

Introduction_to_federated_learning-Alexandre_Bailly

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1 Introduction to federated learning

1.1 Imports

```
[1]: import torch
import torchvision
import numpy as np
import torch
import torch.nn as nn
import torch.nn.functional as F
import torch.nn as nn
import torch.optim as optim
import matplotlib.pyplot as plt
import torchvision.transforms as transforms
from torch.utils.data import DataLoader, Subset
```

1.2 Part 1 : Load the MNIST dataset (or any other dataset like HAM 10000)

```
[2]: # I took this load script from https://discuss.pytorch.org/t/
↳loading-mnist-from-pytorch/137456/4
transform = transforms.Compose([transforms.ToTensor(), transforms.Normalize((0.
↳5,), (0.5,))])

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

testset = torchvision.datasets.MNIST(root='./data/', train=False,
↳download=False, transform=transform)
testloader = torch.utils.data.DataLoader(testset, batch_size=batch_size,
↳shuffle=False, num_workers=2)
```

1.3 Part 2 : Extract two subsets of 600 data points each (without intersection)

```
[3]: # We get 1200
      indices = np.random.choice(len(trainset), size=1200, replace=False)

      # and we split them
      data1_indices = indices[:600]
      data2_indices = indices[600:]

      data1 = [trainset[i] for i in data1_indices]
      data2 = [trainset[i] for i in data2_indices]

      print(data1[0])
```

[illegible]

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```

1.4 Part 3 : Create a simple Convolutional Neural Network (2 convolutional layers and 2 dense layers, for example)

```
[4]: class SimpleCNN(nn.Module):
    def __init__(self):
        super(SimpleCNN, self).__init__()
        self.conv1 = nn.Conv2d(1, 16, 3)
        self.conv2 = nn.Conv2d(16, 32, 3)
        self.fc1 = nn.Linear(32 * 5 * 5, 128)
        self.fc2 = nn.Linear(128, 10)
        self.pool = nn.MaxPool2d(2)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        x = self.pool(F.relu(self.conv2(x)))
        x = torch.flatten(x, 1)
```

```

x = F.relu(self.fc1(x))
x = self.fc2(x)
return x

```

1.5 Part 4 : Create a function `average_model_parameters(models: iterable, average_weight)`: iterable that takes a list of models as an argument and returns the weighted average of the parameters of each model.

```

[5]: def average_model_parameters(models, average_weight):
    averaged_params = {}
    for name, param in models[0].state_dict().items():
        averaged_params[name] = sum(
            average_weight[i] * models[i].state_dict()[name] for i in
↪range(len(models))
        )
    return averaged_params

```

1.6 Part 5 : Create a function that updates the parameters of a model from a list of values

```

[6]: def update_model_parameters(model, parameters):
    model.load_state_dict(parameters)
    return model

```

1.7 Part 6 : Create a script/code/function that reproduces Algorithm 1, considering that both models are on your machine. Use an `average_weight=[1/2, 1/2]`. Reuse the same setup as in the article (50 examples per local batch)

```

[7]: def train_network(model, train_loader, num_epochs, device):
    loss_function = nn.CrossEntropyLoss()
    optimizer = optim.Adam(model.parameters(), lr=0.001)
    model.train()

    for epoch in range(num_epochs):
        correct = 0
        total = 0
        for inputs, labels in train_loader:
            inputs, labels = inputs.to(device), labels.to(device)
            optimizer.zero_grad()
            predictions = model(inputs)
            loss = loss_function(predictions, labels)
            loss.backward()
            optimizer.step()

            _, predicted = torch.max(predictions.data, 1)
            total += labels.size(0)

```

```

        correct += (predicted == labels).sum().item()

    accuracy = 100 * correct / total
    print(f"Small epoch {epoch + 1}, Accuracy: {accuracy:.2f}%")

def test_network(model, test_loader, device):
    model.eval()
    correct_predictions = 0
    total_samples = 0
    with torch.no_grad():
        for inputs, labels in test_loader:
            inputs, labels = inputs.to(device), labels.to(device)
            outputs = model(inputs)
            _, predicted_classes = torch.max(outputs, dim=1)
            total_samples += labels.size(0)
            correct_predictions += (predicted_classes == labels).sum().item()
    accuracy = (correct_predictions / total_samples) * 100
    return accuracy

```

```

[8]: def Algo1(model1, model2, data1, data2, testset,
        Big_Epoch=15, Small_epoch=10, compute_device='cpu'):
    loader1 = DataLoader(data1, batch_size=50, shuffle=True)
    loader2 = DataLoader(data2, batch_size=50, shuffle=True)
    eval_loader = DataLoader(testset, batch_size=100)

    performance_metrics = []

    for cycle in range(Big_Epoch):
        train_network(model1, loader1, Small_epoch, compute_device)
        train_network(model2, loader2, Small_epoch, compute_device)
        shared_params = average_model_parameters([model1, model2], [0.5, 0.5])
        update_model_parameters(model1, shared_params)
        update_model_parameters(model2, shared_params)
        evaluation_accuracy = test_network(model1, eval_loader, compute_device)
        performance_metrics.append(evaluation_accuracy)
        print(f"Cycle {cycle + 1}, Accuracy: {evaluation_accuracy:.2f}%")

    return performance_metrics

```

1.8 Part 7 : Train your models without initializing the common parameters and measure the performance on the entire dataset.

```
[9]: model1 = SimpleCNN().to('cpu')
      model2 = SimpleCNN().to('cpu')

      res_no_common_init = Algo1(model1,model2,data1, data2, testset)
```

```
Small epoch 1, Accuracy: 30.50%
Small epoch 2, Accuracy: 62.50%
Small epoch 3, Accuracy: 77.83%
Small epoch 4, Accuracy: 82.17%
Small epoch 5, Accuracy: 87.17%
Small epoch 6, Accuracy: 89.83%
Small epoch 7, Accuracy: 92.50%
Small epoch 8, Accuracy: 93.17%
Small epoch 9, Accuracy: 95.67%
Small epoch 10, Accuracy: 96.17%
Small epoch 1, Accuracy: 23.67%
Small epoch 2, Accuracy: 63.00%
Small epoch 3, Accuracy: 75.67%
Small epoch 4, Accuracy: 82.17%
Small epoch 5, Accuracy: 85.50%
Small epoch 6, Accuracy: 89.83%
Small epoch 7, Accuracy: 90.50%
Small epoch 8, Accuracy: 92.33%
Small epoch 9, Accuracy: 93.50%
Small epoch 10, Accuracy: 94.67%
Cycle 1, Accuracy: 48.69%
Small epoch 1, Accuracy: 76.33%
Small epoch 2, Accuracy: 86.33%
Small epoch 3, Accuracy: 89.67%
Small epoch 4, Accuracy: 91.33%
Small epoch 5, Accuracy: 91.83%
Small epoch 6, Accuracy: 94.33%
Small epoch 7, Accuracy: 96.00%
Small epoch 8, Accuracy: 96.00%
Small epoch 9, Accuracy: 97.17%
Small epoch 10, Accuracy: 97.00%
Small epoch 1, Accuracy: 76.33%
Small epoch 2, Accuracy: 87.83%
Small epoch 3, Accuracy: 89.67%
Small epoch 4, Accuracy: 90.67%
Small epoch 5, Accuracy: 92.33%
Small epoch 6, Accuracy: 93.50%
Small epoch 7, Accuracy: 95.00%
Small epoch 8, Accuracy: 94.83%
Small epoch 9, Accuracy: 97.67%
Small epoch 10, Accuracy: 97.50%
Cycle 2, Accuracy: 93.08%
```

Small epoch 1, Accuracy: 92.00%
 Small epoch 2, Accuracy: 93.83%
 Small epoch 3, Accuracy: 96.17%
 Small epoch 4, Accuracy: 97.67%
 Small epoch 5, Accuracy: 98.50%
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 Cycle 4, Accuracy: 94.74%
 Small epoch 1, Accuracy: 97.17%
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 Cycle 5, Accuracy: 95.02%
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 Cycle 6, Accuracy: 95.44%
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 Cycle 7, Accuracy: 95.52%
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 Cycle 8, Accuracy: 95.58%
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 Cycle 9, Accuracy: 95.71%
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 Cycle 10, Accuracy: 95.70%
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 Small epoch 10, Accuracy: 100.00%
 Cycle 12, Accuracy: 95.77%
 Small epoch 1, Accuracy: 100.00%
 Small epoch 2, Accuracy: 100.00%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 99.83%
 Small epoch 6, Accuracy: 99.50%
 Small epoch 7, Accuracy: 99.83%
 Small epoch 8, Accuracy: 99.83%
 Small epoch 9, Accuracy: 99.67%
 Small epoch 10, Accuracy: 99.33%
 Small epoch 1, Accuracy: 99.83%
 Small epoch 2, Accuracy: 99.67%
 Small epoch 3, Accuracy: 99.67%
 Small epoch 4, Accuracy: 99.67%
 Small epoch 5, Accuracy: 99.67%
 Small epoch 6, Accuracy: 99.83%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 13, Accuracy: 95.58%
 Small epoch 1, Accuracy: 99.67%
 Small epoch 2, Accuracy: 99.67%
 Small epoch 3, Accuracy: 99.83%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%

```

Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 99.83%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 14, Accuracy: 95.56%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 99.83%
Small epoch 3, Accuracy: 99.83%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 99.83%
Small epoch 7, Accuracy: 99.50%
Small epoch 8, Accuracy: 99.50%
Small epoch 9, Accuracy: 99.67%
Small epoch 10, Accuracy: 99.50%
Small epoch 1, Accuracy: 99.83%
Small epoch 2, Accuracy: 99.83%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 99.83%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 15, Accuracy: 95.40%

```

1.9 Part 8 : Train your models with the initialization of common parameters and verify that the performance is better.

```

[10]: model1 = SimpleCNN().to('cpu')
      model2 = SimpleCNN().to('cpu')
      common_params = average_model_parameters([model1, model2], [0.5, 0.5])
      update_model_parameters(model1, common_params)
      update_model_parameters(model2, common_params)

      res_common_init = Algo1(model1,model2, data1, data2, testset)

```

```

Small epoch 1, Accuracy: 21.67%
Small epoch 2, Accuracy: 44.50%
Small epoch 3, Accuracy: 65.83%

```

Small epoch 4, Accuracy: 76.67%
 Small epoch 5, Accuracy: 80.83%
 Small epoch 6, Accuracy: 86.17%
 Small epoch 7, Accuracy: 85.83%
 Small epoch 8, Accuracy: 89.00%
 Small epoch 9, Accuracy: 90.83%
 Small epoch 10, Accuracy: 92.50%
 Small epoch 1, Accuracy: 28.33%
 Small epoch 2, Accuracy: 53.17%
 Small epoch 3, Accuracy: 67.50%
 Small epoch 4, Accuracy: 76.00%
 Small epoch 5, Accuracy: 81.17%
 Small epoch 6, Accuracy: 86.83%
 Small epoch 7, Accuracy: 87.17%
 Small epoch 8, Accuracy: 88.00%
 Small epoch 9, Accuracy: 90.33%
 Small epoch 10, Accuracy: 93.17%
 Cycle 1, Accuracy: 84.86%
 Small epoch 1, Accuracy: 86.50%
 Small epoch 2, Accuracy: 90.17%
 Small epoch 3, Accuracy: 93.33%
 Small epoch 4, Accuracy: 94.00%
 Small epoch 5, Accuracy: 96.67%
 Small epoch 6, Accuracy: 95.67%
 Small epoch 7, Accuracy: 96.83%
 Small epoch 8, Accuracy: 97.50%
 Small epoch 9, Accuracy: 97.50%
 Small epoch 10, Accuracy: 98.83%
 Small epoch 1, Accuracy: 88.83%
 Small epoch 2, Accuracy: 91.33%
 Small epoch 3, Accuracy: 93.67%
 Small epoch 4, Accuracy: 95.33%
 Small epoch 5, Accuracy: 95.17%
 Small epoch 6, Accuracy: 97.33%
 Small epoch 7, Accuracy: 97.50%
 Small epoch 8, Accuracy: 98.50%
 Small epoch 9, Accuracy: 98.67%
 Small epoch 10, Accuracy: 98.83%
 Cycle 2, Accuracy: 92.35%
 Small epoch 1, Accuracy: 92.50%
 Small epoch 2, Accuracy: 95.00%
 Small epoch 3, Accuracy: 98.00%
 Small epoch 4, Accuracy: 99.33%
 Small epoch 5, Accuracy: 99.67%
 Small epoch 6, Accuracy: 99.83%
 Small epoch 7, Accuracy: 99.83%
 Small epoch 8, Accuracy: 99.83%
 Small epoch 9, Accuracy: 100.00%

Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 94.00%
 Small epoch 2, Accuracy: 96.17%
 Small epoch 3, Accuracy: 98.67%
 Small epoch 4, Accuracy: 99.00%
 Small epoch 5, Accuracy: 99.33%
 Small epoch 6, Accuracy: 99.67%
 Small epoch 7, Accuracy: 99.50%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 99.83%
 Small epoch 10, Accuracy: 100.00%
 Cycle 3, Accuracy: 93.58%
 Small epoch 1, Accuracy: 95.33%
 Small epoch 2, Accuracy: 97.17%
 Small epoch 3, Accuracy: 99.00%
 Small epoch 4, Accuracy: 99.83%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 99.83%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 99.83%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 96.67%
 Small epoch 2, Accuracy: 98.33%
 Small epoch 3, Accuracy: 99.33%
 Small epoch 4, Accuracy: 99.83%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 4, Accuracy: 94.34%
 Small epoch 1, Accuracy: 97.83%
 Small epoch 2, Accuracy: 98.67%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 99.83%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 96.67%
 Small epoch 2, Accuracy: 97.33%
 Small epoch 3, Accuracy: 99.00%
 Small epoch 4, Accuracy: 99.83%
 Small epoch 5, Accuracy: 99.83%

Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 5, Accuracy: 94.58%
Small epoch 1, Accuracy: 98.00%
Small epoch 2, Accuracy: 99.67%
Small epoch 3, Accuracy: 99.83%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.17%
Small epoch 2, Accuracy: 99.67%
Small epoch 3, Accuracy: 99.83%
Small epoch 4, Accuracy: 99.67%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 6, Accuracy: 94.79%
Small epoch 1, Accuracy: 99.50%
Small epoch 2, Accuracy: 99.50%
Small epoch 3, Accuracy: 99.50%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.33%
Small epoch 2, Accuracy: 99.50%
Small epoch 3, Accuracy: 99.83%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 7, Accuracy: 94.97%

Small epoch 1, Accuracy: 97.83%
Small epoch 2, Accuracy: 99.50%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.67%
Small epoch 2, Accuracy: 99.17%
Small epoch 3, Accuracy: 99.33%
Small epoch 4, Accuracy: 99.83%
Small epoch 5, Accuracy: 99.67%
Small epoch 6, Accuracy: 99.83%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 8, Accuracy: 95.06%
Small epoch 1, Accuracy: 99.17%
Small epoch 2, Accuracy: 99.33%
Small epoch 3, Accuracy: 99.33%
Small epoch 4, Accuracy: 99.83%
Small epoch 5, Accuracy: 99.50%
Small epoch 6, Accuracy: 99.83%
Small epoch 7, Accuracy: 99.83%
Small epoch 8, Accuracy: 99.83%
Small epoch 9, Accuracy: 99.83%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.67%
Small epoch 2, Accuracy: 99.83%
Small epoch 3, Accuracy: 99.50%
Small epoch 4, Accuracy: 99.50%
Small epoch 5, Accuracy: 99.83%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 9, Accuracy: 95.22%
Small epoch 1, Accuracy: 99.83%
Small epoch 2, Accuracy: 99.83%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 99.83%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%

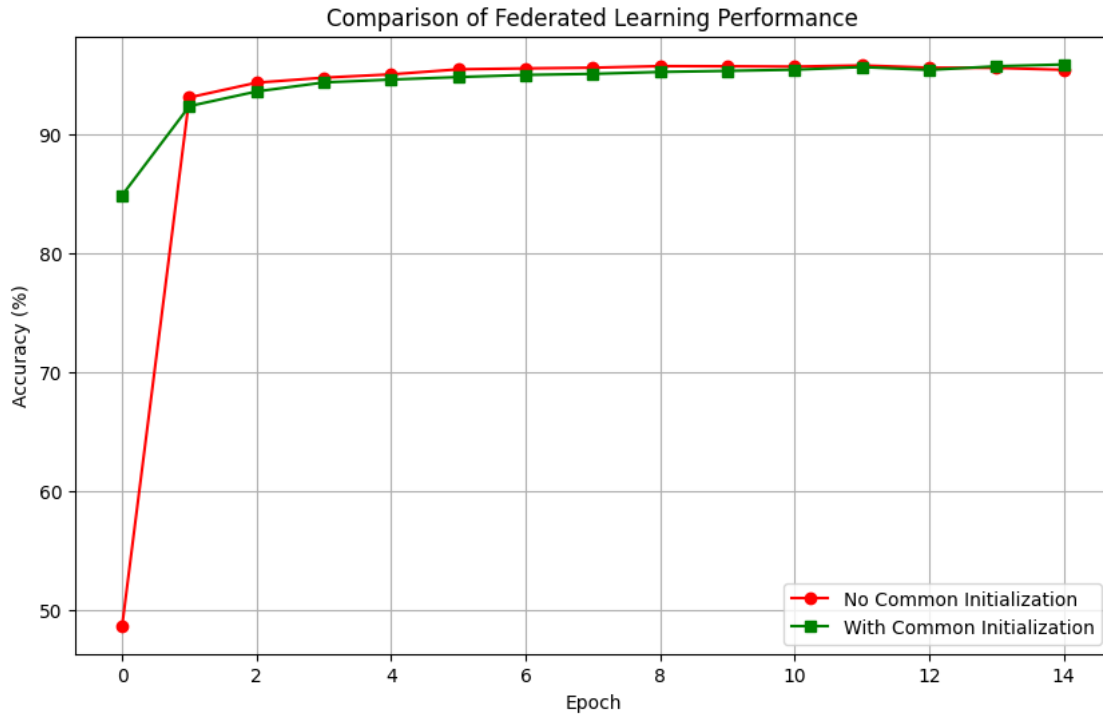
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 99.83%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 10, Accuracy: 95.31%
Small epoch 1, Accuracy: 99.83%
Small epoch 2, Accuracy: 99.83%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.50%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 99.67%
Small epoch 4, Accuracy: 99.83%
Small epoch 5, Accuracy: 99.83%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 11, Accuracy: 95.41%
Small epoch 1, Accuracy: 99.83%
Small epoch 2, Accuracy: 99.83%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 99.83%
Small epoch 5, Accuracy: 99.67%
Small epoch 6, Accuracy: 99.83%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.83%
Small epoch 2, Accuracy: 100.00%

Small epoch 3, Accuracy: 99.83%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 12, Accuracy: 95.63%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.83%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 13, Accuracy: 95.39%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 99.83%
Small epoch 7, Accuracy: 99.50%
Small epoch 8, Accuracy: 99.50%
Small epoch 9, Accuracy: 99.83%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 99.83%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 99.83%
Small epoch 6, Accuracy: 99.83%
Small epoch 7, Accuracy: 99.83%
Small epoch 8, Accuracy: 99.83%

Small epoch 9, Accuracy: 99.67%
 Small epoch 10, Accuracy: 99.50%
 Cycle 14, Accuracy: 95.70%
 Small epoch 1, Accuracy: 99.83%
 Small epoch 2, Accuracy: 99.83%
 Small epoch 3, Accuracy: 99.67%
 Small epoch 4, Accuracy: 99.83%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 99.67%
 Small epoch 2, Accuracy: 100.00%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 15, Accuracy: 95.85%

```

[11]: plt.figure(figsize=(10, 6))
      plt.plot(res_no_common_init, label="No Common Initialization", marker='o',
               color='red')
      plt.plot(res_common_init, label="With Common Initialization", marker='s',
               color='green')
      plt.xlabel("Epoch")
      plt.ylabel("Accuracy (%)")
      plt.title("Comparison of Federated Learning Performance")
      plt.legend()
      plt.grid(True)
      plt.show()
  
```



1.10 Part 9 : Reduce the number of data points in each sub-batch. What is the minimum number of data points necessary for the final model to have acceptable performance? Repeat the study on CIFAR-10

```
[12]: sample_sizes = [300, 600, 2400, 4800]
      results = []

      for size in sample_sizes:
          indices = np.random.choice(len(trainset), size=size, replace=False)
          split = size // 2
          data1 = [trainset[i] for i in indices[:split]]
          data2 = [trainset[i] for i in indices[split:]]

          model1 = SimpleCNN().to('cpu')
          model2 = SimpleCNN().to('cpu')
          common_params = average_model_parameters([model1, model2], [0.5, 0.5])
          update_model_parameters(model1, common_params)
          update_model_parameters(model2, common_params)

          res_common_init = Algo1(model1, model2, data1, data2, testset)
          results.append(res_common_init)
```

Small epoch 1, Accuracy: 7.33%

Small epoch 2, Accuracy: 16.67%

Small epoch 3, Accuracy: 20.00%
Small epoch 4, Accuracy: 34.00%
Small epoch 5, Accuracy: 36.00%
Small epoch 6, Accuracy: 44.00%
Small epoch 7, Accuracy: 56.67%
Small epoch 8, Accuracy: 64.67%
Small epoch 9, Accuracy: 69.33%
Small epoch 10, Accuracy: 70.00%
Small epoch 1, Accuracy: 16.00%
Small epoch 2, Accuracy: 19.33%
Small epoch 3, Accuracy: 19.33%
Small epoch 4, Accuracy: 20.00%
Small epoch 5, Accuracy: 27.33%
Small epoch 6, Accuracy: 38.67%
Small epoch 7, Accuracy: 48.00%
Small epoch 8, Accuracy: 52.67%
Small epoch 9, Accuracy: 55.33%
Small epoch 10, Accuracy: 62.00%
Cycle 1, Accuracy: 41.48%
Small epoch 1, Accuracy: 61.33%
Small epoch 2, Accuracy: 74.67%
Small epoch 3, Accuracy: 80.67%
Small epoch 4, Accuracy: 84.67%
Small epoch 5, Accuracy: 90.67%
Small epoch 6, Accuracy: 88.67%
Small epoch 7, Accuracy: 90.00%
Small epoch 8, Accuracy: 96.67%
Small epoch 9, Accuracy: 96.00%
Small epoch 10, Accuracy: 98.00%
Small epoch 1, Accuracy: 58.67%
Small epoch 2, Accuracy: 70.00%
Small epoch 3, Accuracy: 72.00%
Small epoch 4, Accuracy: 80.00%
Small epoch 5, Accuracy: 80.00%
Small epoch 6, Accuracy: 80.00%
Small epoch 7, Accuracy: 83.33%
Small epoch 8, Accuracy: 86.67%
Small epoch 9, Accuracy: 87.33%
Small epoch 10, Accuracy: 90.67%
Cycle 2, Accuracy: 83.50%
Small epoch 1, Accuracy: 87.33%
Small epoch 2, Accuracy: 92.00%
Small epoch 3, Accuracy: 94.67%
Small epoch 4, Accuracy: 96.00%
Small epoch 5, Accuracy: 97.33%
Small epoch 6, Accuracy: 98.00%
Small epoch 7, Accuracy: 99.33%
Small epoch 8, Accuracy: 99.33%

Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 82.00%
 Small epoch 2, Accuracy: 86.67%
 Small epoch 3, Accuracy: 91.33%
 Small epoch 4, Accuracy: 92.00%
 Small epoch 5, Accuracy: 94.00%
 Small epoch 6, Accuracy: 96.00%
 Small epoch 7, Accuracy: 96.67%
 Small epoch 8, Accuracy: 98.00%
 Small epoch 9, Accuracy: 98.00%
 Small epoch 10, Accuracy: 98.00%
 Cycle 3, Accuracy: 87.58%
 Small epoch 1, Accuracy: 94.00%
 Small epoch 2, Accuracy: 97.33%
 Small epoch 3, Accuracy: 96.67%
 Small epoch 4, Accuracy: 98.67%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 91.33%
 Small epoch 2, Accuracy: 93.33%
 Small epoch 3, Accuracy: 96.00%
 Small epoch 4, Accuracy: 94.00%
 Small epoch 5, Accuracy: 98.67%
 Small epoch 6, Accuracy: 99.33%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 99.33%
 Small epoch 9, Accuracy: 99.33%
 Small epoch 10, Accuracy: 99.33%
 Cycle 4, Accuracy: 88.33%
 Small epoch 1, Accuracy: 100.00%
 Small epoch 2, Accuracy: 100.00%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 97.33%
 Small epoch 2, Accuracy: 98.00%
 Small epoch 3, Accuracy: 98.67%
 Small epoch 4, Accuracy: 100.00%

Small epoch 5, Accuracy: 99.33%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 5, Accuracy: 89.27%
Small epoch 1, Accuracy: 99.33%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 96.67%
Small epoch 2, Accuracy: 96.67%
Small epoch 3, Accuracy: 99.33%
Small epoch 4, Accuracy: 99.33%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 6, Accuracy: 89.26%
Small epoch 1, Accuracy: 99.33%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 99.33%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 99.33%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 98.00%
Small epoch 2, Accuracy: 97.33%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 99.33%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%

Cycle 7, Accuracy: 89.76%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.33%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 99.33%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 8, Accuracy: 89.76%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.33%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 9, Accuracy: 89.63%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%

Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
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 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 10, Accuracy: 90.14%
 Small epoch 1, Accuracy: 98.67%
 Small epoch 2, Accuracy: 99.33%
 Small epoch 3, Accuracy: 99.33%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
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 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
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 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 11, Accuracy: 90.11%
 Small epoch 1, Accuracy: 100.00%
 Small epoch 2, Accuracy: 99.33%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 99.33%
 Small epoch 5, Accuracy: 100.00%
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Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 12, Accuracy: 90.46%
Small epoch 1, Accuracy: 99.33%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 99.33%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
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Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 13, Accuracy: 89.90%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
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Small epoch 7, Accuracy: 100.00%

Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 14, Accuracy: 90.50%
 Small epoch 1, Accuracy: 100.00%
 Small epoch 2, Accuracy: 100.00%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
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 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 99.33%
 Small epoch 2, Accuracy: 100.00%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 100.00%
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 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 15, Accuracy: 89.98%
 Small epoch 1, Accuracy: 14.00%
 Small epoch 2, Accuracy: 46.00%
 Small epoch 3, Accuracy: 50.67%
 Small epoch 4, Accuracy: 58.00%
 Small epoch 5, Accuracy: 62.33%
 Small epoch 6, Accuracy: 72.00%
 Small epoch 7, Accuracy: 78.67%
 Small epoch 8, Accuracy: 82.67%
 Small epoch 9, Accuracy: 84.33%
 Small epoch 10, Accuracy: 86.67%
 Small epoch 1, Accuracy: 15.00%
 Small epoch 2, Accuracy: 25.33%
 Small epoch 3, Accuracy: 46.67%
 Small epoch 4, Accuracy: 55.67%
 Small epoch 5, Accuracy: 69.33%
 Small epoch 6, Accuracy: 76.33%
 Small epoch 7, Accuracy: 81.33%
 Small epoch 8, Accuracy: 86.00%
 Small epoch 9, Accuracy: 87.67%
 Small epoch 10, Accuracy: 90.33%
 Cycle 1, Accuracy: 79.60%
 Small epoch 1, Accuracy: 83.33%
 Small epoch 2, Accuracy: 88.00%

