# assignment 07

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## Binary classification based on fully connected neural network

In [11]:

```python
# ------------------------------------------------------------------------------
# import packages
# ------------------------------------------------------------------------------

import matplotlib.pyplot as plt
import numpy as np

import math
import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.optim as optim
import torch.backends.cudnn as cudnn
from torch.utils.data import Dataset, DataLoader
import torchvision.transforms as transforms
import torchvision

from torchvision import datasets, transforms
from torch.autograd import Variable
from random import shuffle

import argparse
import sys
import os
import numpy as np
import time
import datetime
import csv
import configparser
import argparse
import platform
```

## Neural Network Architecture

In [12]:

```python
class Linear(nn.Module):

    def __init__(self, num_classes=2):
```

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```python
        super(Linear, self).__init__()

        self.number_class = num_classes

        _size_image = 100 * 100
        _num1 = 150
        _num2 = 50

        self.fc1 = nn.Linear(_size_image, _num1, bias=True)
        self.fc2 = nn.Linear(_num1, _num2, bias=True)
        self.fc3 = nn.Linear(_num2, num_classes, bias=True)

        self.fc_layer1 = nn.Sequential(self.fc1, nn.LeakyReLU(True))
        self.fc_layer2 = nn.Sequential(self.fc2, nn.LeakyReLU(True))
        self.fc_layer3 = nn.Sequential(self.fc3, nn.Sigmoid())

        self.classifier = nn.Sequential(self.fc_layer1, self.fc_layer2, self.fc_layer3)

        self._initialize_weight()

    def _initialize_weight(self):
        for name, m in self._modules.items():
            if isinstance(m, nn.Linear):
                n = m.in_features
                m.weight.data.uniform_(- 1.0 / math.sqrt(n), 1.0 / math.sqrt(n))

                if m.bias is not None:
                    m.bias.data.zero_()

    def forward(self, x):

        x = x.view(x.size(0), -1)
        x = self.classifier(x)

        return x
```

In [13]:

```python
# ---------------------------------------------------------------------------
# function for draw table
# ---------------------------------------------------------------------------
def output_frame_plot(tloss, vloss, tacc, vacc, title):
    print(" << %s >>" % title)
    print("----------------------------------------------------------")
    print("                 |    %10s    |    %10s    |" % ('loss', 'accuracy'))
    print("----------------------------------------------------------")
    print("training         |    %.10f    |    %.10f    |" % (tloss, tacc))
    print("----------------------------------------------------------")
    print("validation       |    %.10f    |    %.10f    |" % (vloss, vacc))
    print("----------------------------------------------------------")
```

```python
def output_plot(g1, g2, std, title, color, label, legend):
    plt.title(title)
    plt.plot(np.arange(1, len(g1) + 1), g1, color=color[0], alpha=0.5, label=label[0])
    plt.plot(np.arange(1, len(g2) + 1), g2, color=color[1], alpha=0.5, label=label[1])
    if std is not None:
        plt.fill_between(np.arange(1, len(g1)+1),
                         np.array(g1)-np.array(std),
                         np.array(g1)+np.array(std), color=color[0], alpha=0.3)
    plt.legend(loc=legend)
    plt.show()
```

**Loss function and Implementation**

$$\mathcal{L} = \frac{1}{n} \sum_{i=1}^{n} f_i + \frac{\lambda}{2} \left( \|W\|_2^2 \right)$$

- Cross Entropy : $f_i = -y_i \log \hat{y}_i - (1 - y_i) \log(1 - \hat{y}_i)$, where $y_i$ denotes the ground truth and $\hat{y}_i$ denotes the output of the network

- Regularization : $\|W\|_2^2 = \left( \sum_i w_i^2 \right)$, where $w_i$ denotes all the model parameters

In [8]:

```python
IMAGE_WIDTH = 100
IMAGE_HEIGHT = 100
IMAGE_CHANNEL = 1
DIMENSION = IMAGE_CHANNEL * IMAGE_HEIGHT * IMAGE_WIDTH

# global settings
# torch.set_default_dtype(torch.float64)
# torch.set_default_tensor_type('torch.cuda.DoubleTensor')
torch.set_printoptions(precision=16)
torch.cuda.set_device(0)

# setting check
print("current device : %s" % (torch.cuda.current_device()))
print("device count : %s" % (torch.cuda.device_count()))
print("device name : %s" % (torch.cuda.get_device_name(0)))
print("CUDA available? : %s" % (torch.cuda.is_available()))

batch_size = 30


# ---------------------------------------------------------------------------
# load dataset
# ---------------------------------------------------------------------------

transform = transforms.Compose([  # transforms.Resize((256,256)),
    transforms.Grayscale(),
    # the code transforms.Graysclae() is for changing the size [3,100,100] to [1, 100, 100]
 ↪(notice : [channel, height, width] )
    transforms.ToTensor(), ])
```

```python
# train_data_path = 'relative path of training data set'
# change the valuse of batch_size, num_workers for your program
# if shuffle=True, the data reshuffled at every epoch
train_data_path = './horse-or-human/train'
validation_data_path = './horse-or-human/validation'

set_train = torchvision.datasets.ImageFolder(root=train_data_path, transform=transform)
set_test = torchvision.datasets.ImageFolder(root=validation_data_path, transform=transform)

loader_train = torch.utils.data.DataLoader(
    dataset=set_train,
    batch_size=batch_size,
    shuffle=True,
    num_workers=5
)

loader_test = torch.utils.data.DataLoader(
    dataset=set_test,
    batch_size=batch_size,
    shuffle=False,
    num_workers=5
)

num_classes = 2

# ------------------------------------------------------------------------------
# load neural network model
# ------------------------------------------------------------------------------

model = Linear(num_classes=num_classes)

# ------------------------------------------------------------------------------
# Set the flag for using cuda
# ------------------------------------------------------------------------------
model.cuda()

# torch.backends.cudnn.benchmark = True
# torch.set_default_tensor_type('torch.cuda.FloatTensor')


# ------------------------------------------------------------------------------
# optimization algorithm
# ------------------------------------------------------------------------------
learning_rate = 0.5
optimizer = optim.SGD(model.parameters(), lr=learning_rate, weight_decay=0.093)
scheduler = optim.lr_scheduler.ReduceLROnPlateau(optimizer, 'min', factor=0.25,
 ↪patience=30, min_lr=0.001, verbose=True)
objective = nn.CrossEntropyLoss()


