stanowski_problem2

May 10, 2025

2. Improve the architecture

Experiment with different numbers of layers, size of layers, number of filters, size of filters. You are required to make those adjustment to get the highest accuracy. Watch out for overfitting – we want the highest testing accuracy! Please provide a PDF file of the result, the best test accuracy and the architecture (different numbers of layers, size of layers, number of filters, size of filters)

[6]:
```
import numpy as np
import torch
import torch.nn as nn
import torch.optim as optim

from datetime import datetime

import torchvision
import torchvision.transforms as transforms

from torchvision.datasets import FashionMNIST
import matplotlib.pyplot as plt
%matplotlib inline

from torch.utils.data import random_split
from torch.utils.data import DataLoader
import torch.nn.functional as F

from PIL import Image
```

[7]:
```
github_labels = {
    0: "T-shirt/top",
    1: "Trouser",
    2: "Pullover",
    3: "Dress",
    4: "Coat",
    5: "Sandal",
    6: "Shirt",
    7: "Sneaker",
    8: "Bag",
    9: "Ankle boot"
```

```
}

fmnist_dataset = FashionMNIST(root = 'data/', download=True, train = True,␣
 ↪transform = transforms.ToTensor())

print(fmnist_dataset)
```

```
100%|      | 26.4M/26.4M [00:03<00:00, 7.31MB/s]
100%|      | 29.5k/29.5k [00:00<00:00, 121kB/s]
100%|      | 4.42M/4.42M [00:01<00:00, 2.25MB/s]
100%|      | 5.15k/5.15k [00:00<00:00, 8.94MB/s]
```

```
Dataset FashionMNIST
    Number of datapoints: 60000
    Root location: data/
    Split: Train
    StandardTransform
Transform: ToTensor()
```

[9]:

```
train_data, validation_data = random_split(fmnist_dataset, [50000, 10000])
## Print the length of train and validation datasets
print("length of Train Datasets: ", len(train_data))
print("length of Validation Datasets: ", len(validation_data))

batch_size = 128
train_loader = DataLoader(train_data, batch_size, shuffle = True) # true, bo␣
 ↪tasujemy dla lepszego uczenia się
val_loader = DataLoader(validation_data, batch_size, shuffle = False) # fal


test_dataset = FashionMNIST(root = 'data/', train = False, transform =␣
 ↪transforms.ToTensor())
test_loader = DataLoader(test_dataset, batch_size = 256, shuffle = False)
```

```
length of Train Datasets:  50000
length of Validation Datasets:  10000
```

[10]:

```
def accuracy(outputs, labels):
    _, preds = torch.max(outputs, dim = 1)
    return(torch.tensor(torch.sum(preds == labels).item()/ len(preds)))

class OptimizedCNN(nn.Module):
    def __init__(self, conv_channels=[16, 32], kernel_size=3, fc_size=128):
        super(OptimizedCNN, self).__init__()
        self.convs = nn.ModuleList()
```

```python
        in_channels = 1
        for out_channels in conv_channels:
            self.convs.append(
                nn.Sequential(
                    nn.Conv2d(in_channels, out_channels,␣
 ↪kernel_size=kernel_size, padding=kernel_size // 2),
                    nn.ReLU(),
                    nn.MaxPool2d(2),
                )
            )
            in_channels = out_channels

        # size after convolutions
        self.flatten_size = out_channels * (28 // (2 ** len(conv_channels))) **␣
 ↪2

        self.fc = nn.Linear(self.flatten_size, fc_size)
        self.out = nn.Linear(fc_size, 10)

    def forward(self, x):
        for conv in self.convs:
            x = conv(x)
        x = x.view(x.size(0), -1)
        x = self.fc(x)
        output = self.out(x)
        return output, x

cnn = OptimizedCNN()
print(cnn)
```

```
OptimizedCNN(
  (convs): ModuleList(
    (0): Sequential(
      (0): Conv2d(1, 16, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (1): ReLU()
      (2): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    )
    (1): Sequential(
      (0): Conv2d(16, 32, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1))
      (1): ReLU()
      (2): MaxPool2d(kernel_size=2, stride=2, padding=0, dilation=1,
ceil_mode=False)
    )
  )
  (fc): Linear(in_features=1568, out_features=128, bias=True)
  (out): Linear(in_features=128, out_features=10, bias=True)
```

)