Small epoch 3, Accuracy: 89.00%
 Small epoch 4, Accuracy: 91.00%
 Small epoch 5, Accuracy: 92.00%
 Small epoch 6, Accuracy: 93.67%
 Small epoch 7, Accuracy: 95.33%
 Small epoch 8, Accuracy: 96.33%
 Small epoch 9, Accuracy: 97.67%
 Small epoch 10, Accuracy: 97.33%
 Small epoch 1, Accuracy: 85.33%
 Small epoch 2, Accuracy: 90.67%
 Small epoch 3, Accuracy: 91.00%
 Small epoch 4, Accuracy: 94.67%
 Small epoch 5, Accuracy: 94.00%
 Small epoch 6, Accuracy: 95.33%
 Small epoch 7, Accuracy: 96.33%
 Small epoch 8, Accuracy: 97.00%
 Small epoch 9, Accuracy: 97.00%
 Small epoch 10, Accuracy: 98.67%
 Cycle 2, Accuracy: 90.52%
 Small epoch 1, Accuracy: 92.33%
 Small epoch 2, Accuracy: 93.67%
 Small epoch 3, Accuracy: 95.33%
 Small epoch 4, Accuracy: 98.00%
 Small epoch 5, Accuracy: 98.33%
 Small epoch 6, Accuracy: 98.67%
 Small epoch 7, Accuracy: 99.33%
 Small epoch 8, Accuracy: 99.67%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 93.00%
 Small epoch 2, Accuracy: 95.67%
 Small epoch 3, Accuracy: 97.67%
 Small epoch 4, Accuracy: 97.33%
 Small epoch 5, Accuracy: 98.33%
 Small epoch 6, Accuracy: 99.33%
 Small epoch 7, Accuracy: 99.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 3, Accuracy: 92.21%
 Small epoch 1, Accuracy: 95.00%
 Small epoch 2, Accuracy: 95.33%
 Small epoch 3, Accuracy: 97.00%
 Small epoch 4, Accuracy: 97.33%
 Small epoch 5, Accuracy: 98.67%
 Small epoch 6, Accuracy: 99.67%
 Small epoch 7, Accuracy: 99.67%
 Small epoch 8, Accuracy: 100.00%

Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 96.33%
Small epoch 2, Accuracy: 98.00%
Small epoch 3, Accuracy: 99.00%
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Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 4, Accuracy: 93.19%
Small epoch 1, Accuracy: 97.00%
Small epoch 2, Accuracy: 98.33%
Small epoch 3, Accuracy: 99.67%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 97.67%
Small epoch 2, Accuracy: 98.67%
Small epoch 3, Accuracy: 99.00%
Small epoch 4, Accuracy: 99.67%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 5, Accuracy: 93.37%
Small epoch 1, Accuracy: 98.33%
Small epoch 2, Accuracy: 96.00%
Small epoch 3, Accuracy: 99.00%
Small epoch 4, Accuracy: 98.33%
Small epoch 5, Accuracy: 100.00%
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Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 98.67%
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 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 6, Accuracy: 93.70%
 Small epoch 1, Accuracy: 99.00%
 Small epoch 2, Accuracy: 99.67%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 99.67%
 Small epoch 5, Accuracy: 100.00%
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 Small epoch 2, Accuracy: 99.33%
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 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 7, Accuracy: 93.93%
 Small epoch 1, Accuracy: 99.33%
 Small epoch 2, Accuracy: 99.33%
 Small epoch 3, Accuracy: 98.67%
 Small epoch 4, Accuracy: 99.67%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
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 Small epoch 8, Accuracy: 100.00%
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 Small epoch 10, Accuracy: 100.00%

Cycle 8, Accuracy: 94.04%
Small epoch 1, Accuracy: 99.67%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
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Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.67%
Small epoch 2, Accuracy: 100.00%
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Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 9, Accuracy: 94.14%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
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Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 10, Accuracy: 94.19%
Small epoch 1, Accuracy: 100.00%
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Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 11, Accuracy: 94.50%
Small epoch 1, Accuracy: 99.33%
Small epoch 2, Accuracy: 99.33%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
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Small epoch 10, Accuracy: 100.00%
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Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 12, Accuracy: 94.53%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
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Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 13, Accuracy: 94.28%
Small epoch 1, Accuracy: 99.67%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 99.33%
Small epoch 4, Accuracy: 99.33%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
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Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 14, Accuracy: 94.65%
Small epoch 1, Accuracy: 100.00%
Small epoch 2, Accuracy: 99.67%
Small epoch 3, Accuracy: 99.67%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 99.67%
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Small epoch 10, Accuracy: 100.00%
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Small epoch 7, Accuracy: 100.00%

Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 15, Accuracy: 94.61%
Small epoch 1, Accuracy: 30.00%
Small epoch 2, Accuracy: 72.25%
Small epoch 3, Accuracy: 80.33%
Small epoch 4, Accuracy: 87.75%
Small epoch 5, Accuracy: 90.75%
Small epoch 6, Accuracy: 92.08%
Small epoch 7, Accuracy: 93.33%
Small epoch 8, Accuracy: 95.17%
Small epoch 9, Accuracy: 96.17%
Small epoch 10, Accuracy: 96.25%
Small epoch 1, Accuracy: 27.00%
Small epoch 2, Accuracy: 70.42%
Small epoch 3, Accuracy: 82.25%
Small epoch 4, Accuracy: 89.33%
Small epoch 5, Accuracy: 91.17%
Small epoch 6, Accuracy: 93.50%
Small epoch 7, Accuracy: 94.17%
Small epoch 8, Accuracy: 95.33%
Small epoch 9, Accuracy: 96.33%
Small epoch 10, Accuracy: 97.08%
Cycle 1, Accuracy: 92.44%
Small epoch 1, Accuracy: 94.08%
Small epoch 2, Accuracy: 95.75%
Small epoch 3, Accuracy: 97.00%
Small epoch 4, Accuracy: 97.33%
Small epoch 5, Accuracy: 98.25%
Small epoch 6, Accuracy: 98.33%
Small epoch 7, Accuracy: 98.92%
Small epoch 8, Accuracy: 99.17%
Small epoch 9, Accuracy: 99.33%
Small epoch 10, Accuracy: 99.67%
Small epoch 1, Accuracy: 94.33%
Small epoch 2, Accuracy: 96.17%
Small epoch 3, Accuracy: 97.50%
Small epoch 4, Accuracy: 98.08%
Small epoch 5, Accuracy: 97.75%
Small epoch 6, Accuracy: 99.08%
Small epoch 7, Accuracy: 99.42%
Small epoch 8, Accuracy: 99.58%
Small epoch 9, Accuracy: 99.75%
Small epoch 10, Accuracy: 99.33%
Cycle 2, Accuracy: 95.00%
Small epoch 1, Accuracy: 96.75%
Small epoch 2, Accuracy: 98.50%

Small epoch 3, Accuracy: 99.25%
 Small epoch 4, Accuracy: 99.83%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 99.75%
 Small epoch 9, Accuracy: 99.83%
 Small epoch 10, Accuracy: 99.83%
 Small epoch 1, Accuracy: 97.42%
 Small epoch 2, Accuracy: 99.08%
 Small epoch 3, Accuracy: 99.42%
 Small epoch 4, Accuracy: 99.92%
 Small epoch 5, Accuracy: 99.92%
 Small epoch 6, Accuracy: 99.67%
 Small epoch 7, Accuracy: 99.58%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 3, Accuracy: 95.79%
 Small epoch 1, Accuracy: 98.17%
 Small epoch 2, Accuracy: 99.67%
 Small epoch 3, Accuracy: 99.92%
 Small epoch 4, Accuracy: 99.83%
 Small epoch 5, Accuracy: 99.75%
 Small epoch 6, Accuracy: 100.00%
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 Small epoch 1, Accuracy: 98.17%
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 Small epoch 3, Accuracy: 99.92%
 Small epoch 4, Accuracy: 100.00%
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 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 4, Accuracy: 96.10%
 Small epoch 1, Accuracy: 99.25%
 Small epoch 2, Accuracy: 99.67%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 99.92%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
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 Small epoch 8, Accuracy: 99.75%

Small epoch 9, Accuracy: 99.17%
 Small epoch 10, Accuracy: 99.17%
 Small epoch 1, Accuracy: 99.08%
 Small epoch 2, Accuracy: 99.67%
 Small epoch 3, Accuracy: 99.75%
 Small epoch 4, Accuracy: 100.00%
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 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 5, Accuracy: 95.98%
 Small epoch 1, Accuracy: 99.00%
 Small epoch 2, Accuracy: 99.67%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 100.00%
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 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 99.08%
 Small epoch 2, Accuracy: 99.83%
 Small epoch 3, Accuracy: 99.83%
 Small epoch 4, Accuracy: 99.75%
 Small epoch 5, Accuracy: 99.92%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 6, Accuracy: 96.37%
 Small epoch 1, Accuracy: 99.25%
 Small epoch 2, Accuracy: 99.75%
 Small epoch 3, Accuracy: 99.92%
 Small epoch 4, Accuracy: 100.00%
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 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 99.33%
 Small epoch 2, Accuracy: 100.00%
 Small epoch 3, Accuracy: 99.92%
 Small epoch 4, Accuracy: 100.00%

Small epoch 5, Accuracy: 100.00%
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Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 7, Accuracy: 96.46%
Small epoch 1, Accuracy: 99.67%
Small epoch 2, Accuracy: 99.83%
Small epoch 3, Accuracy: 100.00%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 99.67%
Small epoch 6, Accuracy: 99.50%
Small epoch 7, Accuracy: 99.92%
Small epoch 8, Accuracy: 99.92%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.67%
Small epoch 2, Accuracy: 100.00%
Small epoch 3, Accuracy: 99.58%
Small epoch 4, Accuracy: 99.92%
Small epoch 5, Accuracy: 99.92%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 8, Accuracy: 96.27%
Small epoch 1, Accuracy: 99.58%
Small epoch 2, Accuracy: 99.25%
Small epoch 3, Accuracy: 99.92%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 99.50%
Small epoch 2, Accuracy: 99.75%
Small epoch 3, Accuracy: 99.83%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%

Cycle 9, Accuracy: 96.45%
 Small epoch 1, Accuracy: 99.67%
 Small epoch 2, Accuracy: 99.83%
 Small epoch 3, Accuracy: 100.00%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
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 Cycle 3, Accuracy: 97.68%
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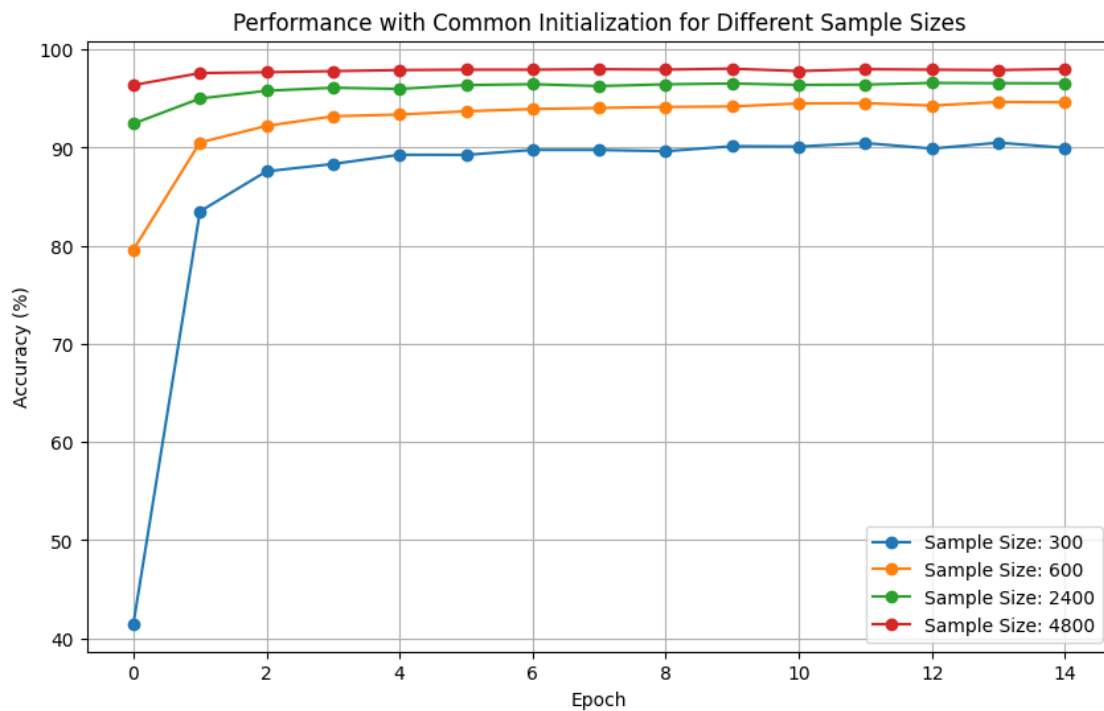
Small epoch 5, Accuracy: 100.00%
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Cycle 11, Accuracy: 97.80%
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Cycle 12, Accuracy: 97.99%
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 Cycle 13, Accuracy: 97.94%
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 Cycle 14, Accuracy: 97.90%
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 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 15, Accuracy: 98.01%

```
[13]: plt.figure(figsize=(10, 6))
      for size, res in zip(sample_sizes, results):
          plt.plot(res, label=f"Sample Size: {size}", marker='o')
      plt.xlabel("Epoch")
      plt.ylabel("Accuracy (%)")
      plt.title("Performance with Common Initialization for Different Sample Sizes")
      plt.legend()
      plt.grid(True)
      plt.show()
```



```
[14]: class SimpleCNN(nn.Module):
      def __init__(self):
          super(SimpleCNN, self).__init__()
```



```

self.conv1 = nn.Conv2d(3, 16, 3, padding=1)
self.conv2 = nn.Conv2d(16, 32, 3, padding=1)
self.conv3 = nn.Conv2d(32, 64, 3, padding=1)
self.pool = nn.MaxPool2d(2, 2)
self.fc1 = nn.Linear(64 * 4 * 4, 128)
self.fc2 = nn.Linear(128, 10)

def forward(self, x):
    x = self.pool(F.relu(self.conv1(x)))
    x = self.pool(F.relu(self.conv2(x)))
    x = self.pool(F.relu(self.conv3(x)))
    x = torch.flatten(x, 1)
    x = F.relu(self.fc1(x))
    x = self.fc2(x)

    return x