# ------------------------------------------------------------------------------
```

```python
# function for training the model
# ----------------------------------------------------------------------------

def train():
    # print('train the model at given epoch')

    loss_train = []
    acc_train = []

    model.train()

    for idx_batch, (data, target) in enumerate(loader_train):

        if len(data) % batch_size != 0:
            continue

        correct = 0

        data, target = data.cuda(), target.cuda()
        data, target = Variable(data).cuda(), Variable(target).cuda()

        optimizer.zero_grad()

        output = model(data)
        loss = objective(output, target)

        loss.backward()
        optimizer.step()

        loss_train_batch = loss.item() / len(data)
        loss_train.append(loss_train_batch)

        pred = output.data.max(1)[1]
        correct += pred.eq(target.data.view_as(pred)).cpu().sum()
        acc_train.append(100. * float(correct) / len(data))

    loss_train_mean = np.mean(loss_train)
    loss_train_std = np.std(loss_train)
    acc_train_mean = np.mean(acc_train)
    acc_train_std = np.std(acc_train)

    return {'loss_train_mean': loss_train_mean,
            'loss_train_std': loss_train_std,
            'accuracy_train_mean': acc_train_mean,
            'accuracy_train_std': acc_train_std}


# ----------------------------------------------------------------------------
# function for testing the model
# ----------------------------------------------------------------------------
```

```python
def test():
    # print('test the model at given epoch')
    loss_test = 0
    correct = 0

    model.eval()

    for idx_batch, (data, target) in enumerate(loader_test):

        data, target = data.cuda(), target.cuda()
        data, target = Variable(data).cuda(), Variable(target).cuda()

        output = model(data)
        loss = objective(output, target)

        loss_test += loss.item()
        pred = output.data.max(1)[1]
        correct += pred.eq(target.data.view_as(pred)).cpu().sum()

    loss_test = loss_test / len(loader_test.dataset)
    accuracy_test = 100. * float(correct) / len(loader_test.dataset)

    return {'loss_test': loss_test, 'accuracy_test': accuracy_test}


# -------------------------------------------------------------------------
# iteration for the epoch
# -------------------------------------------------------------------------

loss_train_mean, loss_train_std, loss_test, accuracy_train_std, accuracy_test,␣
 ↪accuracy_train = [], [], [], [], [], []
prev_train_loss, next_train_loss = 0, 0

for e in range(5000):
    result_train = train()
    result_test = test()

    next_train_loss = result_train['loss_train_mean']

    loss_train_mean.append(result_train['loss_train_mean'])
    loss_train_std.append(result_train['loss_train_std'])
    loss_test.append(result_test['loss_test'])

    accuracy_train.append(result_train['accuracy_train_mean'])
    accuracy_train_std.append(result_train['accuracy_train_std'])
    accuracy_test.append(result_test['accuracy_test'])

    print("[epoch %s] loss: (training) %s, (testing) %s, accuracy: (training) %s, (testing)␣
 ↪%s" %
          (e, loss_train_mean[-1], loss_test[-1], accuracy_train[-1], accuracy_test[-1]))
```

```
    if abs(next_train_loss - prev_train_loss) < 10e-8:
        break
    else:
        prev_train_loss = next_train_loss
        scheduler.step(result_test['accuracy_test'], e)
```

current device : 0
device count : 1
device name : GeForce RTX 2060
CUDA available? : True
[epoch 0] loss: (training) 0.022681362956177953, (testing) 0.02383565134368837, accuracy:
(training) 56.27450980392157, (testing) 50.0
[epoch 1] loss: (training) 0.022729988542257572, (testing) 0.023642352782189846,
accuracy: (training) 55.392156862745104, (testing) 50.0
[epoch 2] loss: (training) 0.02230165080696929, (testing) 0.023322093067690073, accuracy:
(training) 59.01960784313726, (testing) 50.0
[epoch 3] loss: (training) 0.02223628893786786, (testing) 0.023778158240020275, accuracy:
(training) 57.64705882352941, (testing) 50.0
[epoch 4] loss: (training) 0.022542530531976735, (testing) 0.02349218726158142, accuracy:
(training) 59.90196078431373, (testing) 85.546875
[epoch 5] loss: (training) 0.02230632842755785, (testing) 0.022709327517077327, accuracy:
(training) 60.588235294117645, (testing) 50.390625
[epoch 6] loss: (training) 0.021984822551409405, (testing) 0.02205603988841176, accuracy:
(training) 61.27450980392156, (testing) 80.859375
[epoch 7] loss: (training) 0.022539628136391734, (testing) 0.02289466164074838, accuracy:
(training) 57.94117647058823, (testing) 71.484375
[epoch 8] loss: (training) 0.022604976039306793, (testing) 0.023161081364378333,
accuracy: (training) 58.03921568627452, (testing) 50.390625
[epoch 9] loss: (training) 0.02220175330545388, (testing) 0.022589663043618202, accuracy:
(training) 60.294117647058826, (testing) 52.734375
[epoch 10] loss: (training) 0.022372915522724978, (testing) 0.02296970644965768,
accuracy: (training) 58.43137254901961, (testing) 66.40625
[epoch 11] loss: (training) 0.02228198834494040485, (testing) 0.023484087781980634,
accuracy: (training) 59.2156862745098, (testing) 50.0
[epoch 12] loss: (training) 0.0225267908152412, (testing) 0.022786707035265863, accuracy:
(training) 60.294117647058826, (testing) 50.78125
[epoch 13] loss: (training) 0.02222456277585497, (testing) 0.02325662551447749, accuracy:
(training) 60.0, (testing) 50.0
[epoch 14] loss: (training) 0.022534240636171078, (testing) 0.0238320886855945, accuracy:
(training) 59.313725490196084, (testing) 50.0
[epoch 15] loss: (training) 0.022436989464011847, (testing) 0.023430643253959715,
accuracy: (training) 57.05882352941177, (testing) 50.0
[epoch 16] loss: (training) 0.022486191637375776, (testing) 0.024140167515724897,
accuracy: (training) 60.19607843137254, (testing) 50.0
[epoch 17] loss: (training) 0.02246082927666464585, (testing) 0.02328531863167882,
accuracy: (training) 58.72549019607843, (testing) 50.0
[epoch 18] loss: (training) 0.0226535078941607, (testing) 0.02395908534526825, accuracy:
(training) 54.60784313725491, (testing) 83.59375
[epoch 19] loss: (training) 0.0226948351836672, (testing) 0.023834393359720707, accuracy:
(training) 58.13725490196078, (testing) 50.0
[epoch 20] loss: (training) 0.022772045638047012, (testing) 0.024102028692141175,
accuracy: (training) 54.705882352941174, (testing) 88.671875
```

