a4

April 22, 2025

Test with Iris dataset and Test and train split function

[1]:
```
from sklearn.datasets import load_iris
from sklearn.model_selection import train_test_split

iris = load_iris()
X, y = iris.data, iris.target

X_train,X_test,y_train,y_test=train_test_split(X,y,test_size=0.2,random_state=1)

print(X_train.shape)
print(X_test.shape)
print(y_train.shape)
print(y_test.shape)

print(X_train[0])
print(y_test[0])
```

```
(120, 4)
(30, 4)
(120,)
(30,)
[6.1 3.  4.6 1.4]
0
```

0.0.1 Architecture definition

[2]:
```
#define ANN architecture as a Torch NN Module

import torch.nn as nn

class ANN(nn.Module):
    def __init__(self, num_classes=3):
        super().__init__()
        self.lin1 = nn.Linear(4, 10)
        self.act1 = nn.ReLU()
        self.lin2 = nn.Linear(10, 20)
        self.act2 = nn.ReLU()
        self.lin3 = nn.Linear(20, num_classes)
```

```
    def forward(self, x, debug=False):
        if debug : print(f'Shape de entrada: {x.shape}')
        x = self.lin1(x)
        if debug : print(f'Shape de entrada: {x.shape}')
        x = self.act1(x)
        if debug : print(f'Shape de entrada: {x.shape}')
        x = self.lin2(x)
        if debug : print(f'Shape de entrada: {x.shape}')
        x = self.act2(x)
        if debug : print(f'Shape de entrada: {x.shape}')
        y = self.lin3(x)
        if debug : print(f'Shape de entrada: {y.shape}')
        return y
```

0.0.2 Model analysis

[3]:
```
import torch

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

print(f"Running on {my_device.type}.")

net = ANN( num_classes=3 )
#net = ANN()

net = net.to(my_device)

a = torch.rand( (1, 4) )
a = a.to(my_device)
b = net( a , debug=True)

del a, b, net
```

```
Running on cpu.
Shape de entrada: torch.Size([1, 4])
Shape de entrada: torch.Size([1, 10])
Shape de entrada: torch.Size([1, 10])
Shape de entrada: torch.Size([1, 20])
Shape de entrada: torch.Size([1, 20])
Shape de entrada: torch.Size([1, 3])
```

[4]:
```
from torchsummary import summary
```

```
net = ANN( num_classes=3 )

net = net.to(my_device)

summary(net, input_size=(1, 4), batch_size=1)

del net
```

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Linear-1                [1, 1, 10]              50
              ReLU-2                [1, 1, 10]               0
            Linear-3                [1, 1, 20]             220
              ReLU-4                [1, 1, 20]               0
            Linear-5                 [1, 1, 3]              63
================================================================
Total params: 333
Trainable params: 333
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.00
Forward/backward pass size (MB): 0.00
Params size (MB): 0.00
Estimated Total Size (MB): 0.00
----------------------------------------------------------------
```

0.0.3 Training functions

[5]:
```
from datetime import datetime

from torch.utils.tensorboard import SummaryWriter

import matplotlib.pyplot as plt
import copy
from tqdm import tqdm

from torch.utils.data import TensorDataset, DataLoader

def train ( dataset, prefix=None, upper_bound=101.0, save=False, epochs=100,␣
 ↪batch_based = False,
          lr=1e-1, device='cpu', debug=False, layers2tensorboard=True,␣
 ↪lambda_reg=0 ) :

    num_classes = 3
```

```
    tensorboard_path = '/home/jose-roberto/Documents/Disciplinas/INF492/
↪assignment/a4/train_runs/'

    net = ANN( num_classes )
    net.to(device)

    optimizer = torch.optim.SGD(net.parameters(), lr=lr,␣
↪weight_decay=lambda_reg)
    criterion = nn.CrossEntropyLoss()

    now = datetime.now()
    suffix = now.strftime("%Y%m%d_%H%M%S")
    prefix = suffix if prefix is None else prefix + '-' + suffix

    writer = SummaryWriter( log_dir=tensorboard_path+prefix )