```

```

[18]: transform = transforms.Compose([transforms.ToTensor(), transforms.Normalize((0.
    ↪5, 0.5, 0.5), (0.5, 0.5, 0.5))])
results = {}
batch_size = 4
trainset = torchvision.datasets.CIFAR10(root='./data', train=True,
    ↪download=True, transform=transform)
testset = torchvision.datasets.CIFAR10(root='./data', train=False,
    ↪download=True, transform=transform)

for num_samples in [300, 600, 3000, 8000, 15000]:
    num_samples= num_samples*2
    indices = np.random.choice(len(trainset), size=num_samples, replace=False)
    data1_indices = indices[:num_samples // 2]
    data2_indices = indices[num_samples // 2:]

    data1 = [trainset[i] for i in data1_indices]
    data2 = [trainset[i] for i in data2_indices]

    model1 = SimpleCNN().to('cpu')
    model2 = SimpleCNN().to('cpu')
    common_params = average_model_parameters([model1, model2], [0.5, 0.5])
    update_model_parameters(model1, common_params)
    update_model_parameters(model2, common_params)

    res_common_init = Algo1(model1, model2, data1, data2, testset)
    results[num_samples] = res_common_init

```

Files already downloaded and verified

Files already downloaded and verified

Small epoch 1, Accuracy: 10.00%

Small epoch 2, Accuracy: 12.33%
 Small epoch 3, Accuracy: 17.67%
 Small epoch 4, Accuracy: 24.00%
 Small epoch 5, Accuracy: 28.33%
 Small epoch 6, Accuracy: 33.67%
 Small epoch 7, Accuracy: 35.33%
 Small epoch 8, Accuracy: 38.33%
 Small epoch 9, Accuracy: 39.67%
 Small epoch 10, Accuracy: 42.33%
 Small epoch 1, Accuracy: 17.00%
 Small epoch 2, Accuracy: 17.00%
 Small epoch 3, Accuracy: 19.00%
 Small epoch 4, Accuracy: 23.00%
 Small epoch 5, Accuracy: 24.00%
 Small epoch 6, Accuracy: 28.67%
 Small epoch 7, Accuracy: 31.00%
 Small epoch 8, Accuracy: 33.33%
 Small epoch 9, Accuracy: 36.67%
 Small epoch 10, Accuracy: 39.67%
 Cycle 1, Accuracy: 26.48%
 Small epoch 1, Accuracy: 35.33%
 Small epoch 2, Accuracy: 43.67%
 Small epoch 3, Accuracy: 44.00%
 Small epoch 4, Accuracy: 44.00%
 Small epoch 5, Accuracy: 43.00%
 Small epoch 6, Accuracy: 45.67%
 Small epoch 7, Accuracy: 49.00%
 Small epoch 8, Accuracy: 55.00%
 Small epoch 9, Accuracy: 58.33%
 Small epoch 10, Accuracy: 61.33%
 Small epoch 1, Accuracy: 32.00%
 Small epoch 2, Accuracy: 32.67%
 Small epoch 3, Accuracy: 36.67%
 Small epoch 4, Accuracy: 38.00%
 Small epoch 5, Accuracy: 40.00%
 Small epoch 6, Accuracy: 43.00%
 Small epoch 7, Accuracy: 45.33%
 Small epoch 8, Accuracy: 48.33%
 Small epoch 9, Accuracy: 52.33%
 Small epoch 10, Accuracy: 55.00%
 Cycle 2, Accuracy: 30.40%
 Small epoch 1, Accuracy: 42.67%
 Small epoch 2, Accuracy: 48.33%
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Small epoch 8, Accuracy: 68.33%
 Small epoch 9, Accuracy: 74.33%
 Small epoch 10, Accuracy: 75.33%
 Small epoch 1, Accuracy: 39.00%
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 Small epoch 10, Accuracy: 71.33%
 Cycle 3, Accuracy: 32.28%
 Small epoch 1, Accuracy: 56.33%
 Small epoch 2, Accuracy: 60.33%
 Small epoch 3, Accuracy: 64.33%
 Small epoch 4, Accuracy: 68.33%
 Small epoch 5, Accuracy: 73.67%
 Small epoch 6, Accuracy: 78.00%
 Small epoch 7, Accuracy: 81.67%
 Small epoch 8, Accuracy: 84.33%
 Small epoch 9, Accuracy: 86.67%
 Small epoch 10, Accuracy: 86.33%
 Small epoch 1, Accuracy: 43.33%
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 Small epoch 3, Accuracy: 56.00%
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 Small epoch 5, Accuracy: 66.67%
 Small epoch 6, Accuracy: 68.67%
 Small epoch 7, Accuracy: 74.67%
 Small epoch 8, Accuracy: 74.00%
 Small epoch 9, Accuracy: 77.00%
 Small epoch 10, Accuracy: 78.00%
 Cycle 4, Accuracy: 32.88%
 Small epoch 1, Accuracy: 60.33%
 Small epoch 2, Accuracy: 75.67%
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 Small epoch 10, Accuracy: 96.00%
 Small epoch 1, Accuracy: 55.67%
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 Small epoch 3, Accuracy: 72.00%

Small epoch 4, Accuracy: 80.00%
Small epoch 5, Accuracy: 79.00%
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Small epoch 7, Accuracy: 85.67%
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Cycle 5, Accuracy: 32.87%
Small epoch 1, Accuracy: 70.33%
Small epoch 2, Accuracy: 84.67%
Small epoch 3, Accuracy: 88.00%
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Small epoch 9, Accuracy: 96.33%
Small epoch 10, Accuracy: 95.67%
Cycle 6, Accuracy: 32.48%
Small epoch 1, Accuracy: 77.00%
Small epoch 2, Accuracy: 84.00%
Small epoch 3, Accuracy: 90.33%
Small epoch 4, Accuracy: 93.00%
Small epoch 5, Accuracy: 96.00%
Small epoch 6, Accuracy: 97.33%
Small epoch 7, Accuracy: 98.33%
Small epoch 8, Accuracy: 98.67%
Small epoch 9, Accuracy: 99.00%
Small epoch 10, Accuracy: 99.33%
Small epoch 1, Accuracy: 69.33%
Small epoch 2, Accuracy: 83.67%
Small epoch 3, Accuracy: 84.00%
Small epoch 4, Accuracy: 90.00%
Small epoch 5, Accuracy: 94.00%
Small epoch 6, Accuracy: 97.67%
Small epoch 7, Accuracy: 98.67%
Small epoch 8, Accuracy: 98.67%
Small epoch 9, Accuracy: 97.67%

Small epoch 10, Accuracy: 98.67%
 Cycle 7, Accuracy: 32.24%
 Small epoch 1, Accuracy: 80.67%
 Small epoch 2, Accuracy: 93.00%
 Small epoch 3, Accuracy: 91.67%
 Small epoch 4, Accuracy: 95.67%
 Small epoch 5, Accuracy: 98.67%
 Small epoch 6, Accuracy: 99.00%
 Small epoch 7, Accuracy: 99.33%
 Small epoch 8, Accuracy: 99.33%
 Small epoch 9, Accuracy: 99.33%
 Small epoch 10, Accuracy: 99.33%
 Small epoch 1, Accuracy: 75.00%
 Small epoch 2, Accuracy: 83.33%
 Small epoch 3, Accuracy: 92.00%
 Small epoch 4, Accuracy: 96.67%
 Small epoch 5, Accuracy: 98.67%
 Small epoch 6, Accuracy: 99.33%
 Small epoch 7, Accuracy: 99.67%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 8, Accuracy: 32.07%
 Small epoch 1, Accuracy: 82.00%
 Small epoch 2, Accuracy: 94.67%
 Small epoch 3, Accuracy: 96.00%
 Small epoch 4, Accuracy: 95.67%
 Small epoch 5, Accuracy: 98.33%
 Small epoch 6, Accuracy: 99.67%
 Small epoch 7, Accuracy: 99.33%
 Small epoch 8, Accuracy: 99.67%
 Small epoch 9, Accuracy: 99.67%
 Small epoch 10, Accuracy: 99.67%
 Small epoch 1, Accuracy: 75.67%
 Small epoch 2, Accuracy: 89.33%
 Small epoch 3, Accuracy: 95.00%
 Small epoch 4, Accuracy: 97.67%
 Small epoch 5, Accuracy: 99.33%
 Small epoch 6, Accuracy: 99.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 9, Accuracy: 32.38%
 Small epoch 1, Accuracy: 87.67%
 Small epoch 2, Accuracy: 93.67%
 Small epoch 3, Accuracy: 96.00%
 Small epoch 4, Accuracy: 99.00%

Small epoch 5, Accuracy: 99.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 99.67%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 84.67%
 Small epoch 2, Accuracy: 92.67%
 Small epoch 3, Accuracy: 95.00%
 Small epoch 4, Accuracy: 98.33%
 Small epoch 5, Accuracy: 99.00%
 Small epoch 6, Accuracy: 99.33%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 10, Accuracy: 31.85%
 Small epoch 1, Accuracy: 92.00%
 Small epoch 2, Accuracy: 97.33%
 Small epoch 3, Accuracy: 98.67%
 Small epoch 4, Accuracy: 99.00%
 Small epoch 5, Accuracy: 98.67%
 Small epoch 6, Accuracy: 99.33%
 Small epoch 7, Accuracy: 99.67%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 91.00%
 Small epoch 2, Accuracy: 93.67%
 Small epoch 3, Accuracy: 97.67%
 Small epoch 4, Accuracy: 98.00%
 Small epoch 5, Accuracy: 99.00%
 Small epoch 6, Accuracy: 99.67%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 11, Accuracy: 32.93%
 Small epoch 1, Accuracy: 89.00%
 Small epoch 2, Accuracy: 96.00%
 Small epoch 3, Accuracy: 99.00%
 Small epoch 4, Accuracy: 98.67%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%

Small epoch 1, Accuracy: 88.00%
 Small epoch 2, Accuracy: 94.67%
 Small epoch 3, Accuracy: 96.00%
 Small epoch 4, Accuracy: 98.67%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 12, Accuracy: 32.79%
 Small epoch 1, Accuracy: 93.67%
 Small epoch 2, Accuracy: 96.00%
 Small epoch 3, Accuracy: 94.33%
 Small epoch 4, Accuracy: 98.67%
 Small epoch 5, Accuracy: 99.67%
 Small epoch 6, Accuracy: 99.67%
 Small epoch 7, Accuracy: 99.67%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 93.00%
 Small epoch 2, Accuracy: 96.33%
 Small epoch 3, Accuracy: 97.33%
 Small epoch 4, Accuracy: 98.67%
 Small epoch 5, Accuracy: 99.33%
 Small epoch 6, Accuracy: 99.67%
 Small epoch 7, Accuracy: 99.33%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 13, Accuracy: 32.16%
 Small epoch 1, Accuracy: 93.33%
 Small epoch 2, Accuracy: 95.00%
 Small epoch 3, Accuracy: 98.33%
 Small epoch 4, Accuracy: 98.67%
 Small epoch 5, Accuracy: 98.33%
 Small epoch 6, Accuracy: 99.67%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 92.67%
 Small epoch 2, Accuracy: 96.33%
 Small epoch 3, Accuracy: 99.33%
 Small epoch 4, Accuracy: 99.33%
 Small epoch 5, Accuracy: 98.67%
 Small epoch 6, Accuracy: 99.33%

Small epoch 7, Accuracy: 99.67%
 Small epoch 8, Accuracy: 99.33%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 99.33%
 Cycle 14, Accuracy: 32.61%
 Small epoch 1, Accuracy: 97.67%
 Small epoch 2, Accuracy: 98.67%
 Small epoch 3, Accuracy: 95.67%
 Small epoch 4, Accuracy: 98.00%
 Small epoch 5, Accuracy: 99.33%
 Small epoch 6, Accuracy: 99.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 95.67%
 Small epoch 2, Accuracy: 96.33%
 Small epoch 3, Accuracy: 99.00%
 Small epoch 4, Accuracy: 98.00%
 Small epoch 5, Accuracy: 99.67%
 Small epoch 6, Accuracy: 99.67%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 99.67%
 Small epoch 9, Accuracy: 99.67%
 Small epoch 10, Accuracy: 99.33%
 Cycle 15, Accuracy: 32.99%
 Small epoch 1, Accuracy: 10.33%
 Small epoch 2, Accuracy: 16.33%
 Small epoch 3, Accuracy: 28.00%
 Small epoch 4, Accuracy: 26.50%
 Small epoch 5, Accuracy: 28.17%
 Small epoch 6, Accuracy: 29.00%
 Small epoch 7, Accuracy: 32.33%
 Small epoch 8, Accuracy: 34.00%
 Small epoch 9, Accuracy: 34.33%
 Small epoch 10, Accuracy: 39.67%
 Small epoch 1, Accuracy: 10.83%
 Small epoch 2, Accuracy: 12.17%
 Small epoch 3, Accuracy: 18.67%
 Small epoch 4, Accuracy: 21.83%
 Small epoch 5, Accuracy: 24.83%
 Small epoch 6, Accuracy: 28.83%
 Small epoch 7, Accuracy: 31.33%
 Small epoch 8, Accuracy: 35.67%
 Small epoch 9, Accuracy: 36.83%
 Small epoch 10, Accuracy: 39.83%
 Cycle 1, Accuracy: 30.27%
 Small epoch 1, Accuracy: 31.00%