[epoch 21] loss: (training) 0.022887534019993803, (testing) 0.023761639837175608,
accuracy: (training) 55.490196078431374, (testing) 50.0
[epoch 22] loss: (training) 0.022697245548753176, (testing) 0.023770242230966687,
accuracy: (training) 57.64705882352941, (testing) 85.546875
[epoch 23] loss: (training) 0.022557397040666317, (testing) 0.023552003665827215,
accuracy: (training) 60.49019607843138, (testing) 50.0
[epoch 24] loss: (training) 0.022515628150865146, (testing) 0.023504239739850163,
accuracy: (training) 57.54901960784314, (testing) 50.0
[epoch 25] loss: (training) 0.022328155590038673, (testing) 0.02271294523961842,
accuracy: (training) 58.8235294117647, (testing) 76.171875
[epoch 26] loss: (training) 0.022493693115664463, (testing) 0.023669881746172905,
accuracy: (training) 56.07843137254902, (testing) 85.9375
[epoch 27] loss: (training) 0.022391181482988246, (testing) 0.02316259127110243,
accuracy: (training) 61.37254901960785, (testing) 75.0
[epoch 28] loss: (training) 0.022582664676741054, (testing) 0.02387157641351223,
accuracy: (training) 57.745098039215684, (testing) 50.0
[epoch 29] loss: (training) 0.022352366704566806, (testing) 0.02265375549905002,
accuracy: (training) 58.92156862745098, (testing) 88.28125
[epoch 30] loss: (training) 0.022682314234621387, (testing) 0.02337608835659921,
accuracy: (training) 56.07843137254901, (testing) 76.171875
[epoch 31] loss: (training) 0.02253839093096116, (testing) 0.02369179599918425, accuracy:
(training) 56.76470588235294, (testing) 50.0
Epoch    31: reducing learning rate of group 0 to 1.2500e-01.
[epoch 32] loss: (training) 0.02242114351076238, (testing) 0.022495907032862306,
accuracy: (training) 60.49019607843137, (testing) 81.25
[epoch 33] loss: (training) 0.02190068621261447, (testing) 0.0220797099173069, accuracy:
(training) 64.80392156862746, (testing) 59.375
[epoch 34] loss: (training) 0.021341302932477466, (testing) 0.02032917900942266,
accuracy: (training) 65.0, (testing) 84.765625
[epoch 35] loss: (training) 0.02070522863490909, (testing) 0.02016092522535473, accuracy:
(training) 67.6470588235294, (testing) 69.921875
[epoch 36] loss: (training) 0.020675645564116683, (testing) 0.01965750881936401,
accuracy: (training) 67.54901960784314, (testing) 74.609375
[epoch 37] loss: (training) 0.020227642445003285, (testing) 0.020164188463240862,
accuracy: (training) 70.7843137254902, (testing) 64.84375
[epoch 38] loss: (training) 0.02072588395254285, (testing) 0.018565636593848467,
accuracy: (training) 65.88235294117646, (testing) 87.5
[epoch 39] loss: (training) 0.020299608391873974, (testing) 0.01796014793217182,
accuracy: (training) 69.80392156862746, (testing) 86.71875
[epoch 40] loss: (training) 0.02008247720260246, (testing) 0.018064369563944638,
accuracy: (training) 70.19607843137254, (testing) 86.328125
[epoch 41] loss: (training) 0.020020656725939584, (testing) 0.02054583257995546,
accuracy: (training) 70.49019607843137, (testing) 63.28125
[epoch 42] loss: (training) 0.020405081732600343, (testing) 0.018038744456134737,
accuracy: (training) 67.25490196078432, (testing) 87.5
[epoch 43] loss: (training) 0.02067656575464735, (testing) 0.018878709874115884,
accuracy: (training) 66.56862745098039, (testing) 85.9375
[epoch 44] loss: (training) 0.0206119649550494, (testing) 0.018478982499800622, accuracy:
(training) 66.86274509803921, (testing) 88.28125
[epoch 45] loss: (training) 0.02014573701456481, (testing) 0.019483584561385214,
accuracy: (training) 71.27450980392156, (testing) 72.265625
[epoch 46] loss: (training) 0.020296764432215224, (testing) 0.017686293344013393,

accuracy: (training) 69.6078431372549, (testing) 87.5
[epoch 47] loss: (training) 0.020193663999146107, (testing) 0.023675254196859896,
accuracy: (training) 70.29411764705884, (testing) 52.34375
[epoch 48] loss: (training) 0.02041868590841106, (testing) 0.017857313039712608,
accuracy: (training) 67.45098039215686, (testing) 86.71875
[epoch 49] loss: (training) 0.020633949368607768, (testing) 0.024990097153931856,
accuracy: (training) 68.03921568627452, (testing) 50.390625
[epoch 50] loss: (training) 0.020824399707364098, (testing) 0.018536188756115735,
accuracy: (training) 67.35294117647058, (testing) 85.546875
[epoch 51] loss: (training) 0.020216930029438994, (testing) 0.018334500724449754,
accuracy: (training) 68.82352941176472, (testing) 87.5
[epoch 52] loss: (training) 0.020581356392187233, (testing) 0.018701401073485613,
accuracy: (training) 69.01960784313725, (testing) 82.03125
[epoch 53] loss: (training) 0.020196352168625472, (testing) 0.01808372314553708,
accuracy: (training) 69.90196078431373, (testing) 86.71875
[epoch 54] loss: (training) 0.02034735726375206, (testing) 0.021250388585031033,
accuracy: (training) 68.13725490196079, (testing) 60.546875
[epoch 55] loss: (training) 0.020240475383459355, (testing) 0.019081093720160425,
accuracy: (training) 68.13725490196077, (testing) 76.953125
[epoch 56] loss: (training) 0.020487855404031044, (testing) 0.018775208620354533,
accuracy: (training) 68.33333333333334, (testing) 80.859375
[epoch 57] loss: (training) 0.02043531151378558, (testing) 0.019452246953733265,
accuracy: (training) 67.45098039215685, (testing) 80.46875
[epoch 58] loss: (training) 0.020255605847227808, (testing) 0.018220448633655906,
accuracy: (training) 70.0, (testing) 86.71875
[epoch 59] loss: (training) 0.020453464984893796, (testing) 0.019548533484339714,
accuracy: (training) 68.72549019607844, (testing) 78.90625
[epoch 60] loss: (training) 0.02027269134334489, (testing) 0.019911319326609373, accuracy:
(training) 70.09803921568627, (testing) 80.859375
[epoch 61] loss: (training) 0.020389368312031614, (testing) 0.018666207557544112,
accuracy: (training) 69.01960784313725, (testing) 80.078125
[epoch 62] loss: (training) 0.020183263339248355, (testing) 0.018801587051711977,
accuracy: (training) 69.01960784313727, (testing) 77.734375
Epoch    62: reducing learning rate of group 0 to 3.1250e-02.
[epoch 63] loss: (training) 0.019335907814549462, (testing) 0.01752426160965115,
accuracy: (training) 77.15686274509802, (testing) 86.328125
[epoch 64] loss: (training) 0.019052692020640655, (testing) 0.016937735374085605,
accuracy: (training) 77.45098039215685, (testing) 88.28125
[epoch 65] loss: (training) 0.018946075906940536, (testing) 0.017198347486555576,
accuracy: (training) 76.66666666666667, (testing) 86.71875
[epoch 66] loss: (training) 0.01882717796400482, (testing) 0.018754944088868797,
accuracy: (training) 78.0392156862745, (testing) 75.390625
[epoch 67] loss: (training) 0.018768926286229903, (testing) 0.018524202634580433,
accuracy: (training) 77.6470588235294, (testing) 75.78125
[epoch 68] loss: (training) 0.018713862814155276, (testing) 0.01639400445856154,
accuracy: (training) 77.94117647058823, (testing) 87.890625
[epoch 69] loss: (training) 0.018572857771434036, (testing) 0.01645444065798074,
accuracy: (training) 78.03921568627452, (testing) 87.109375
[epoch 70] loss: (training) 0.01849708998320149, (testing) 0.01680198300164193, accuracy:
(training) 77.64705882352942, (testing) 86.71875
[epoch 71] loss: (training) 0.01849358379840851, (testing) 0.01761428825557232, accuracy:
(training) 78.82352941176471, (testing) 81.25