    accuracies = []
    max_accuracy = -1.0

    # Divisão do dataset em treino e teste
    data_loader = train_test_split( dataset.data,
                                    dataset.target,
                                    test_size=0.2,
                                    random_state=1 )

    train_x,test_x,train_label,test_label = data_loader

    train_x = torch.from_numpy(train_x).float()
    train_x = train_x.to(device)
    train_label = torch.from_numpy(train_label).float()
    train_label = train_label.to(device)

    test_x = torch.from_numpy(test_x).float()
    test_x = test_x.to(device)
    test_label = torch.from_numpy(test_label).float()
    test_label = test_label.to(device)

    if batch_based:
        train_set = TensorDataset(train_x, train_label)

        train_dataloader = DataLoader(train_set, batch_size=4, shuffle=True)

        train_dataloader_size = len(train_dataloader)

    writer.add_graph(net, train_x)

    for epoch in tqdm( range(epochs) , desc='Training epochs...' ) :
```

```
    if batch_based:

        accumulated_error_train = 0.0

        train_accuracies = []

        net.train()
        for train_batch in train_dataloader:
            optimizer.zero_grad()

            train_x_batch, train_label_batch = train_batch

            predict_y = net(train_x_batch)

            error = criterion(predict_y, train_label_batch.long())
            accumulated_error_train += error.item()

            error.backward()
            optimizer.step()

            predict_ys = torch.max(predict_y, axis=1)[1]
            correct = torch.sum(predict_ys == train_label_batch)
            accuracy_train = correct/train_label_batch.size(0)

            train_accuracies.append(accuracy_train)

        full_error_train = accumulated_error_train/train_dataloader_size

        avg_train_acurracie = sum(train_accuracies)/train_dataloader_size

        accuracy_test = validate(net, test_x, test_label, device=device)
        accuracies.append(accuracy_test)

        writer.add_scalar( 'Loss/train', full_error_train, epoch )
        writer.add_scalar( 'Accuracy/train', avg_train_acurracie, epoch )
        writer.add_scalar( 'Accuracy/test', accuracy_test, epoch )

    else:
        # Set Pytorch variables
        net.train()
        optimizer.zero_grad()

        # Forward step
        predict_y = net( train_x )

        # Loss
```

```
            error = criterion( predict_y , train_label.long() )

            # Back propagation
            error.backward()
            optimizer.step()

            # Accuracies:
            predict_ys = torch.max( predict_y, axis=1 )[1]
            correct    = torch.sum( predict_ys == train_label )
            accuracy_train = correct/train_x.size(0)

            accuracy_test = validate(net, test_x, test_label, device=device)
            accuracies.append(accuracy_test)

            # Tensor board writing
            writer.add_scalar( 'Loss/train', error.item(), epoch )
            writer.add_scalar( 'Accuracy/train', accuracy_train, epoch )
            writer.add_scalar( 'Accuracy/test', accuracy_test, epoch )

        if layers2tensorboard :
            plot_layers( net, writer, epoch )

        # Test model
        if accuracy_test > max_accuracy:
            best_model = copy.deepcopy(net)
            max_accuracy = accuracy_test
            print(f'Saving the best model at epoch {epoch+1:3d} ' +
                    f'with Accuracy: {accuracy_test:8.4f}%')

        if debug : print( f'Epoch: {epoch+1:3d} |'
                        + f'Accuracy Test: {accuracy_test:3.4f}%' )

        if accuracy_test > upper_bound :
            break

    if save :
        models_path = '/home/jose-roberto/Documents/Disciplinas/INF492/
↪assignment/a4/models/'
        path = f'{models_path}{prefix}-{max_accuracy:.2f}.pkl'
        torch.save( best_model, path )
        print( f'Model saved in: {path}' )

    plt.figure(figsize=(16, 8))
    plt.plot(accuracies)

    writer.flush()
    writer.close()
```

```
    return best_model
```

[6]:
```
def validate ( model , test_x, test_label , device='cpu') :

    model.eval()

    predict_y = model( test_x ).detach()
    predict_ys = torch.max( predict_y, axis=1 )[1]
    correct = torch.sum(predict_ys == test_label)