Small epoch 2, Accuracy: 39.00%
 Small epoch 3, Accuracy: 40.17%
 Small epoch 4, Accuracy: 43.17%
 Small epoch 5, Accuracy: 46.67%
 Small epoch 6, Accuracy: 48.50%
 Small epoch 7, Accuracy: 50.33%
 Small epoch 8, Accuracy: 54.33%
 Small epoch 9, Accuracy: 56.00%
 Small epoch 10, Accuracy: 58.67%
 Small epoch 1, Accuracy: 29.33%
 Small epoch 2, Accuracy: 35.50%
 Small epoch 3, Accuracy: 38.17%
 Small epoch 4, Accuracy: 39.83%
 Small epoch 5, Accuracy: 44.00%
 Small epoch 6, Accuracy: 47.33%
 Small epoch 7, Accuracy: 49.00%
 Small epoch 8, Accuracy: 47.17%
 Small epoch 9, Accuracy: 53.83%
 Small epoch 10, Accuracy: 57.83%
 Cycle 2, Accuracy: 38.22%
 Small epoch 1, Accuracy: 48.17%
 Small epoch 2, Accuracy: 54.33%
 Small epoch 3, Accuracy: 58.33%
 Small epoch 4, Accuracy: 59.17%
 Small epoch 5, Accuracy: 63.50%
 Small epoch 6, Accuracy: 64.00%
 Small epoch 7, Accuracy: 67.83%
 Small epoch 8, Accuracy: 72.33%
 Small epoch 9, Accuracy: 76.33%
 Small epoch 10, Accuracy: 76.67%
 Small epoch 1, Accuracy: 44.33%
 Small epoch 2, Accuracy: 51.50%
 Small epoch 3, Accuracy: 54.50%
 Small epoch 4, Accuracy: 61.00%
 Small epoch 5, Accuracy: 60.17%
 Small epoch 6, Accuracy: 62.17%
 Small epoch 7, Accuracy: 66.83%
 Small epoch 8, Accuracy: 71.00%
 Small epoch 9, Accuracy: 72.33%
 Small epoch 10, Accuracy: 74.17%
 Cycle 3, Accuracy: 41.06%
 Small epoch 1, Accuracy: 56.50%
 Small epoch 2, Accuracy: 66.17%
 Small epoch 3, Accuracy: 69.33%
 Small epoch 4, Accuracy: 73.67%
 Small epoch 5, Accuracy: 76.83%
 Small epoch 6, Accuracy: 80.50%
 Small epoch 7, Accuracy: 82.83%

Small epoch 8, Accuracy: 85.33%
 Small epoch 9, Accuracy: 89.67%
 Small epoch 10, Accuracy: 87.00%
 Small epoch 1, Accuracy: 55.50%
 Small epoch 2, Accuracy: 64.50%
 Small epoch 3, Accuracy: 68.33%
 Small epoch 4, Accuracy: 72.00%
 Small epoch 5, Accuracy: 77.17%
 Small epoch 6, Accuracy: 83.00%
 Small epoch 7, Accuracy: 82.17%
 Small epoch 8, Accuracy: 83.83%
 Small epoch 9, Accuracy: 88.17%
 Small epoch 10, Accuracy: 89.00%
 Cycle 4, Accuracy: 40.59%
 Small epoch 1, Accuracy: 64.00%
 Small epoch 2, Accuracy: 76.83%
 Small epoch 3, Accuracy: 83.17%
 Small epoch 4, Accuracy: 87.50%
 Small epoch 5, Accuracy: 88.33%
 Small epoch 6, Accuracy: 91.67%
 Small epoch 7, Accuracy: 93.33%
 Small epoch 8, Accuracy: 95.33%
 Small epoch 9, Accuracy: 96.17%
 Small epoch 10, Accuracy: 96.17%
 Small epoch 1, Accuracy: 69.17%
 Small epoch 2, Accuracy: 78.00%
 Small epoch 3, Accuracy: 85.00%
 Small epoch 4, Accuracy: 88.67%
 Small epoch 5, Accuracy: 91.67%
 Small epoch 6, Accuracy: 93.17%
 Small epoch 7, Accuracy: 92.33%
 Small epoch 8, Accuracy: 95.83%
 Small epoch 9, Accuracy: 97.33%
 Small epoch 10, Accuracy: 98.00%
 Cycle 5, Accuracy: 40.33%
 Small epoch 1, Accuracy: 71.67%
 Small epoch 2, Accuracy: 82.83%
 Small epoch 3, Accuracy: 91.50%
 Small epoch 4, Accuracy: 95.67%
 Small epoch 5, Accuracy: 95.50%
 Small epoch 6, Accuracy: 98.33%
 Small epoch 7, Accuracy: 99.33%
 Small epoch 8, Accuracy: 99.33%
 Small epoch 9, Accuracy: 99.83%
 Small epoch 10, Accuracy: 99.50%
 Small epoch 1, Accuracy: 73.50%
 Small epoch 2, Accuracy: 87.67%
 Small epoch 3, Accuracy: 92.00%

Small epoch 4, Accuracy: 95.83%
 Small epoch 5, Accuracy: 97.17%
 Small epoch 6, Accuracy: 97.67%
 Small epoch 7, Accuracy: 98.83%
 Small epoch 8, Accuracy: 99.33%
 Small epoch 9, Accuracy: 99.33%
 Small epoch 10, Accuracy: 99.00%
 Cycle 6, Accuracy: 40.32%
 Small epoch 1, Accuracy: 79.67%
 Small epoch 2, Accuracy: 86.67%
 Small epoch 3, Accuracy: 94.83%
 Small epoch 4, Accuracy: 97.00%
 Small epoch 5, Accuracy: 98.67%
 Small epoch 6, Accuracy: 99.67%
 Small epoch 7, Accuracy: 99.50%
 Small epoch 8, Accuracy: 99.83%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 80.83%
 Small epoch 2, Accuracy: 91.33%
 Small epoch 3, Accuracy: 97.00%
 Small epoch 4, Accuracy: 98.33%
 Small epoch 5, Accuracy: 98.33%
 Small epoch 6, Accuracy: 99.00%
 Small epoch 7, Accuracy: 99.33%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 99.67%
 Small epoch 10, Accuracy: 99.50%
 Cycle 7, Accuracy: 40.59%
 Small epoch 1, Accuracy: 87.17%
 Small epoch 2, Accuracy: 95.33%
 Small epoch 3, Accuracy: 99.67%
 Small epoch 4, Accuracy: 99.67%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 99.67%
 Small epoch 8, Accuracy: 99.00%
 Small epoch 9, Accuracy: 99.17%
 Small epoch 10, Accuracy: 99.00%
 Small epoch 1, Accuracy: 81.83%
 Small epoch 2, Accuracy: 88.17%
 Small epoch 3, Accuracy: 95.17%
 Small epoch 4, Accuracy: 97.33%
 Small epoch 5, Accuracy: 99.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%

Small epoch 10, Accuracy: 100.00%
 Cycle 8, Accuracy: 39.87%
 Small epoch 1, Accuracy: 86.67%
 Small epoch 2, Accuracy: 93.33%
 Small epoch 3, Accuracy: 96.83%
 Small epoch 4, Accuracy: 98.83%
 Small epoch 5, Accuracy: 99.67%
 Small epoch 6, Accuracy: 99.83%
 Small epoch 7, Accuracy: 99.83%
 Small epoch 8, Accuracy: 99.83%
 Small epoch 9, Accuracy: 99.67%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 83.17%
 Small epoch 2, Accuracy: 93.83%
 Small epoch 3, Accuracy: 95.17%
 Small epoch 4, Accuracy: 99.67%
 Small epoch 5, Accuracy: 99.83%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 9, Accuracy: 40.43%
 Small epoch 1, Accuracy: 93.33%
 Small epoch 2, Accuracy: 95.50%
 Small epoch 3, Accuracy: 97.67%
 Small epoch 4, Accuracy: 99.50%
 Small epoch 5, Accuracy: 99.00%
 Small epoch 6, Accuracy: 99.00%
 Small epoch 7, Accuracy: 99.67%
 Small epoch 8, Accuracy: 99.67%
 Small epoch 9, Accuracy: 99.83%
 Small epoch 10, Accuracy: 99.83%
 Small epoch 1, Accuracy: 89.33%
 Small epoch 2, Accuracy: 97.33%
 Small epoch 3, Accuracy: 99.50%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 10, Accuracy: 40.26%
 Small epoch 1, Accuracy: 92.67%
 Small epoch 2, Accuracy: 96.33%
 Small epoch 3, Accuracy: 99.50%
 Small epoch 4, Accuracy: 99.67%

Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 90.17%
Small epoch 2, Accuracy: 94.17%
Small epoch 3, Accuracy: 97.00%
Small epoch 4, Accuracy: 99.00%
Small epoch 5, Accuracy: 99.83%
Small epoch 6, Accuracy: 99.67%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 11, Accuracy: 40.37%
Small epoch 1, Accuracy: 91.00%
Small epoch 2, Accuracy: 95.00%
Small epoch 3, Accuracy: 98.50%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 90.33%
Small epoch 2, Accuracy: 96.83%
Small epoch 3, Accuracy: 97.50%
Small epoch 4, Accuracy: 99.50%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 12, Accuracy: 40.29%
Small epoch 1, Accuracy: 95.17%
Small epoch 2, Accuracy: 97.83%
Small epoch 3, Accuracy: 99.17%
Small epoch 4, Accuracy: 99.67%
Small epoch 5, Accuracy: 99.67%
Small epoch 6, Accuracy: 99.67%
Small epoch 7, Accuracy: 98.67%
Small epoch 8, Accuracy: 98.33%
Small epoch 9, Accuracy: 98.00%
Small epoch 10, Accuracy: 96.17%

Small epoch 1, Accuracy: 93.50%
Small epoch 2, Accuracy: 95.50%
Small epoch 3, Accuracy: 98.83%
Small epoch 4, Accuracy: 98.67%
Small epoch 5, Accuracy: 98.50%
Small epoch 6, Accuracy: 99.50%
Small epoch 7, Accuracy: 99.50%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 13, Accuracy: 39.71%
Small epoch 1, Accuracy: 94.50%
Small epoch 2, Accuracy: 97.67%
Small epoch 3, Accuracy: 98.83%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 93.00%
Small epoch 2, Accuracy: 96.00%
Small epoch 3, Accuracy: 97.83%
Small epoch 4, Accuracy: 99.83%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 14, Accuracy: 40.52%
Small epoch 1, Accuracy: 94.83%
Small epoch 2, Accuracy: 98.50%
Small epoch 3, Accuracy: 99.67%
Small epoch 4, Accuracy: 100.00%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 96.67%
Small epoch 2, Accuracy: 98.50%
Small epoch 3, Accuracy: 99.67%
Small epoch 4, Accuracy: 99.33%
Small epoch 5, Accuracy: 98.83%
Small epoch 6, Accuracy: 98.50%

Small epoch 7, Accuracy: 98.83%
 Small epoch 8, Accuracy: 99.17%
 Small epoch 9, Accuracy: 97.83%
 Small epoch 10, Accuracy: 98.50%
 Cycle 15, Accuracy: 40.67%
 Small epoch 1, Accuracy: 20.90%
 Small epoch 2, Accuracy: 28.83%
 Small epoch 3, Accuracy: 38.03%
 Small epoch 4, Accuracy: 40.00%
 Small epoch 5, Accuracy: 44.20%
 Small epoch 6, Accuracy: 45.87%
 Small epoch 7, Accuracy: 48.87%
 Small epoch 8, Accuracy: 52.00%
 Small epoch 9, Accuracy: 54.33%
 Small epoch 10, Accuracy: 55.63%
 Small epoch 1, Accuracy: 18.70%
 Small epoch 2, Accuracy: 28.83%
 Small epoch 3, Accuracy: 36.10%
 Small epoch 4, Accuracy: 38.90%
 Small epoch 5, Accuracy: 41.40%
 Small epoch 6, Accuracy: 44.93%
 Small epoch 7, Accuracy: 46.13%
 Small epoch 8, Accuracy: 47.67%
 Small epoch 9, Accuracy: 49.47%
 Small epoch 10, Accuracy: 52.77%
 Cycle 1, Accuracy: 42.85%
 Small epoch 1, Accuracy: 47.13%
 Small epoch 2, Accuracy: 53.80%
 Small epoch 3, Accuracy: 57.17%
 Small epoch 4, Accuracy: 59.77%
 Small epoch 5, Accuracy: 61.70%
 Small epoch 6, Accuracy: 62.37%
 Small epoch 7, Accuracy: 67.60%
 Small epoch 8, Accuracy: 70.80%
 Small epoch 9, Accuracy: 72.40%
 Small epoch 10, Accuracy: 74.77%
 Small epoch 1, Accuracy: 48.07%
 Small epoch 2, Accuracy: 51.87%
 Small epoch 3, Accuracy: 54.10%
 Small epoch 4, Accuracy: 57.77%
 Small epoch 5, Accuracy: 59.37%
 Small epoch 6, Accuracy: 62.20%
 Small epoch 7, Accuracy: 65.17%
 Small epoch 8, Accuracy: 67.13%
 Small epoch 9, Accuracy: 70.60%
 Small epoch 10, Accuracy: 74.13%
 Cycle 2, Accuracy: 52.59%
 Small epoch 1, Accuracy: 65.23%

Small epoch 2, Accuracy: 70.90%
Small epoch 3, Accuracy: 74.73%
Small epoch 4, Accuracy: 78.30%
Small epoch 5, Accuracy: 82.07%
Small epoch 6, Accuracy: 85.80%
Small epoch 7, Accuracy: 86.17%
Small epoch 8, Accuracy: 88.07%
Small epoch 9, Accuracy: 93.23%
Small epoch 10, Accuracy: 94.83%
Small epoch 1, Accuracy: 62.87%
Small epoch 2, Accuracy: 69.30%
Small epoch 3, Accuracy: 73.23%
Small epoch 4, Accuracy: 78.27%
Small epoch 5, Accuracy: 79.80%
Small epoch 6, Accuracy: 84.37%
Small epoch 7, Accuracy: 87.30%
Small epoch 8, Accuracy: 89.57%
Small epoch 9, Accuracy: 92.63%
Small epoch 10, Accuracy: 93.57%
Cycle 3, Accuracy: 53.91%
Small epoch 1, Accuracy: 77.87%
Small epoch 2, Accuracy: 87.17%
Small epoch 3, Accuracy: 91.70%
Small epoch 4, Accuracy: 94.73%
Small epoch 5, Accuracy: 96.93%
Small epoch 6, Accuracy: 96.13%
Small epoch 7, Accuracy: 96.93%
Small epoch 8, Accuracy: 98.63%
Small epoch 9, Accuracy: 98.33%
Small epoch 10, Accuracy: 98.77%
Small epoch 1, Accuracy: 77.47%
Small epoch 2, Accuracy: 87.17%
Small epoch 3, Accuracy: 91.53%
Small epoch 4, Accuracy: 93.37%
Small epoch 5, Accuracy: 96.47%
Small epoch 6, Accuracy: 96.87%
Small epoch 7, Accuracy: 98.23%
Small epoch 8, Accuracy: 98.40%
Small epoch 9, Accuracy: 99.40%
Small epoch 10, Accuracy: 99.80%
Cycle 4, Accuracy: 54.52%
Small epoch 1, Accuracy: 85.27%
Small epoch 2, Accuracy: 95.70%
Small epoch 3, Accuracy: 97.40%
Small epoch 4, Accuracy: 98.07%
Small epoch 5, Accuracy: 98.87%
Small epoch 6, Accuracy: 99.47%
Small epoch 7, Accuracy: 99.90%

Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 84.57%
 Small epoch 2, Accuracy: 94.47%
 Small epoch 3, Accuracy: 97.17%
 Small epoch 4, Accuracy: 98.67%
 Small epoch 5, Accuracy: 99.70%
 Small epoch 6, Accuracy: 99.97%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 5, Accuracy: 54.43%
 Small epoch 1, Accuracy: 88.60%
 Small epoch 2, Accuracy: 96.83%
 Small epoch 3, Accuracy: 99.07%
 Small epoch 4, Accuracy: 99.77%
 Small epoch 5, Accuracy: 99.90%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 88.33%
 Small epoch 2, Accuracy: 96.77%
 Small epoch 3, Accuracy: 98.13%
 Small epoch 4, Accuracy: 99.37%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 6, Accuracy: 54.17%
 Small epoch 1, Accuracy: 91.57%
 Small epoch 2, Accuracy: 98.77%
 Small epoch 3, Accuracy: 99.77%
 Small epoch 4, Accuracy: 99.77%
 Small epoch 5, Accuracy: 99.97%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 89.97%
 Small epoch 2, Accuracy: 98.70%
 Small epoch 3, Accuracy: 99.53%

Small epoch 4, Accuracy: 99.97%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 7, Accuracy: 54.06%
 Small epoch 1, Accuracy: 92.13%
 Small epoch 2, Accuracy: 97.80%
 Small epoch 3, Accuracy: 99.63%
 Small epoch 4, Accuracy: 99.97%
 Small epoch 5, Accuracy: 99.93%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 93.00%
 Small epoch 2, Accuracy: 98.13%
 Small epoch 3, Accuracy: 99.03%
 Small epoch 4, Accuracy: 99.77%
 Small epoch 5, Accuracy: 99.90%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 8, Accuracy: 54.06%
 Small epoch 1, Accuracy: 94.20%
 Small epoch 2, Accuracy: 97.13%
 Small epoch 3, Accuracy: 98.30%
 Small epoch 4, Accuracy: 98.70%
 Small epoch 5, Accuracy: 98.23%
 Small epoch 6, Accuracy: 96.20%
 Small epoch 7, Accuracy: 97.93%
 Small epoch 8, Accuracy: 97.47%
 Small epoch 9, Accuracy: 97.13%
 Small epoch 10, Accuracy: 98.93%
 Small epoch 1, Accuracy: 93.53%
 Small epoch 2, Accuracy: 97.90%
 Small epoch 3, Accuracy: 97.27%
 Small epoch 4, Accuracy: 97.57%
 Small epoch 5, Accuracy: 98.83%
 Small epoch 6, Accuracy: 98.87%
 Small epoch 7, Accuracy: 99.97%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%

Small epoch 10, Accuracy: 100.00%
 Cycle 9, Accuracy: 54.10%
 Small epoch 1, Accuracy: 95.80%
 Small epoch 2, Accuracy: 98.33%
 Small epoch 3, Accuracy: 99.17%
 Small epoch 4, Accuracy: 99.13%
 Small epoch 5, Accuracy: 98.13%
 Small epoch 6, Accuracy: 97.40%
 Small epoch 7, Accuracy: 94.00%
 Small epoch 8, Accuracy: 95.73%
 Small epoch 9, Accuracy: 98.53%
 Small epoch 10, Accuracy: 99.83%
 Small epoch 1, Accuracy: 92.47%
 Small epoch 2, Accuracy: 98.93%
 Small epoch 3, Accuracy: 99.27%
 Small epoch 4, Accuracy: 99.83%
 Small epoch 5, Accuracy: 99.97%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 10, Accuracy: 53.85%
 Small epoch 1, Accuracy: 96.67%
 Small epoch 2, Accuracy: 99.00%
 Small epoch 3, Accuracy: 98.60%
 Small epoch 4, Accuracy: 98.53%
 Small epoch 5, Accuracy: 96.63%
 Small epoch 6, Accuracy: 95.97%
 Small epoch 7, Accuracy: 97.93%
 Small epoch 8, Accuracy: 99.27%
 Small epoch 9, Accuracy: 99.97%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 93.47%
 Small epoch 2, Accuracy: 97.97%
 Small epoch 3, Accuracy: 99.73%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 99.97%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
 Small epoch 8, Accuracy: 100.00%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 11, Accuracy: 54.15%
 Small epoch 1, Accuracy: 98.27%
 Small epoch 2, Accuracy: 97.20%
 Small epoch 3, Accuracy: 98.57%
 Small epoch 4, Accuracy: 99.40%

Small epoch 5, Accuracy: 98.77%
Small epoch 6, Accuracy: 99.43%
Small epoch 7, Accuracy: 99.83%
Small epoch 8, Accuracy: 99.83%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 93.53%
Small epoch 2, Accuracy: 97.97%
Small epoch 3, Accuracy: 99.37%
Small epoch 4, Accuracy: 99.97%
Small epoch 5, Accuracy: 100.00%
Small epoch 6, Accuracy: 100.00%
Small epoch 7, Accuracy: 100.00%
Small epoch 8, Accuracy: 100.00%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 12, Accuracy: 54.08%
Small epoch 1, Accuracy: 97.27%
Small epoch 2, Accuracy: 99.13%
Small epoch 3, Accuracy: 99.40%
Small epoch 4, Accuracy: 98.50%
Small epoch 5, Accuracy: 96.57%
Small epoch 6, Accuracy: 98.57%
Small epoch 7, Accuracy: 99.10%
Small epoch 8, Accuracy: 99.90%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Small epoch 1, Accuracy: 93.50%
Small epoch 2, Accuracy: 98.17%
Small epoch 3, Accuracy: 99.70%
Small epoch 4, Accuracy: 99.57%
Small epoch 5, Accuracy: 99.13%
Small epoch 6, Accuracy: 98.50%
Small epoch 7, Accuracy: 95.80%
Small epoch 8, Accuracy: 95.70%
Small epoch 9, Accuracy: 97.40%
Small epoch 10, Accuracy: 99.30%
Cycle 13, Accuracy: 54.32%
Small epoch 1, Accuracy: 97.67%
Small epoch 2, Accuracy: 99.20%
Small epoch 3, Accuracy: 98.63%
Small epoch 4, Accuracy: 97.03%
Small epoch 5, Accuracy: 96.73%
Small epoch 6, Accuracy: 99.33%
Small epoch 7, Accuracy: 99.73%
Small epoch 8, Accuracy: 99.63%
Small epoch 9, Accuracy: 99.03%
Small epoch 10, Accuracy: 95.43%

Small epoch 1, Accuracy: 96.50%
 Small epoch 2, Accuracy: 98.67%
 Small epoch 3, Accuracy: 98.27%
 Small epoch 4, Accuracy: 97.73%
 Small epoch 5, Accuracy: 98.00%
 Small epoch 6, Accuracy: 99.00%
 Small epoch 7, Accuracy: 99.37%
 Small epoch 8, Accuracy: 99.87%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 14, Accuracy: 54.47%
 Small epoch 1, Accuracy: 97.83%
 Small epoch 2, Accuracy: 99.00%
 Small epoch 3, Accuracy: 98.93%
 Small epoch 4, Accuracy: 98.70%
 Small epoch 5, Accuracy: 98.27%
 Small epoch 6, Accuracy: 97.60%
 Small epoch 7, Accuracy: 97.93%
 Small epoch 8, Accuracy: 99.30%
 Small epoch 9, Accuracy: 99.93%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 97.07%
 Small epoch 2, Accuracy: 99.60%
 Small epoch 3, Accuracy: 99.67%
 Small epoch 4, Accuracy: 99.70%
 Small epoch 5, Accuracy: 97.57%
 Small epoch 6, Accuracy: 93.63%
 Small epoch 7, Accuracy: 98.47%
 Small epoch 8, Accuracy: 99.80%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 15, Accuracy: 54.09%
 Small epoch 1, Accuracy: 26.59%
 Small epoch 2, Accuracy: 37.73%
 Small epoch 3, Accuracy: 44.12%
 Small epoch 4, Accuracy: 48.38%
 Small epoch 5, Accuracy: 50.50%
 Small epoch 6, Accuracy: 54.29%
 Small epoch 7, Accuracy: 56.40%
 Small epoch 8, Accuracy: 59.06%
 Small epoch 9, Accuracy: 61.36%
 Small epoch 10, Accuracy: 64.36%
 Small epoch 1, Accuracy: 28.05%
 Small epoch 2, Accuracy: 41.15%
 Small epoch 3, Accuracy: 45.89%
 Small epoch 4, Accuracy: 49.70%
 Small epoch 5, Accuracy: 52.80%
 Small epoch 6, Accuracy: 54.88%

Small epoch 7, Accuracy: 58.17%
Small epoch 8, Accuracy: 61.31%
Small epoch 9, Accuracy: 63.31%
Small epoch 10, Accuracy: 66.16%
Cycle 1, Accuracy: 49.94%
Small epoch 1, Accuracy: 57.84%
Small epoch 2, Accuracy: 62.08%
Small epoch 3, Accuracy: 65.76%
Small epoch 4, Accuracy: 68.33%
Small epoch 5, Accuracy: 71.79%
Small epoch 6, Accuracy: 75.12%
Small epoch 7, Accuracy: 77.95%
Small epoch 8, Accuracy: 81.20%
Small epoch 9, Accuracy: 84.71%
Small epoch 10, Accuracy: 87.04%
Small epoch 1, Accuracy: 57.88%
Small epoch 2, Accuracy: 63.20%
Small epoch 3, Accuracy: 66.83%
Small epoch 4, Accuracy: 69.44%
Small epoch 5, Accuracy: 72.90%
Small epoch 6, Accuracy: 75.81%
Small epoch 7, Accuracy: 79.59%
Small epoch 8, Accuracy: 83.03%
Small epoch 9, Accuracy: 85.39%
Small epoch 10, Accuracy: 87.41%
Cycle 2, Accuracy: 62.35%
Small epoch 1, Accuracy: 74.51%
Small epoch 2, Accuracy: 81.38%
Small epoch 3, Accuracy: 86.46%
Small epoch 4, Accuracy: 88.89%
Small epoch 5, Accuracy: 91.70%
Small epoch 6, Accuracy: 93.95%
Small epoch 7, Accuracy: 95.91%
Small epoch 8, Accuracy: 96.58%
Small epoch 9, Accuracy: 97.28%
Small epoch 10, Accuracy: 97.29%
Small epoch 1, Accuracy: 74.90%
Small epoch 2, Accuracy: 81.41%
Small epoch 3, Accuracy: 86.62%
Small epoch 4, Accuracy: 90.14%
Small epoch 5, Accuracy: 92.54%
Small epoch 6, Accuracy: 93.83%
Small epoch 7, Accuracy: 94.69%
Small epoch 8, Accuracy: 96.45%
Small epoch 9, Accuracy: 96.89%
Small epoch 10, Accuracy: 97.88%
Cycle 3, Accuracy: 62.46%
Small epoch 1, Accuracy: 84.54%

Small epoch 2, Accuracy: 92.30%
Small epoch 3, Accuracy: 96.41%
Small epoch 4, Accuracy: 96.90%
Small epoch 5, Accuracy: 97.58%
Small epoch 6, Accuracy: 97.69%
Small epoch 7, Accuracy: 96.84%
Small epoch 8, Accuracy: 96.71%
Small epoch 9, Accuracy: 96.89%
Small epoch 10, Accuracy: 98.25%
Small epoch 1, Accuracy: 84.12%
Small epoch 2, Accuracy: 92.75%
Small epoch 3, Accuracy: 95.45%
Small epoch 4, Accuracy: 97.60%
Small epoch 5, Accuracy: 98.31%
Small epoch 6, Accuracy: 96.65%
Small epoch 7, Accuracy: 97.75%
Small epoch 8, Accuracy: 97.92%
Small epoch 9, Accuracy: 97.44%
Small epoch 10, Accuracy: 96.54%
Cycle 4, Accuracy: 62.80%
Small epoch 1, Accuracy: 89.58%
Small epoch 2, Accuracy: 97.50%
Small epoch 3, Accuracy: 97.76%
Small epoch 4, Accuracy: 98.30%
Small epoch 5, Accuracy: 98.34%
Small epoch 6, Accuracy: 96.44%
Small epoch 7, Accuracy: 96.97%
Small epoch 8, Accuracy: 97.39%
Small epoch 9, Accuracy: 99.25%
Small epoch 10, Accuracy: 99.69%
Small epoch 1, Accuracy: 89.12%
Small epoch 2, Accuracy: 97.24%
Small epoch 3, Accuracy: 98.81%
Small epoch 4, Accuracy: 98.38%
Small epoch 5, Accuracy: 97.80%
Small epoch 6, Accuracy: 95.65%
Small epoch 7, Accuracy: 97.86%
Small epoch 8, Accuracy: 98.35%
Small epoch 9, Accuracy: 99.47%
Small epoch 10, Accuracy: 99.76%
Cycle 5, Accuracy: 63.91%
Small epoch 1, Accuracy: 92.99%
Small epoch 2, Accuracy: 98.21%
Small epoch 3, Accuracy: 99.58%
Small epoch 4, Accuracy: 99.19%
Small epoch 5, Accuracy: 95.70%
Small epoch 6, Accuracy: 97.03%
Small epoch 7, Accuracy: 99.35%