[epoch 72] loss: (training) 0.018463789335652892, (testing) 0.01631808013189584, accuracy: (training) 78.72549019607843, (testing) 86.328125
[epoch 73] loss: (training) 0.018396002054214478, (testing) 0.01785894692875445, accuracy: (training) 78.43137254901961, (testing) 80.078125
[epoch 74] loss: (training) 0.018475956630473044, (testing) 0.01684493839275092, accuracy: (training) 78.72549019607844, (testing) 85.9375
[epoch 75] loss: (training) 0.01834924083714392, (testing) 0.017319776001386344, accuracy: (training) 80.68627450980391, (testing) 84.375
[epoch 76] loss: (training) 0.018364308891343134, (testing) 0.0162840464618057, accuracy: (training) 79.11764705882352, (testing) 87.109375
[epoch 77] loss: (training) 0.018526670512031104, (testing) 0.016547669423744082, accuracy: (training) 78.23529411764706, (testing) 87.109375
[epoch 78] loss: (training) 0.018115312503833397, (testing) 0.01607467222493142, accuracy: (training) 81.66666666666666, (testing) 88.671875
[epoch 79] loss: (training) 0.018360678413335017, (testing) 0.016939715133048594, accuracy: (training) 80.00000000000001, (testing) 84.375
[epoch 80] loss: (training) 0.018189421325337657, (testing) 0.01620002114214003, accuracy: (training) 80.58823529411764, (testing) 87.109375
[epoch 81] loss: (training) 0.01821184032687954, (testing) 0.017223553033545613, accuracy: (training) 80.49019607843138, (testing) 83.984375
[epoch 82] loss: (training) 0.018244859050301945, (testing) 0.016900506103411317, accuracy: (training) 79.80392156862746, (testing) 84.375
[epoch 83] loss: (training) 0.018247088789939882, (testing) 0.018732239492237568, accuracy: (training) 79.50980392156862, (testing) 74.21875
[epoch 84] loss: (training) 0.01844284061123343, (testing) 0.016088509000837803, accuracy: (training) 78.72549019607843, (testing) 87.5
[epoch 85] loss: (training) 0.018253414829572042, (testing) 0.01610150490887463, accuracy: (training) 78.23529411764706, (testing) 87.890625
[epoch 86] loss: (training) 0.018272304038206736, (testing) 0.017250633565708995, accuracy: (training) 78.82352941176471, (testing) 83.984375
[epoch 87] loss: (training) 0.018163923802329042, (testing) 0.016775522264651954, accuracy: (training) 80.49019607843137, (testing) 85.15625
[epoch 88] loss: (training) 0.01824603007704604, (testing) 0.01626898511312902, accuracy: (training) 78.33333333333333, (testing) 87.5
[epoch 89] loss: (training) 0.018160131398369278, (testing) 0.01614152721595019, accuracy: (training) 79.21568627450979, (testing) 87.109375
[epoch 90] loss: (training) 0.018116602067853895, (testing) 0.01604560052510351, accuracy: (training) 78.62745098039215, (testing) 89.0625
[epoch 91] loss: (training) 0.018140338828750685, (testing) 0.016478743171319366, accuracy: (training) 79.99999999999999, (testing) 87.109375
[epoch 92] loss: (training) 0.018275216630860874, (testing) 0.016068454715423286, accuracy: (training) 79.99999999999999, (testing) 87.5
[epoch 93] loss: (training) 0.01827245337121627, (testing) 0.016098934807814658, accuracy: (training) 79.50980392156862, (testing) 87.5
Epoch    93: reducing learning rate of group 0 to 7.8125e-03.
[epoch 94] loss: (training) 0.017827875678445775, (testing) 0.016547767212614417, accuracy: (training) 82.74509803921569, (testing) 85.9375
[epoch 95] loss: (training) 0.017824567503788892, (testing) 0.016167021240107715, accuracy: (training) 83.13725490196079, (testing) 87.890625
[epoch 96] loss: (training) 0.01782686061718885, (testing) 0.016347331227734685, accuracy: (training) 81.66666666666667, (testing) 87.890625
[epoch 97] loss: (training) 0.017820072011162253, (testing) 0.01654219871852547, accuracy:

(training) 82.15686274509804, (testing) 85.9375
[epoch 98] loss: (training) 0.01776994016824984, (testing) 0.016452109441161156,
accuracy: (training) 82.94117647058823, (testing) 87.109375
[epoch 99] loss: (training) 0.017729475539104613, (testing) 0.016147587564773858,
accuracy: (training) 83.13725490196077, (testing) 87.890625
[epoch 100] loss: (training) 0.017727617072124106, (testing) 0.016115897218696773,
accuracy: (training) 82.94117647058823, (testing) 87.890625
[epoch 101] loss: (training) 0.01770031694688049, (testing) 0.015913706156425178,
accuracy: (training) 82.74509803921569, (testing) 88.28125
[epoch 102] loss: (training) 0.017742945984298108, (testing) 0.016346768708899617,
accuracy: (training) 82.74509803921569, (testing) 87.109375
[epoch 103] loss: (training) 0.01767054498195648, (testing) 0.016163502004928887,
accuracy: (training) 82.94117647058825, (testing) 87.890625
[epoch 104] loss: (training) 0.017713138724074644, (testing) 0.016696059028618038,
accuracy: (training) 82.54901960784314, (testing) 84.765625
[epoch 105] loss: (training) 0.017664474657937596, (testing) 0.016898915637284517,
accuracy: (training) 82.7450980392157, (testing) 83.984375
[epoch 106] loss: (training) 0.01767710648915347, (testing) 0.01695098716299981,
accuracy: (training) 82.45098039215686, (testing) 84.375
[epoch 107] loss: (training) 0.017637053628762563, (testing) 0.015891099232248962,
accuracy: (training) 82.94117647058823, (testing) 88.28125
[epoch 108] loss: (training) 0.017628842037098084, (testing) 0.01669038354884833,
accuracy: (training) 83.33333333333334, (testing) 84.765625
[epoch 109] loss: (training) 0.01765480187593722, (testing) 0.01728152681607753,
accuracy: (training) 83.33333333333334, (testing) 82.03125
[epoch 110] loss: (training) 0.01760831460648892, (testing) 0.015856409328989685,
accuracy: (training) 83.03921568627452, (testing) 89.453125
[epoch 111] loss: (training) 0.01758527784955268, (testing) 0.016666936222463846,
accuracy: (training) 82.94117647058822, (testing) 84.765625
[epoch 112] loss: (training) 0.017629406528145656, (testing) 0.0162668313132599,
accuracy: (training) 82.84313725490195, (testing) 87.890625
[epoch 113] loss: (training) 0.01755635358539282, (testing) 0.015900929691269994,
accuracy: (training) 84.01960784313725, (testing) 88.28125
[epoch 114] loss: (training) 0.017573398877592652, (testing) 0.016281673568300903,
accuracy: (training) 83.72549019607844, (testing) 87.109375
[epoch 115] loss: (training) 0.017599174467956318, (testing) 0.015858010505326092,
accuracy: (training) 83.33333333333334, (testing) 87.890625
[epoch 116] loss: (training) 0.01756896993108824, (testing) 0.016260153497569263,
accuracy: (training) 83.921568627451, (testing) 87.890625
[epoch 117] loss: (training) 0.017619421785952997, (testing) 0.016139808343723416,
accuracy: (training) 83.23529411764706, (testing) 87.890625
[epoch 118] loss: (training) 0.017545181629704493, (testing) 0.01594004046637565,
accuracy: (training) 83.62745098039215, (testing) 87.890625
[epoch 119] loss: (training) 0.01759124716707304, (testing) 0.01730201137252152,
accuracy: (training) 82.94117647058823, (testing) 81.640625
[epoch 120] loss: (training) 0.01757557228499768, (testing) 0.015828016214072704,
accuracy: (training) 83.62745098039215, (testing) 88.671875
[epoch 121] loss: (training) 0.017490273012834436, (testing) 0.01590270921587944,
accuracy: (training) 83.72549019607843, (testing) 88.28125
[epoch 122] loss: (training) 0.017526231735360387, (testing) 0.01606000622268766,
accuracy: (training) 83.43137254901961, (testing) 87.890625
[epoch 123] loss: (training) 0.017506591917253008, (testing) 0.016379488515667617,

accuracy: (training) 83.62745098039215, (testing) 85.9375
[epoch 124] loss: (training) 0.01757844876424939, (testing) 0.01685101434122771,
accuracy: (training) 83.33333333333334, (testing) 83.984375
Epoch   124: reducing learning rate of group 0 to 1.9531e-03.
[epoch 125] loss: (training) 0.01748517091367759, (testing) 0.01615566189866513,
accuracy: (training) 84.6078431372549, (testing) 87.890625
[epoch 126] loss: (training) 0.01744535769902024, (testing) 0.016260835342109203,
accuracy: (training) 83.52941176470588, (testing) 87.109375
[epoch 127] loss: (training) 0.01746248763565924, (testing) 0.01617677416652441,
accuracy: (training) 83.72549019607843, (testing) 87.890625
[epoch 128] loss: (training) 0.017455995959394118, (testing) 0.01610770425759256,
accuracy: (training) 84.11764705882354, (testing) 87.890625
[epoch 129] loss: (training) 0.017461429653214476, (testing) 0.016240154625847936,
accuracy: (training) 84.11764705882352, (testing) 87.890625
[epoch 130] loss: (training) 0.01744356587821362, (testing) 0.016416255035437644,
accuracy: (training) 84.01960784313727, (testing) 85.15625
[epoch 131] loss: (training) 0.0174566246423668, (testing) 0.01635983109008521,
accuracy: (training) 83.52941176470588, (testing) 86.71875
[epoch 132] loss: (training) 0.0174442046121055, (testing) 0.01633517479058355, accuracy:
(training) 84.11764705882352, (testing) 86.71875
[epoch 133] loss: (training) 0.017437828346794727, (testing) 0.01613393099978566,
accuracy: (training) 84.31372549019606, (testing) 87.890625
[epoch 134] loss: (training) 0.017426724673486223, (testing) 0.016243928228504956,
accuracy: (training) 84.01960784313725, (testing) 87.890625
[epoch 135] loss: (training) 0.01745899483269336, (testing) 0.016176791745238006,
accuracy: (training) 83.82352941176472, (testing) 87.890625
[epoch 136] loss: (training) 0.01746408194303513, (testing) 0.01604840694926679,
accuracy: (training) 83.92156862745098, (testing) 88.28125
[epoch 137] loss: (training) 0.0173951451977094, (testing) 0.01625324960332364, accuracy:
(training) 83.8235294117647, (testing) 87.5
[epoch 138] loss: (training) 0.017405341828570647, (testing) 0.016465520719066262,
accuracy: (training) 84.11764705882354, (testing) 85.546875
[epoch 139] loss: (training) 0.017436405636516276, (testing) 0.01630426081828773,
accuracy: (training) 83.8235294117647, (testing) 86.71875
[epoch 140] loss: (training) 0.017426775395870207, (testing) 0.01604869426228106,
accuracy: (training) 84.70588235294117, (testing) 88.28125
[epoch 141] loss: (training) 0.01743023302040848, (testing) 0.01607650041114539,
accuracy: (training) 83.92156862745097, (testing) 87.890625
[epoch 142] loss: (training) 0.017400175391459, (testing) 0.01626859954558313, accuracy:
(training) 84.11764705882354, (testing) 87.109375
[epoch 143] loss: (training) 0.01743159472357993, (testing) 0.016006271354854107,
accuracy: (training) 84.70588235294117, (testing) 89.0625
[epoch 144] loss: (training) 0.0173776052161759, (testing) 0.016144594294019043,
accuracy: (training) 83.92156862745097, (testing) 87.890625
[epoch 145] loss: (training) 0.017361393044976626, (testing) 0.01645290374290198,
accuracy: (training) 83.82352941176471, (testing) 85.546875
[epoch 146] loss: (training) 0.017425391194867152, (testing) 0.01612085197120905,
accuracy: (training) 84.41176470588235, (testing) 87.890625
[epoch 147] loss: (training) 0.01739769163084965, (testing) 0.01642328593879938,
accuracy: (training) 83.82352941176471, (testing) 85.546875
[epoch 148] loss: (training) 0.01741447363998375, (testing) 0.01633571519050747,
accuracy: (training) 84.80392156862744, (testing) 86.71875