    return correct.to('cpu').numpy()*100./test_x.size(0)
```

[7]:
```
def plot_layers ( net , writer, epoch ) :
    layers = list(net.modules())

    layer_id = 1
    for layer in layers:
        if isinstance(layer, nn.Linear) :
            writer.add_histogram(f'Bias/linear-{layer_id}', layer.bias, epoch )
            writer.add_histogram(f'Weight/linear-{layer_id}', layer.weight,␣
 ↪epoch )
            writer.add_histogram(f'Grad/linear-{layer_id}', layer.weight.grad,␣
 ↪epoch )
            layer_id += 1
```

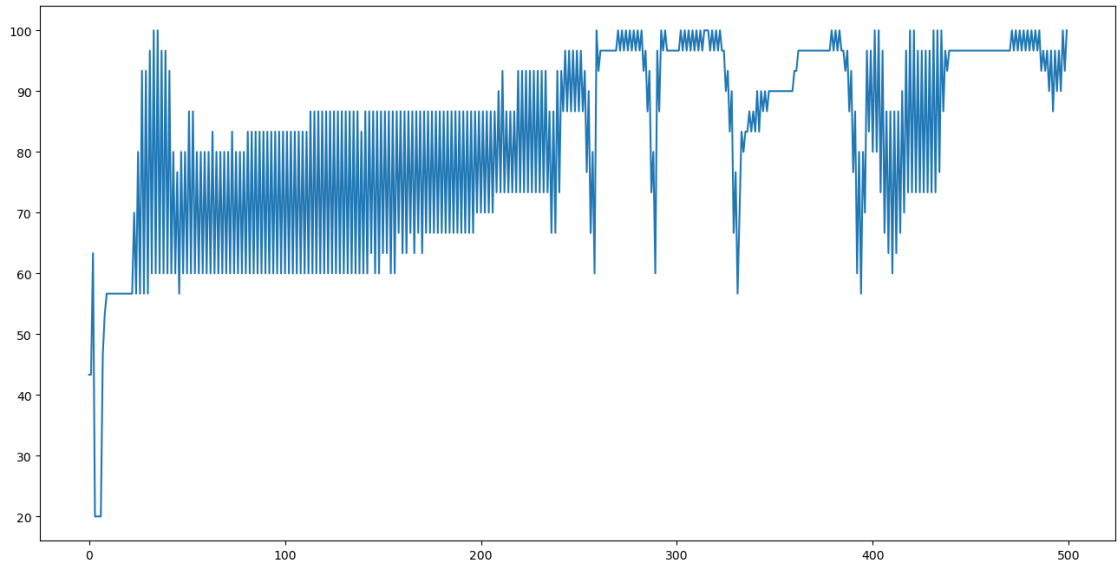
0.0.4 Run the training phase

[8]:
```
from sklearn.datasets import load_iris

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

print(f"Running on {my_device.type}")

dataset = 'Iris'
epochs = 500
lr = 1e-1
lambda_reg = 1e-4
standard_prefix = 'ANN-{}-e-{}-lr-{}'.format(dataset, epochs, lr)
batch_based_prefix = 'bANN-{}-e-{}-lr-{}'.format(dataset, epochs, lr)