Small epoch 8, Accuracy: 99.44%
 Small epoch 9, Accuracy: 99.84%
 Small epoch 10, Accuracy: 100.00%
 Small epoch 1, Accuracy: 93.08%
 Small epoch 2, Accuracy: 98.49%
 Small epoch 3, Accuracy: 99.38%
 Small epoch 4, Accuracy: 98.58%
 Small epoch 5, Accuracy: 96.25%
 Small epoch 6, Accuracy: 96.12%
 Small epoch 7, Accuracy: 97.99%
 Small epoch 8, Accuracy: 98.33%
 Small epoch 9, Accuracy: 99.80%
 Small epoch 10, Accuracy: 100.00%
 Cycle 6, Accuracy: 64.07%
 Small epoch 1, Accuracy: 94.65%
 Small epoch 2, Accuracy: 98.41%
 Small epoch 3, Accuracy: 99.11%
 Small epoch 4, Accuracy: 97.71%
 Small epoch 5, Accuracy: 97.49%
 Small epoch 6, Accuracy: 98.01%
 Small epoch 7, Accuracy: 97.25%
 Small epoch 8, Accuracy: 97.96%
 Small epoch 9, Accuracy: 98.67%
 Small epoch 10, Accuracy: 98.53%
 Small epoch 1, Accuracy: 94.95%
 Small epoch 2, Accuracy: 98.81%
 Small epoch 3, Accuracy: 99.34%
 Small epoch 4, Accuracy: 98.05%
 Small epoch 5, Accuracy: 95.62%
 Small epoch 6, Accuracy: 97.74%
 Small epoch 7, Accuracy: 99.66%
 Small epoch 8, Accuracy: 99.81%
 Small epoch 9, Accuracy: 100.00%
 Small epoch 10, Accuracy: 100.00%
 Cycle 7, Accuracy: 63.49%
 Small epoch 1, Accuracy: 96.47%
 Small epoch 2, Accuracy: 98.26%
 Small epoch 3, Accuracy: 98.60%
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 Small epoch 5, Accuracy: 97.21%
 Small epoch 6, Accuracy: 98.26%
 Small epoch 7, Accuracy: 98.44%
 Small epoch 8, Accuracy: 98.76%
 Small epoch 9, Accuracy: 98.79%
 Small epoch 10, Accuracy: 98.34%
 Small epoch 1, Accuracy: 95.72%
 Small epoch 2, Accuracy: 98.72%
 Small epoch 3, Accuracy: 98.86%

Small epoch 4, Accuracy: 98.31%
 Small epoch 5, Accuracy: 97.35%
 Small epoch 6, Accuracy: 96.11%
 Small epoch 7, Accuracy: 98.41%
 Small epoch 8, Accuracy: 99.56%
 Small epoch 9, Accuracy: 99.56%
 Small epoch 10, Accuracy: 99.14%
 Cycle 8, Accuracy: 62.22%
 Small epoch 1, Accuracy: 97.21%
 Small epoch 2, Accuracy: 98.70%
 Small epoch 3, Accuracy: 98.72%
 Small epoch 4, Accuracy: 98.62%
 Small epoch 5, Accuracy: 98.44%
 Small epoch 6, Accuracy: 97.26%
 Small epoch 7, Accuracy: 98.91%
 Small epoch 8, Accuracy: 98.29%
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 Small epoch 1, Accuracy: 96.25%
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 Small epoch 3, Accuracy: 98.56%
 Small epoch 4, Accuracy: 97.59%
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 Small epoch 7, Accuracy: 99.17%
 Small epoch 8, Accuracy: 98.59%
 Small epoch 9, Accuracy: 98.83%
 Small epoch 10, Accuracy: 98.67%
 Cycle 9, Accuracy: 63.44%
 Small epoch 1, Accuracy: 97.19%
 Small epoch 2, Accuracy: 98.88%
 Small epoch 3, Accuracy: 98.81%
 Small epoch 4, Accuracy: 98.17%
 Small epoch 5, Accuracy: 98.89%
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 Small epoch 7, Accuracy: 97.94%
 Small epoch 8, Accuracy: 98.35%
 Small epoch 9, Accuracy: 98.97%
 Small epoch 10, Accuracy: 99.34%
 Small epoch 1, Accuracy: 96.42%
 Small epoch 2, Accuracy: 98.86%
 Small epoch 3, Accuracy: 99.89%
 Small epoch 4, Accuracy: 100.00%
 Small epoch 5, Accuracy: 100.00%
 Small epoch 6, Accuracy: 100.00%
 Small epoch 7, Accuracy: 100.00%
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 Small epoch 9, Accuracy: 100.00%

Small epoch 10, Accuracy: 100.00%
 Cycle 10, Accuracy: 63.26%
 Small epoch 1, Accuracy: 98.40%
 Small epoch 2, Accuracy: 98.94%
 Small epoch 3, Accuracy: 99.45%
 Small epoch 4, Accuracy: 99.74%
 Small epoch 5, Accuracy: 98.28%
 Small epoch 6, Accuracy: 96.79%
 Small epoch 7, Accuracy: 98.50%
 Small epoch 8, Accuracy: 99.21%
 Small epoch 9, Accuracy: 98.59%
 Small epoch 10, Accuracy: 98.19%
 Small epoch 1, Accuracy: 95.78%
 Small epoch 2, Accuracy: 99.06%
 Small epoch 3, Accuracy: 99.53%
 Small epoch 4, Accuracy: 99.01%
 Small epoch 5, Accuracy: 97.36%
 Small epoch 6, Accuracy: 97.85%
 Small epoch 7, Accuracy: 97.84%
 Small epoch 8, Accuracy: 97.95%
 Small epoch 9, Accuracy: 99.14%
 Small epoch 10, Accuracy: 99.42%
 Cycle 11, Accuracy: 63.38%
 Small epoch 1, Accuracy: 98.26%
 Small epoch 2, Accuracy: 98.97%
 Small epoch 3, Accuracy: 99.26%
 Small epoch 4, Accuracy: 98.50%
 Small epoch 5, Accuracy: 98.58%
 Small epoch 6, Accuracy: 98.74%
 Small epoch 7, Accuracy: 98.60%
 Small epoch 8, Accuracy: 98.24%
 Small epoch 9, Accuracy: 99.71%
 Small epoch 10, Accuracy: 99.56%
 Small epoch 1, Accuracy: 97.21%
 Small epoch 2, Accuracy: 98.53%
 Small epoch 3, Accuracy: 98.92%
 Small epoch 4, Accuracy: 98.96%
 Small epoch 5, Accuracy: 98.88%
 Small epoch 6, Accuracy: 98.26%
 Small epoch 7, Accuracy: 98.61%
 Small epoch 8, Accuracy: 98.64%
 Small epoch 9, Accuracy: 98.74%
 Small epoch 10, Accuracy: 96.96%
 Cycle 12, Accuracy: 62.58%
 Small epoch 1, Accuracy: 98.28%
 Small epoch 2, Accuracy: 99.38%
 Small epoch 3, Accuracy: 99.26%
 Small epoch 4, Accuracy: 97.31%

Small epoch 5, Accuracy: 97.90%
Small epoch 6, Accuracy: 99.38%
Small epoch 7, Accuracy: 99.45%
Small epoch 8, Accuracy: 99.79%
Small epoch 9, Accuracy: 98.64%
Small epoch 10, Accuracy: 97.49%
Small epoch 1, Accuracy: 97.55%
Small epoch 2, Accuracy: 98.81%
Small epoch 3, Accuracy: 99.03%
Small epoch 4, Accuracy: 98.11%
Small epoch 5, Accuracy: 98.09%
Small epoch 6, Accuracy: 99.66%
Small epoch 7, Accuracy: 99.92%
Small epoch 8, Accuracy: 99.62%
Small epoch 9, Accuracy: 97.89%
Small epoch 10, Accuracy: 98.12%
Cycle 13, Accuracy: 62.17%
Small epoch 1, Accuracy: 98.38%
Small epoch 2, Accuracy: 99.01%
Small epoch 3, Accuracy: 99.03%
Small epoch 4, Accuracy: 99.44%
Small epoch 5, Accuracy: 98.30%
Small epoch 6, Accuracy: 98.35%
Small epoch 7, Accuracy: 99.19%
Small epoch 8, Accuracy: 99.60%
Small epoch 9, Accuracy: 99.17%
Small epoch 10, Accuracy: 99.09%
Small epoch 1, Accuracy: 97.51%
Small epoch 2, Accuracy: 99.56%
Small epoch 3, Accuracy: 99.15%
Small epoch 4, Accuracy: 97.81%
Small epoch 5, Accuracy: 97.62%
Small epoch 6, Accuracy: 99.24%
Small epoch 7, Accuracy: 99.78%
Small epoch 8, Accuracy: 99.95%
Small epoch 9, Accuracy: 100.00%
Small epoch 10, Accuracy: 100.00%
Cycle 14, Accuracy: 63.32%
Small epoch 1, Accuracy: 98.65%
Small epoch 2, Accuracy: 98.97%
Small epoch 3, Accuracy: 98.75%
Small epoch 4, Accuracy: 98.39%
Small epoch 5, Accuracy: 99.69%
Small epoch 6, Accuracy: 99.74%
Small epoch 7, Accuracy: 99.21%
Small epoch 8, Accuracy: 97.26%
Small epoch 9, Accuracy: 97.94%
Small epoch 10, Accuracy: 98.75%

Small epoch 1, Accuracy: 98.19%
 Small epoch 2, Accuracy: 99.17%
 Small epoch 3, Accuracy: 98.90%
 Small epoch 4, Accuracy: 98.12%
 Small epoch 5, Accuracy: 98.25%
 Small epoch 6, Accuracy: 98.74%
 Small epoch 7, Accuracy: 98.92%
 Small epoch 8, Accuracy: 98.59%
 Small epoch 9, Accuracy: 98.69%
 Small epoch 10, Accuracy: 99.10%
 Cycle 15, Accuracy: 62.41%
 Small epoch 1, Accuracy: 31.15%
 Small epoch 2, Accuracy: 45.51%
 Small epoch 3, Accuracy: 50.92%
 Small epoch 4, Accuracy: 56.25%
 Small epoch 5, Accuracy: 60.47%
 Small epoch 6, Accuracy: 63.73%
 Small epoch 7, Accuracy: 66.60%
 Small epoch 8, Accuracy: 69.67%
 Small epoch 9, Accuracy: 71.67%
 Small epoch 10, Accuracy: 74.85%
 Small epoch 1, Accuracy: 32.55%
 Small epoch 2, Accuracy: 45.85%
 Small epoch 3, Accuracy: 52.04%
 Small epoch 4, Accuracy: 57.28%
 Small epoch 5, Accuracy: 61.02%
 Small epoch 6, Accuracy: 64.41%
 Small epoch 7, Accuracy: 67.23%
 Small epoch 8, Accuracy: 69.69%
 Small epoch 9, Accuracy: 72.03%
 Small epoch 10, Accuracy: 74.25%
 Cycle 1, Accuracy: 56.64%
 Small epoch 1, Accuracy: 65.89%
 Small epoch 2, Accuracy: 71.41%
 Small epoch 3, Accuracy: 74.65%
 Small epoch 4, Accuracy: 77.48%
 Small epoch 5, Accuracy: 80.30%
 Small epoch 6, Accuracy: 82.59%
 Small epoch 7, Accuracy: 85.20%
 Small epoch 8, Accuracy: 87.59%
 Small epoch 9, Accuracy: 89.99%
 Small epoch 10, Accuracy: 91.93%
 Small epoch 1, Accuracy: 65.49%
 Small epoch 2, Accuracy: 71.09%
 Small epoch 3, Accuracy: 74.53%
 Small epoch 4, Accuracy: 77.87%
 Small epoch 5, Accuracy: 80.49%
 Small epoch 6, Accuracy: 82.16%

Small epoch 7, Accuracy: 84.93%
Small epoch 8, Accuracy: 87.29%
Small epoch 9, Accuracy: 89.31%
Small epoch 10, Accuracy: 91.53%
Cycle 2, Accuracy: 68.41%
Small epoch 1, Accuracy: 80.14%
Small epoch 2, Accuracy: 86.15%
Small epoch 3, Accuracy: 89.53%
Small epoch 4, Accuracy: 92.37%
Small epoch 5, Accuracy: 94.23%
Small epoch 6, Accuracy: 94.89%
Small epoch 7, Accuracy: 95.91%
Small epoch 8, Accuracy: 97.15%
Small epoch 9, Accuracy: 97.07%
Small epoch 10, Accuracy: 96.91%
Small epoch 1, Accuracy: 79.37%
Small epoch 2, Accuracy: 85.49%
Small epoch 3, Accuracy: 89.71%
Small epoch 4, Accuracy: 91.83%
Small epoch 5, Accuracy: 93.61%
Small epoch 6, Accuracy: 94.64%
Small epoch 7, Accuracy: 95.35%
Small epoch 8, Accuracy: 95.86%
Small epoch 9, Accuracy: 97.55%
Small epoch 10, Accuracy: 97.21%
Cycle 3, Accuracy: 68.69%
Small epoch 1, Accuracy: 86.74%
Small epoch 2, Accuracy: 93.92%
Small epoch 3, Accuracy: 96.19%
Small epoch 4, Accuracy: 96.50%
Small epoch 5, Accuracy: 97.08%
Small epoch 6, Accuracy: 97.33%
Small epoch 7, Accuracy: 97.73%
Small epoch 8, Accuracy: 96.80%
Small epoch 9, Accuracy: 97.85%
Small epoch 10, Accuracy: 97.36%
Small epoch 1, Accuracy: 86.24%
Small epoch 2, Accuracy: 93.55%
Small epoch 3, Accuracy: 95.64%
Small epoch 4, Accuracy: 96.14%
Small epoch 5, Accuracy: 98.07%
Small epoch 6, Accuracy: 97.20%
Small epoch 7, Accuracy: 97.25%
Small epoch 8, Accuracy: 96.93%
Small epoch 9, Accuracy: 97.29%
Small epoch 10, Accuracy: 97.77%
Cycle 4, Accuracy: 68.42%
Small epoch 1, Accuracy: 90.48%