[epoch 149] loss: (training) 0.017415942865259507, (testing) 0.01630186999682337,
accuracy: (training) 83.92156862745098, (testing) 86.71875
[epoch 150] loss: (training) 0.017417300799313713, (testing) 0.016102363937534392,
accuracy: (training) 84.50980392156862, (testing) 87.890625
[epoch 151] loss: (training) 0.017408205568790438, (testing) 0.016087700380012393,
accuracy: (training) 84.11764705882354, (testing) 87.890625
[epoch 152] loss: (training) 0.01740359491577335, (testing) 0.016159107442945242,
accuracy: (training) 84.11764705882354, (testing) 87.890625
[epoch 153] loss: (training) 0.017389376958211265, (testing) 0.016076092957518995,
accuracy: (training) 84.50980392156865, (testing) 87.890625
[epoch 154] loss: (training) 0.01741051948538013, (testing) 0.016282041207887232,
accuracy: (training) 84.01960784313727, (testing) 86.71875
[epoch 155] loss: (training) 0.01739084700158998, (testing) 0.016248312080278993,
accuracy: (training) 84.41176470588235, (testing) 87.5
Epoch   155: reducing learning rate of group 0 to 1.0000e-03.
[epoch 156] loss: (training) 0.01738925655098522, (testing) 0.016284693963825703,
accuracy: (training) 83.92156862745098, (testing) 86.71875
[epoch 157] loss: (training) 0.017376261335961957, (testing) 0.016218536533415318,
accuracy: (training) 84.31372549019608, (testing) 87.890625
[epoch 158] loss: (training) 0.01735873342144723, (testing) 0.016127372160553932,
accuracy: (training) 84.21568627450979, (testing) 87.890625
[epoch 159] loss: (training) 0.01740044364157845, (testing) 0.01612847193609923,
accuracy: (training) 84.21568627450979, (testing) 87.890625
[epoch 160] loss: (training) 0.017367099634572572, (testing) 0.016145739587955177,
accuracy: (training) 84.31372549019608, (testing) 87.890625
[epoch 161] loss: (training) 0.017381451468841704, (testing) 0.0162417656974867,
accuracy: (training) 84.01960784313727, (testing) 87.5
[epoch 162] loss: (training) 0.017376869303338666, (testing) 0.016106777009554207,
accuracy: (training) 84.41176470588235, (testing) 87.890625
[epoch 163] loss: (training) 0.017345974083040273, (testing) 0.016130414558574557,
accuracy: (training) 84.31372549019608, (testing) 87.890625
[epoch 164] loss: (training) 0.017401451427562567, (testing) 0.016251487541012466,
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[epoch 165] loss: (training) 0.017365002982756672, (testing) 0.016149793984368443,
accuracy: (training) 84.80392156862746, (testing) 87.890625
[epoch 166] loss: (training) 0.017396541524167156, (testing) 0.016135132871568203,
accuracy: (training) 83.92156862745098, (testing) 87.890625
[epoch 167] loss: (training) 0.01739244034477309, (testing) 0.016168523114174604,
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[epoch 168] loss: (training) 0.0173740725014724, (testing) 0.016178669757209718,
accuracy: (training) 84.11764705882354, (testing) 87.890625
[epoch 169] loss: (training) 0.017394666724345264, (testing) 0.016153669450432062,
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[epoch 170] loss: (training) 0.017359805720693927, (testing) 0.01615109806880355,
accuracy: (training) 84.70588235294117, (testing) 87.890625
[epoch 171] loss: (training) 0.017364474400585778, (testing) 0.016186891472898424,
accuracy: (training) 84.2156862745098, (testing) 87.890625
[epoch 172] loss: (training) 0.017377697252759748, (testing) 0.01637000625487417,
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[epoch 173] loss: (training) 0.01739108439754037, (testing) 0.01617499825078994,
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[epoch 174] loss: (training) 0.017376865621875313, (testing) 0.016105966409668326,