iris = load_iris()
dataset = iris
```

```
Running on cpu
```

[9]:
```
net = train( dataset=dataset, epochs=epochs, batch_based=False,␣
↪device=my_device,
           upper_bound=101.0, lr=lr, lambda_reg=lambda_reg,
           layers2tensorboard=True, save=True, prefix=standard_prefix
          )
```

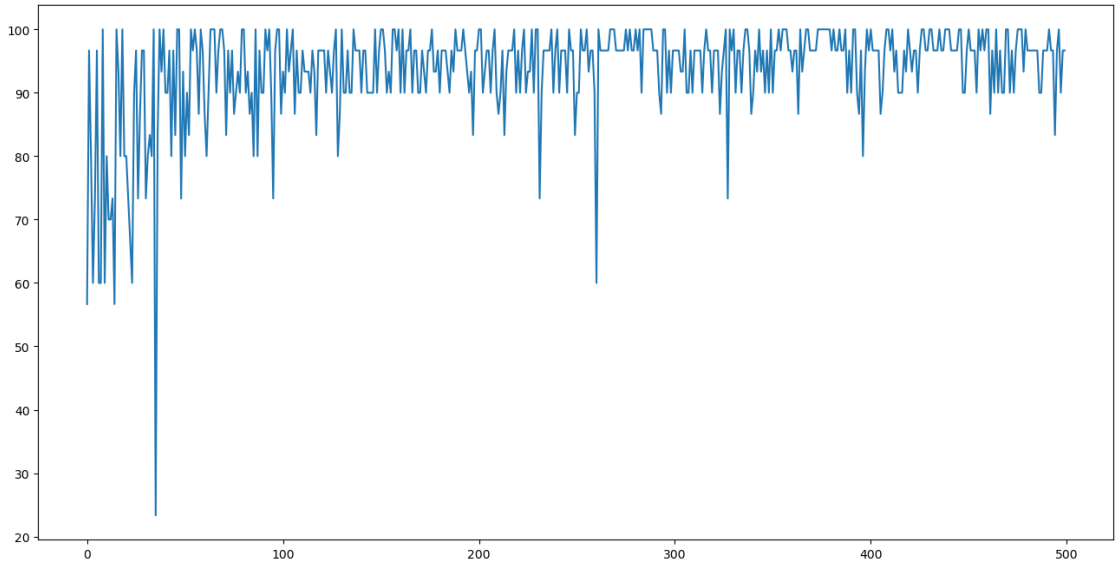
```
Training epochs…:   1%|          | 4/500 [00:00<00:17, 28.35it/s]

Saving the best model at epoch   1 with Accuracy:  43.3333%
Saving the best model at epoch   3 with Accuracy:  63.3333%

Training epochs…:   5%|          | 27/500 [00:00<00:14, 31.56it/s]

Saving the best model at epoch  24 with Accuracy:  70.0000%
Saving the best model at epoch  26 with Accuracy:  80.0000%
Saving the best model at epoch  28 with Accuracy:  93.3333%

Training epochs…:   7%|          | 35/500 [00:01<00:15, 29.53it/s]

Saving the best model at epoch  32 with Accuracy:  96.6667%
Saving the best model at epoch  34 with Accuracy: 100.0000%

Training epochs…: 100%|      | 500/500 [00:17<00:00, 28.80it/s]

Model saved in: /home/jose-
roberto/Documents/Disciplinas/INF492/assignment/a4/models/ANN-
Iris-e-500-lr-0.1-20250422_174228-100.00.pkl
```



[10]:
```
net_b = train( dataset=dataset, epochs=epochs, batch_based=True,␣
↪device=my_device,
           upper_bound=101.0, lr=lr, lambda_reg=lambda_reg,
           layers2tensorboard=True, save=True, prefix=batch_based_prefix
```

```
        )
```

```
Training epochs…:   1%|          | 4/500 [00:00<00:25, 19.19it/s]
Saving the best model at epoch   1 with Accuracy:  56.6667%
Saving the best model at epoch   2 with Accuracy:  96.6667%
Training epochs…:   2%|          | 10/500 [00:00<00:29, 16.61it/s]
Saving the best model at epoch   9 with Accuracy: 100.0000%
Training epochs…: 100%|      | 500/500 [00:37<00:00, 13.41it/s]
Model saved in: /home/jose-
roberto/Documents/Disciplinas/INF492/assignment/a4/models/bANN-
Iris-e-500-lr-0.1-20250422_174246-100.00.pkl
```



1 Discussão

Observando os resultados apresentados por cada modo de treinamento, nota-se que o modo baseado em batches apresenta uma convergência muito mais rápida. Esta é uma consequência esperada deste tipo de treinamento, pois, em vez de apresentar o dataset todo de uma vez, a apresentação por batches implica no aumento do número de vezes em que os pesos serão atualizados, desta forma, mesmo que a precisão diminua, a frequência de atualização induz à convergência.

- Dataset inteiro: 34 épocas para atingir 100% de acurácia nos testes
- Batch-based: 9 épocas para atingir 100% de acurácia nos testes