Small epoch 2, Accuracy: 96.81%
 Small epoch 3, Accuracy: 98.09%
 Small epoch 4, Accuracy: 97.72%
 Small epoch 5, Accuracy: 96.70%
 Small epoch 6, Accuracy: 97.66%
 Small epoch 7, Accuracy: 98.17%
 Small epoch 8, Accuracy: 97.66%
 Small epoch 9, Accuracy: 97.63%
 Small epoch 10, Accuracy: 97.27%
 Small epoch 1, Accuracy: 89.90%
 Small epoch 2, Accuracy: 96.42%
 Small epoch 3, Accuracy: 97.57%
 Small epoch 4, Accuracy: 97.79%
 Small epoch 5, Accuracy: 97.44%
 Small epoch 6, Accuracy: 96.87%
 Small epoch 7, Accuracy: 98.19%
 Small epoch 8, Accuracy: 97.41%
 Small epoch 9, Accuracy: 98.17%
 Small epoch 10, Accuracy: 97.60%
 Cycle 5, Accuracy: 68.38%
 Small epoch 1, Accuracy: 92.89%
 Small epoch 2, Accuracy: 97.93%
 Small epoch 3, Accuracy: 98.93%
 Small epoch 4, Accuracy: 97.98%
 Small epoch 5, Accuracy: 97.18%
 Small epoch 6, Accuracy: 97.16%
 Small epoch 7, Accuracy: 97.21%
 Small epoch 8, Accuracy: 98.28%
 Small epoch 9, Accuracy: 98.65%
 Small epoch 10, Accuracy: 98.52%
 Small epoch 1, Accuracy: 92.53%
 Small epoch 2, Accuracy: 97.85%
 Small epoch 3, Accuracy: 98.26%
 Small epoch 4, Accuracy: 97.11%
 Small epoch 5, Accuracy: 97.59%
 Small epoch 6, Accuracy: 98.31%
 Small epoch 7, Accuracy: 97.68%
 Small epoch 8, Accuracy: 97.23%
 Small epoch 9, Accuracy: 98.43%
 Small epoch 10, Accuracy: 98.19%
 Cycle 6, Accuracy: 68.39%
 Small epoch 1, Accuracy: 94.41%
 Small epoch 2, Accuracy: 98.51%
 Small epoch 3, Accuracy: 99.14%
 Small epoch 4, Accuracy: 96.60%
 Small epoch 5, Accuracy: 97.45%
 Small epoch 6, Accuracy: 98.11%
 Small epoch 7, Accuracy: 98.15%

Small epoch 8, Accuracy: 98.93%
Small epoch 9, Accuracy: 98.61%
Small epoch 10, Accuracy: 98.71%
Small epoch 1, Accuracy: 94.35%
Small epoch 2, Accuracy: 98.67%
Small epoch 3, Accuracy: 98.79%
Small epoch 4, Accuracy: 97.25%
Small epoch 5, Accuracy: 96.96%
Small epoch 6, Accuracy: 98.16%
Small epoch 7, Accuracy: 97.79%
Small epoch 8, Accuracy: 97.49%
Small epoch 9, Accuracy: 98.93%
Small epoch 10, Accuracy: 98.95%
Cycle 7, Accuracy: 69.01%
Small epoch 1, Accuracy: 95.32%
Small epoch 2, Accuracy: 98.83%
Small epoch 3, Accuracy: 98.60%
Small epoch 4, Accuracy: 98.24%
Small epoch 5, Accuracy: 97.22%
Small epoch 6, Accuracy: 97.96%
Small epoch 7, Accuracy: 98.64%
Small epoch 8, Accuracy: 98.11%
Small epoch 9, Accuracy: 98.84%
Small epoch 10, Accuracy: 98.61%
Small epoch 1, Accuracy: 95.55%
Small epoch 2, Accuracy: 98.57%
Small epoch 3, Accuracy: 98.11%
Small epoch 4, Accuracy: 98.43%
Small epoch 5, Accuracy: 98.01%
Small epoch 6, Accuracy: 98.39%
Small epoch 7, Accuracy: 97.50%
Small epoch 8, Accuracy: 97.97%
Small epoch 9, Accuracy: 97.67%
Small epoch 10, Accuracy: 98.73%
Cycle 8, Accuracy: 68.78%
Small epoch 1, Accuracy: 96.22%
Small epoch 2, Accuracy: 98.49%
Small epoch 3, Accuracy: 98.09%
Small epoch 4, Accuracy: 98.19%
Small epoch 5, Accuracy: 98.33%
Small epoch 6, Accuracy: 98.16%
Small epoch 7, Accuracy: 98.04%
Small epoch 8, Accuracy: 98.93%
Small epoch 9, Accuracy: 98.65%
Small epoch 10, Accuracy: 99.03%
Small epoch 1, Accuracy: 96.17%
Small epoch 2, Accuracy: 98.65%
Small epoch 3, Accuracy: 99.15%

Small epoch 4, Accuracy: 98.12%
Small epoch 5, Accuracy: 97.57%
Small epoch 6, Accuracy: 97.73%
Small epoch 7, Accuracy: 98.64%
Small epoch 8, Accuracy: 99.12%
Small epoch 9, Accuracy: 99.25%
Small epoch 10, Accuracy: 97.74%
Cycle 9, Accuracy: 67.57%
Small epoch 1, Accuracy: 96.70%
Small epoch 2, Accuracy: 99.08%
Small epoch 3, Accuracy: 98.36%
Small epoch 4, Accuracy: 97.75%
Small epoch 5, Accuracy: 98.16%
Small epoch 6, Accuracy: 99.04%
Small epoch 7, Accuracy: 99.19%
Small epoch 8, Accuracy: 98.27%
Small epoch 9, Accuracy: 97.73%
Small epoch 10, Accuracy: 98.55%
Small epoch 1, Accuracy: 96.60%
Small epoch 2, Accuracy: 98.85%
Small epoch 3, Accuracy: 98.81%
Small epoch 4, Accuracy: 97.47%
Small epoch 5, Accuracy: 98.34%
Small epoch 6, Accuracy: 98.39%
Small epoch 7, Accuracy: 98.79%
Small epoch 8, Accuracy: 98.97%
Small epoch 9, Accuracy: 98.53%
Small epoch 10, Accuracy: 98.15%
Cycle 10, Accuracy: 68.36%
Small epoch 1, Accuracy: 97.14%
Small epoch 2, Accuracy: 99.02%
Small epoch 3, Accuracy: 98.53%
Small epoch 4, Accuracy: 97.69%
Small epoch 5, Accuracy: 98.44%
Small epoch 6, Accuracy: 98.63%
Small epoch 7, Accuracy: 98.76%
Small epoch 8, Accuracy: 98.52%
Small epoch 9, Accuracy: 99.15%
Small epoch 10, Accuracy: 98.51%
Small epoch 1, Accuracy: 96.87%
Small epoch 2, Accuracy: 99.08%
Small epoch 3, Accuracy: 98.59%
Small epoch 4, Accuracy: 98.49%
Small epoch 5, Accuracy: 97.79%
Small epoch 6, Accuracy: 98.75%
Small epoch 7, Accuracy: 98.12%
Small epoch 8, Accuracy: 98.38%
Small epoch 9, Accuracy: 99.28%

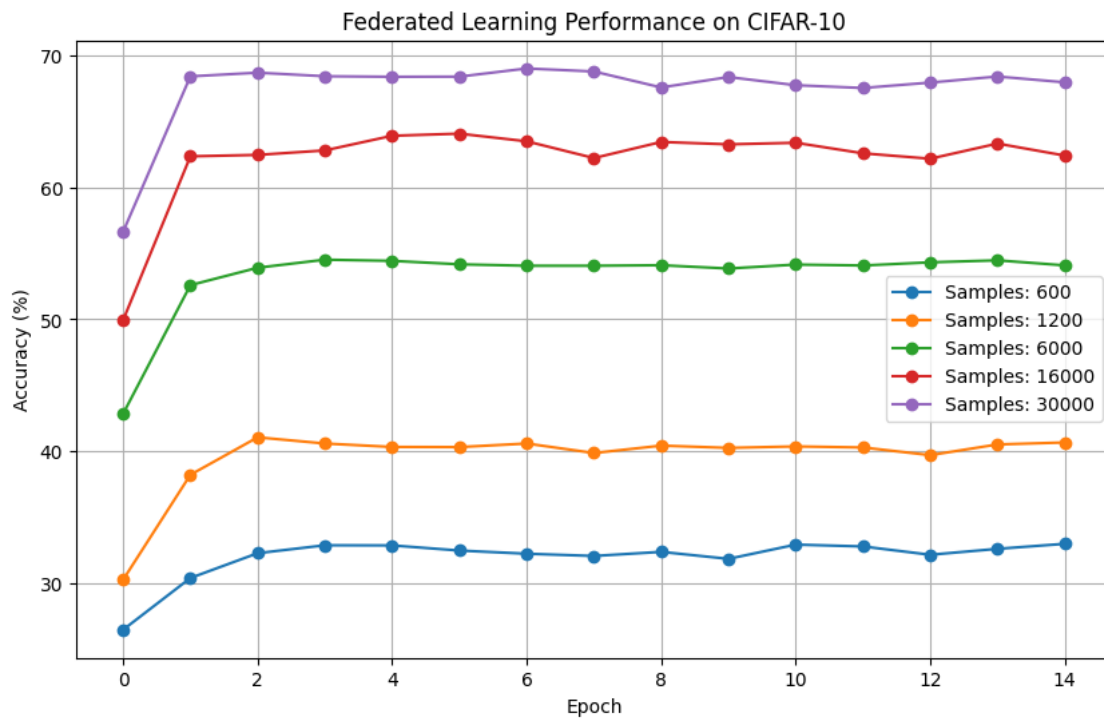
Small epoch 10, Accuracy: 99.39%
Cycle 11, Accuracy: 67.74%
Small epoch 1, Accuracy: 97.28%
Small epoch 2, Accuracy: 99.11%
Small epoch 3, Accuracy: 98.85%
Small epoch 4, Accuracy: 97.91%
Small epoch 5, Accuracy: 98.47%
Small epoch 6, Accuracy: 98.74%
Small epoch 7, Accuracy: 98.67%
Small epoch 8, Accuracy: 99.53%
Small epoch 9, Accuracy: 99.29%
Small epoch 10, Accuracy: 97.27%
Small epoch 1, Accuracy: 97.76%
Small epoch 2, Accuracy: 98.61%
Small epoch 3, Accuracy: 98.53%
Small epoch 4, Accuracy: 98.56%
Small epoch 5, Accuracy: 97.60%
Small epoch 6, Accuracy: 98.54%
Small epoch 7, Accuracy: 99.48%
Small epoch 8, Accuracy: 99.15%
Small epoch 9, Accuracy: 97.88%
Small epoch 10, Accuracy: 98.05%
Cycle 12, Accuracy: 67.53%
Small epoch 1, Accuracy: 97.51%
Small epoch 2, Accuracy: 99.07%
Small epoch 3, Accuracy: 99.09%
Small epoch 4, Accuracy: 97.99%
Small epoch 5, Accuracy: 98.61%
Small epoch 6, Accuracy: 98.69%
Small epoch 7, Accuracy: 98.72%
Small epoch 8, Accuracy: 98.21%
Small epoch 9, Accuracy: 99.01%
Small epoch 10, Accuracy: 98.80%
Small epoch 1, Accuracy: 97.43%
Small epoch 2, Accuracy: 99.03%
Small epoch 3, Accuracy: 99.10%
Small epoch 4, Accuracy: 98.19%
Small epoch 5, Accuracy: 98.35%
Small epoch 6, Accuracy: 98.17%
Small epoch 7, Accuracy: 98.86%
Small epoch 8, Accuracy: 99.37%
Small epoch 9, Accuracy: 98.57%
Small epoch 10, Accuracy: 98.06%
Cycle 13, Accuracy: 67.94%
Small epoch 1, Accuracy: 97.77%
Small epoch 2, Accuracy: 99.06%
Small epoch 3, Accuracy: 99.03%
Small epoch 4, Accuracy: 98.84%

Small epoch 5, Accuracy: 98.24%
 Small epoch 6, Accuracy: 98.15%
 Small epoch 7, Accuracy: 98.61%
 Small epoch 8, Accuracy: 99.26%
 Small epoch 9, Accuracy: 99.06%
 Small epoch 10, Accuracy: 98.61%
 Small epoch 1, Accuracy: 98.22%
 Small epoch 2, Accuracy: 98.57%
 Small epoch 3, Accuracy: 98.71%
 Small epoch 4, Accuracy: 98.47%
 Small epoch 5, Accuracy: 98.37%
 Small epoch 6, Accuracy: 99.30%
 Small epoch 7, Accuracy: 99.05%
 Small epoch 8, Accuracy: 98.37%
 Small epoch 9, Accuracy: 98.36%
 Small epoch 10, Accuracy: 98.73%
 Cycle 14, Accuracy: 68.40%
 Small epoch 1, Accuracy: 97.95%
 Small epoch 2, Accuracy: 98.92%
 Small epoch 3, Accuracy: 98.33%
 Small epoch 4, Accuracy: 98.61%
 Small epoch 5, Accuracy: 99.03%
 Small epoch 6, Accuracy: 99.48%
 Small epoch 7, Accuracy: 98.62%
 Small epoch 8, Accuracy: 98.78%
 Small epoch 9, Accuracy: 98.31%
 Small epoch 10, Accuracy: 98.97%
 Small epoch 1, Accuracy: 98.01%
 Small epoch 2, Accuracy: 99.29%
 Small epoch 3, Accuracy: 98.23%
 Small epoch 4, Accuracy: 98.70%
 Small epoch 5, Accuracy: 99.09%
 Small epoch 6, Accuracy: 98.75%
 Small epoch 7, Accuracy: 98.33%
 Small epoch 8, Accuracy: 99.17%
 Small epoch 9, Accuracy: 98.53%
 Small epoch 10, Accuracy: 98.59%
 Cycle 15, Accuracy: 67.96%

```

[19]: plt.figure(figsize=(10, 6))
      for num_samples, res in results.items():
          plt.plot(res, label=f"Samples: {num_samples}", marker='o')
      plt.xlabel("Epoch")
      plt.ylabel("Accuracy (%)")
      plt.title("Federated Learning Performance on CIFAR-10")
      plt.legend()
      plt.grid(True)
  
```

```
plt.show()
```



```
[ ]: # The more points there is, the better. At 15000 it was a bit under 70% which is  
      ↪ okay. That means 30 000 points since we have 2 models without intersection  
      ↪ in their data.
```