accuracy: (training) 84.50980392156862, (testing) 87.890625
[epoch 175] loss: (training) 0.017368825481218455, (testing) 0.016205697786062956,
accuracy: (training) 83.92156862745097, (testing) 87.890625
[epoch 176] loss: (training) 0.017356425494539973, (testing) 0.0162063913885504,
accuracy: (training) 84.41176470588233, (testing) 87.890625
[epoch 177] loss: (training) 0.01735456442716075, (testing) 0.016305734869092703,
accuracy: (training) 84.21568627450979, (testing) 86.71875
[epoch 178] loss: (training) 0.017348071757484883, (testing) 0.01614807767327875,
accuracy: (training) 84.50980392156863, (testing) 87.890625
[epoch 179] loss: (training) 0.01737669393712399, (testing) 0.01615985913667828,
accuracy: (training) 83.92156862745097, (testing) 87.890625
[epoch 180] loss: (training) 0.017376999790761984, (testing) 0.01610675430856645,
accuracy: (training) 84.50980392156863, (testing) 87.890625
[epoch 181] loss: (training) 0.017353053274107914, (testing) 0.0162190452683717,
accuracy: (training) 84.01960784313725, (testing) 87.890625
[epoch 182] loss: (training) 0.017384254289608377, (testing) 0.016138101811520755,
accuracy: (training) 84.21568627450979, (testing) 87.890625
[epoch 183] loss: (training) 0.01737838852054932, (testing) 0.016146924695931375,
accuracy: (training) 84.01960784313725, (testing) 87.890625
[epoch 184] loss: (training) 0.017352853394022177, (testing) 0.01619405939709395,
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[epoch 185] loss: (training) 0.017361082195066938, (testing) 0.016182792140170932,
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[epoch 186] loss: (training) 0.017355818403702157, (testing) 0.01638719579204917,
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[epoch 187] loss: (training) 0.017365545151280422, (testing) 0.01624898996669799,
accuracy: (training) 84.21568627450979, (testing) 87.5
[epoch 188] loss: (training) 0.017352242826246745, (testing) 0.016139322891831398,
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[epoch 189] loss: (training) 0.017345167901001726, (testing) 0.016063597868196666,
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[epoch 190] loss: (training) 0.017355518218349006, (testing) 0.016229203320108354,
accuracy: (training) 84.01960784313725, (testing) 87.890625
[epoch 191] loss: (training) 0.017377399755459207, (testing) 0.016264482401311398,
accuracy: (training) 84.31372549019609, (testing) 86.71875
[epoch 192] loss: (training) 0.017363715843827118, (testing) 0.016152358963154256,
accuracy: (training) 84.41176470588236, (testing) 87.890625
[epoch 193] loss: (training) 0.017372771250266657, (testing) 0.01613504986744374,
accuracy: (training) 84.31372549019608, (testing) 87.890625
[epoch 194] loss: (training) 0.017354142548991185, (testing) 0.016202561324462295,
accuracy: (training) 84.21568627450979, (testing) 87.890625
[epoch 195] loss: (training) 0.017360808364316527, (testing) 0.016199844307266176,
accuracy: (training) 84.31372549019609, (testing) 87.890625
[epoch 196] loss: (training) 0.017354213402551763, (testing) 0.01618110970593989,
accuracy: (training) 84.21568627450979, (testing) 87.890625
[epoch 197] loss: (training) 0.017379694417411204, (testing) 0.01633714744821191,
accuracy: (training) 84.2156862745098, (testing) 86.328125
[epoch 198] loss: (training) 0.017353576509391556, (testing) 0.016185001004487276,
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[epoch 199] loss: (training) 0.017343933588149497, (testing) 0.0161211903905496,
accuracy: (training) 84.41176470588233, (testing) 87.890625
[epoch 200] loss: (training) 0.017355679209325826, (testing) 0.016188790905289352,

accuracy: (training) 84.90196078431372, (testing) 87.890625
[epoch 201] loss: (training) 0.017339119344365366, (testing) 0.016181265120394528,
accuracy: (training) 84.50980392156862, (testing) 87.890625
[epoch 202] loss: (training) 0.017356896371233693, (testing) 0.01621948357205838,
accuracy: (training) 84.01960784313727, (testing) 87.890625
[epoch 203] loss: (training) 0.017357834589247608, (testing) 0.01616990624461323,
accuracy: (training) 84.21568627450979, (testing) 87.890625
[epoch 204] loss: (training) 0.017350584999019023, (testing) 0.016290622996166355,
accuracy: (training) 84.31372549019608, (testing) 87.109375
[epoch 205] loss: (training) 0.017336486046220744, (testing) 0.016139004146680236,
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[epoch 206] loss: (training) 0.017365928812354218, (testing) 0.016305868863128126,
accuracy: (training) 84.01960784313725, (testing) 86.71875
[epoch 207] loss: (training) 0.017351666326616326, (testing) 0.016186927212402225,
accuracy: (training) 84.41176470588235, (testing) 87.890625
[epoch 208] loss: (training) 0.017334864975190628, (testing) 0.016207479289732873,
accuracy: (training) 84.2156862745098, (testing) 87.890625
[epoch 209] loss: (training) 0.01736050157570371, (testing) 0.016202359925955534,
accuracy: (training) 84.41176470588233, (testing) 87.890625
[epoch 210] loss: (training) 0.01730853278262942, (testing) 0.01615583128295839,
accuracy: (training) 84.50980392156862, (testing) 87.890625
[epoch 211] loss: (training) 0.01733774253550698, (testing) 0.016199846984818578,
accuracy: (training) 84.50980392156862, (testing) 87.890625
[epoch 212] loss: (training) 0.017362789050036784, (testing) 0.01622796175070107,
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[epoch 215] loss: (training) 0.01734653994733212, (testing) 0.016193871619179845,
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[epoch 216] loss: (training) 0.017346134343568013, (testing) 0.016253703739494085,
accuracy: (training) 84.2156862745098, (testing) 86.71875
[epoch 217] loss: (training) 0.017351827405247034, (testing) 0.016319131362251937,
accuracy: (training) 84.31372549019608, (testing) 86.328125
[epoch 218] loss: (training) 0.01735076585821077, (testing) 0.016190440393984318,
accuracy: (training) 84.2156862745098, (testing) 87.890625
[epoch 219] loss: (training) 0.0173324044720799, (testing) 0.016262826044112444,
accuracy: (training) 84.2156862745098, (testing) 86.71875
[epoch 220] loss: (training) 0.017340004444122314, (testing) 0.016124761779792607,
accuracy: (training) 84.6078431372549, (testing) 87.890625
[epoch 221] loss: (training) 0.01732653478781382, (testing) 0.01616920274682343,
accuracy: (training) 84.41176470588235, (testing) 87.890625
[epoch 222] loss: (training) 0.017335052116244448, (testing) 0.016132973367348313,
accuracy: (training) 84.41176470588235, (testing) 87.890625
[epoch 223] loss: (training) 0.01733073156838323, (testing) 0.01616601983550936,
accuracy: (training) 84.21568627450979, (testing) 87.890625
[epoch 224] loss: (training) 0.017335275955059952, (testing) 0.01617520477157086,
accuracy: (training) 84.50980392156865, (testing) 87.890625
[epoch 225] loss: (training) 0.01733984958891775, (testing) 0.01618950453121215,
accuracy: (training) 84.50980392156865, (testing) 87.890625
[epoch 226] loss: (training) 0.017315420975872117, (testing) 0.016064391704276204,

