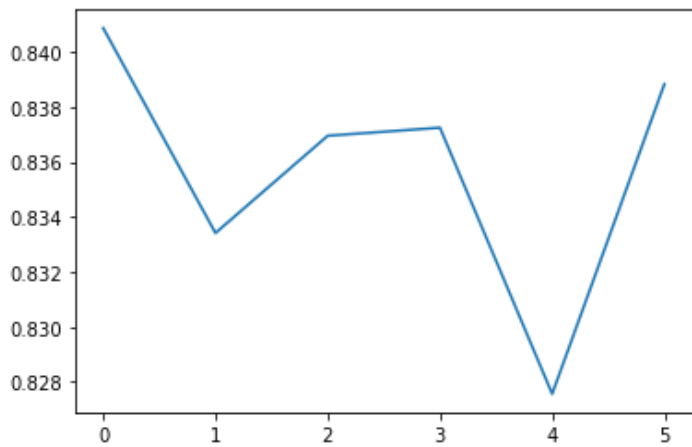
In [72]:

```
train(net, num_epochs=5)
```

```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:6: TqdmDeprecationWarn  
ing: This function will be removed in tqdm==5.0.0  
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
for epoch in tqdm_notebook(range(num_epochs)):
```

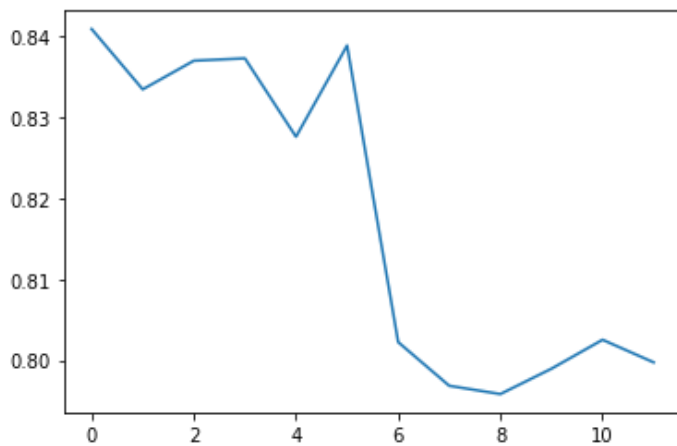
```
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarn  
ing: This function will be removed in tqdm==5.0.0  
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`  
for i, batch in enumerate(tqdm_notebook(trainloader)):
```

```
[1, 2000] loss: 0.841  
[1, 4000] loss: 0.833  
[1, 6000] loss: 0.837  
[1, 8000] loss: 0.837  
[1, 10000] loss: 0.828  
[1, 12000] loss: 0.839  
[0 1 2 3 4 5] [0.84086917 0.83341764 0.83695336 0.83724794 0.827568  0.83883377]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

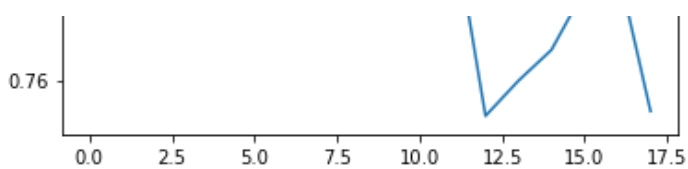
```
[2, 2000] loss: 0.802
[2, 4000] loss: 0.797
[2, 6000] loss: 0.796
[2, 8000] loss: 0.799
[2, 10000] loss: 0.803
[2, 12000] loss: 0.800
[ 0  1  2  3  4  5  6  7  8  9 10 11] [0.84086917 0.83341764 0.83695336 0.83724794 0.827
568 0.83883377
0.80222355 0.79683634 0.79581642 0.7989463 0.8025152 0.79972734]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

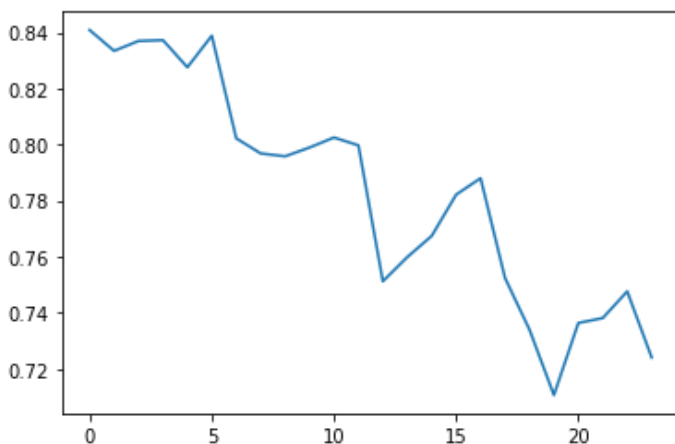
```
[3, 2000] loss: 0.751
[3, 4000] loss: 0.760
[3, 6000] loss: 0.767
[3, 8000] loss: 0.782
[3, 10000] loss: 0.788
[3, 12000] loss: 0.752
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17] [0.84086917 0.83341764 0.83695336
0.83724794 0.827568 0.83883377
0.80222355 0.79683634 0.79581642 0.7989463 0.8025152 0.79972734
0.75123447 0.75986672 0.76742608 0.78215073 0.78800121 0.75239479]
```