accuracy: (training) 84.80392156862747, (testing) 87.890625
[epoch 227] loss: (training) 0.017340745411667167, (testing) 0.016186908585950732,
accuracy: (training) 84.31372549019608, (testing) 87.890625
[epoch 228] loss: (training) 0.01731260085807127, (testing) 0.016249615815468132,
accuracy: (training) 84.60784313725489, (testing) 87.109375
[epoch 229] loss: (training) 0.017323076666570177, (testing) 0.01623887463938445,
accuracy: (training) 84.50980392156862, (testing) 87.109375
[epoch 230] loss: (training) 0.01733151218470405, (testing) 0.016088636475615203,
accuracy: (training) 84.70588235294119, (testing) 87.890625
[epoch 231] loss: (training) 0.017318898468625315, (testing) 0.016255577094852924,
accuracy: (training) 83.72549019607843, (testing) 86.71875
[epoch 232] loss: (training) 0.017339846959301068, (testing) 0.016212322283536196,
accuracy: (training) 84.70588235294117, (testing) 87.890625
[epoch 233] loss: (training) 0.0173129680109959, (testing) 0.01623458042740822, accuracy:
(training) 84.50980392156863, (testing) 87.5
[epoch 234] loss: (training) 0.017338348048574787, (testing) 0.016171899740584195,
accuracy: (training) 84.21568627450979, (testing) 87.890625
[epoch 235] loss: (training) 0.017327940873071258, (testing) 0.016214708448387682,
accuracy: (training) 84.41176470588235, (testing) 87.890625
[epoch 236] loss: (training) 0.017316822882960825, (testing) 0.016144066117703915,
accuracy: (training) 84.70588235294117, (testing) 87.890625
[epoch 237] loss: (training) 0.0173242043046390, (testing) 0.016213038354180753,
accuracy: (training) 84.50980392156862, (testing) 87.890625
[epoch 238] loss: (training) 0.017278977118286434, (testing) 0.01615469006355852,
accuracy: (training) 84.50980392156862, (testing) 87.890625
[epoch 239] loss: (training) 0.017306664352323496, (testing) 0.016060925903730094,
accuracy: (training) 85.09803921568628, (testing) 87.890625
[epoch 240] loss: (training) 0.017341440360920102, (testing) 0.016147149726748466,
accuracy: (training) 84.2156862745098, (testing) 87.890625
[epoch 241] loss: (training) 0.017323650741109663, (testing) 0.016197754070162773,
accuracy: (training) 84.31372549019608, (testing) 87.890625
[epoch 242] loss: (training) 0.017300657811118107, (testing) 0.016267379629425704,
accuracy: (training) 84.6078431372549, (testing) 86.71875
[epoch 243] loss: (training) 0.017304849303236197, (testing) 0.016210412024520338,
accuracy: (training) 84.31372549019609, (testing) 87.890625
[epoch 244] loss: (training) 0.017308500058510725, (testing) 0.01603020215407014,
accuracy: (training) 84.80392156862744, (testing) 88.28125
[epoch 245] loss: (training) 0.017323515870991874, (testing) 0.0161369142588228,
accuracy: (training) 84.2156862745098, (testing) 87.890625
[epoch 246] loss: (training) 0.017320841287865357, (testing) 0.016184335807338357,
accuracy: (training) 84.41176470588236, (testing) 87.890625
[epoch 247] loss: (training) 0.017303220781625484, (testing) 0.01627279818058014,
accuracy: (training) 84.41176470588235, (testing) 86.71875
[epoch 248] loss: (training) 0.0173065672025961, (testing) 0.016213975846767426,
accuracy: (training) 84.70588235294119, (testing) 87.890625
[epoch 249] loss: (training) 0.017323365544571596, (testing) 0.016136024263687432,
accuracy: (training) 84.60784313725492, (testing) 87.890625
[epoch 250] loss: (training) 0.017302664091774063, (testing) 0.016107126139104366,
accuracy: (training) 84.41176470588235, (testing) 87.890625
[epoch 251] loss: (training) 0.017305012602432102, (testing) 0.01609820907469839,
accuracy: (training) 84.2156862745098, (testing) 87.890625
[epoch 252] loss: (training) 0.017312271074921476, (testing) 0.016200992744416, accuracy:

```
(training) 84.60784313725492, (testing) 87.890625
[epoch 253] loss: (training) 0.01730124766335768, (testing) 0.01625622808933258,
accuracy: (training) 84.41176470588235, (testing) 86.71875
[epoch 254] loss: (training) 0.0173266647493138, (testing) 0.0161888818256557, accuracy:
(training) 84.31372549019609, (testing) 87.890625
[epoch 255] loss: (training) 0.01731820436669331, (testing) 0.016128985094837844,
accuracy: (training) 84.70588235294117, (testing) 87.890625
[epoch 256] loss: (training) 0.017321569224198658, (testing) 0.016235597082413733,
accuracy: (training) 84.2156862745098, (testing) 87.5
[epoch 257] loss: (training) 0.017300615737251203, (testing) 0.016135810175910592,
accuracy: (training) 84.70588235294117, (testing) 87.890625
[epoch 258] loss: (training) 0.017300475783207835, (testing) 0.016152442898601294,
accuracy: (training) 84.31372549019606, (testing) 87.890625
[epoch 259] loss: (training) 0.017303267384276667, (testing) 0.01606466737575829,
accuracy: (training) 84.70588235294117, (testing) 87.890625
[epoch 260] loss: (training) 0.01730771815659953, (testing) 0.016221458208747208,
accuracy: (training) 84.70588235294117, (testing) 87.890625
[epoch 261] loss: (training) 0.017307649991091557, (testing) 0.016201681923121214,
accuracy: (training) 84.6078431372549, (testing) 87.890625
```

**Plot**

In [9]:

```
output_frame_plot(loss_train_mean[-1], loss_test[-1], accuracy_train[-1],␣
 ↪accuracy_test[-1], "Result")
```

```
<< Result >>
-------------------------------------------------------
             |       loss      |       accuracy     |
-------------------------------------------------------
training     |   0.0173076500  |    84.6078431373   |
-------------------------------------------------------
validation   |   0.0162016819  |    87.8906250000   |
-------------------------------------------------------
```

In [10]:

```
output_plot(loss_train_mean, loss_test, std=loss_train_std, title="Loss", color=('blue',␣
 ↪'red'),
           label=('train loss', 'validation loss'), legend='upper right')
output_plot(accuracy_train, accuracy_test, std=accuracy_train_std, title="Accuracy",␣
 ↪color=('blue', 'red'),
           label=('train accuracy', 'validation accuracy'), legend='lower right')
```

Loss



Accuracy