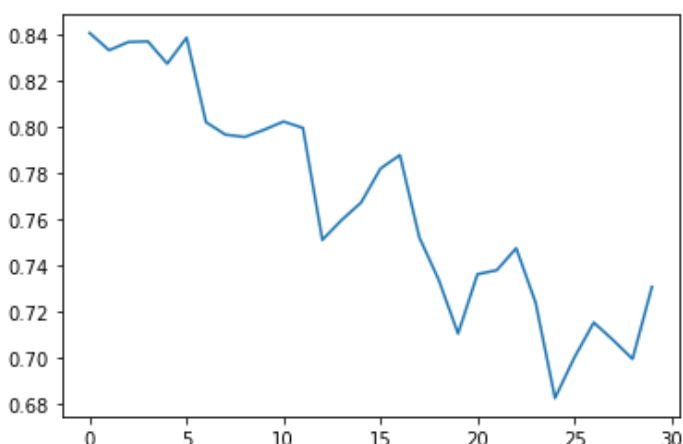
C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[4, 2000] loss: 0.734
[4, 4000] loss: 0.711
[4, 6000] loss: 0.736
[4, 8000] loss: 0.738
[4, 10000] loss: 0.748
[4, 12000] loss: 0.724
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23] [0.84086917 0.8
3341764 0.83695336 0.83724794 0.827568 0.83883377
0.80222355 0.79683634 0.79581642 0.7989463 0.8025152 0.79972734
0.75123447 0.75986672 0.76742608 0.78215073 0.78800121 0.75239479
0.73399185 0.71065271 0.73636724 0.73811904 0.74763705 0.72406081]
```



C:\Users\KOSHI8~1\AppData\Local\Temp\ipykernel_23484\2320894408.py:8: TqdmDeprecationWarning: This function will be removed in tqdm==5.0.0
Please use `tqdm.notebook.tqdm` instead of `tqdm.tqdm_notebook`
for i, batch in enumerate(tqdm_notebook(trainloader)):

```
[5, 2000] loss: 0.683
[5, 4000] loss: 0.700
[5, 6000] loss: 0.715
[5, 8000] loss: 0.708
[5, 10000] loss: 0.700
[5, 12000] loss: 0.731
[ 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
24 25 26 27 28 29] [0.84086917 0.83341764 0.83695336 0.83724794 0.827568 0.83883377
0.80222355 0.79683634 0.79581642 0.7989463 0.8025152 0.79972734
0.75123447 0.75986672 0.76742608 0.78215073 0.78800121 0.75239479
0.73399185 0.71065271 0.73636724 0.73811904 0.74763705 0.72406081
0.68272925 0.70030579 0.71543753 0.70783064 0.69967207 0.73090148]
```



OK

In [73]:

```
check_network(net)
```

```
Accuracy of plane : 78 %  
Accuracy of   car : 85 %  
Accuracy of  bird : 63 %  
Accuracy of   cat : 50 %  
Accuracy of  deer : 61 %  
Accuracy of   dog : 55 %  
Accuracy of  frog : 76 %  
Accuracy of horse : 73 %  
Accuracy of  ship : 76 %  
Accuracy of truck : 73 %  
Средняя точность: 69.42
```

ИТОГИ Попытка использовать сетку из **MNIST** оказалась достаточно интересной, так как без доп настроек получилось достичь точности **61%** за **16** эпох. Еще **16** эпох дало **2.1%**, не эффективно Пробую добиться такого же результата, но за меньшее кол-во эпох засчет добавления **pool** слоя и подбора параметров - результат плохой, **49,5%**/ Дообучение модели дало прирост до **56%**, все-равно не очень Не большой прирост. Попробую добавить дропаут и сделать **4 conv** слоя. и двумя **fc** слоями Пробую ф-ю **leaky_relu**. Результат **56%**. Но после повторного обучения получил **66.2%**, пока что это рекорд. Попробую еще обучить

Лучший результат: **69.42%** на **4 conv** слое и двумя **fc** слоями. С тремя было заметно хуже.