[11]:
```python
from torch.autograd import Variable

def train(num_epochs, cnn, loaders):
    cnn.train()
    optimizer = optim.Adam(cnn.parameters(), lr=0.01)
    loss_func = nn.CrossEntropyLoss()

    all_accuracies = []

    total_step = len(loaders)

    for epoch in range(num_epochs):
        epoch_loss = 0.0
        correct = 0
        total = 0

        for i, (images, labels) in enumerate(loaders):
            b_x = Variable(images)   # batch x
            b_y = Variable(labels)   # batch y
            output = cnn(b_x)[0]
            loss = loss_func(output, b_y)

            epoch_loss += loss.item()

            optimizer.zero_grad()
            loss.backward()
            optimizer.step()

            _, predicted = torch.max(output.data, 1)
            total += labels.size(0)
            correct += (predicted == labels).sum().item()

            if (i+1) % 100 == 0:
                print(f"Epoch [{epoch+1}/{num_epochs}], Step [{i+1}/
↪{total_step}], Loss: {loss.item():.4f}")

        avg_loss = epoch_loss / total_step
        accuracy = 100 * correct / total

        all_accuracies.append(accuracy)

        print(f"Epoch [{epoch+1}/{num_epochs}] - Loss: {avg_loss:.4f}, Accuracy:
↪ {accuracy:.2f}%")

    return all_accuracies
```

[12]:

```python
architectures = [
    {'conv_channels': [8, 16], 'kernel_size': 3, 'fc_size': 64},
    {'conv_channels': [16, 32], 'kernel_size': 3, 'fc_size': 128},
    {'conv_channels': [32, 64], 'kernel_size': 5, 'fc_size': 128},
    {'conv_channels': [32, 128], 'kernel_size': 5, 'fc_size': 256},
    {'conv_channels': [8, 16, 32], 'kernel_size': 3, 'fc_size': 128},
    {'conv_channels': [16, 32, 64], 'kernel_size': 3, 'fc_size': 256},
    {'conv_channels': [16, 32, 128], 'kernel_size': 5, 'fc_size': 256},
    {'conv_channels': [8, 16, 32, 64], 'kernel_size': 3, 'fc_size': 256},
    {'conv_channels': [16, 32, 64, 128], 'kernel_size': 3, 'fc_size': 256},
    {'conv_channels': [16, 32, 64, 128], 'kernel_size': 5, 'fc_size': 256},
]

results = []

for config in architectures:
    print(f"Testing architecture: {config}")

    # Tworzenie modelu
    cnn = OptimizedCNN(conv_channels=config['conv_channels'],
                       kernel_size=config['kernel_size'],
                       fc_size=config['fc_size'])

    # counting initial accuracies and lossess
    cnn.eval()
    with torch.no_grad():
        correct = 0
        total = 0
        epoch_loss = 0.0
        for images, labels in train_loader:
            test_output, _ = cnn(images)
            loss = nn.CrossEntropyLoss()(test_output, labels)
            epoch_loss += loss.item()

            pred_y = torch.max(test_output, 1)[1].data.squeeze()
            correct += (pred_y == labels).sum().item()
            total += labels.size(0)

        initial_accuracy = correct / total
        initial_loss = epoch_loss / total  # avg starting loss

    print(f"Initial accuracy: {initial_accuracy:.2f}")

    # saving the first accuracy
    accuracies = [initial_accuracy]

    # training
```

```
train_accuracies = train(num_epochs=5, cnn=cnn, loaders=train_loader)

accuracies.extend(train_accuracies)

# accuracy after training
cnn.eval()
with torch.no_grad():
    correct = 0
    total = 0
    for images, labels in train_loader:
        test_output, _ = cnn(images)
        pred_y = torch.max(test_output, 1)[1].data.squeeze()
        correct += (pred_y == labels).sum().item()
        total += labels.size(0)
    final_accuracy = correct / total

print(f"Final accuracy: {final_accuracy:.2f}")

results.append({
    'config': config,
    'initial_accuracy': initial_accuracy,
    'final_accuracy': final_accuracy,
    'accuracies': accuracies
})
```

```
Testing architecture: {'conv_channels': [8, 16], 'kernel_size': 3, 'fc_size':
64}
Initial accuracy: 0.12
Epoch [1/5], Step [100/391], Loss: 0.6208
Epoch [1/5], Step [200/391], Loss: 0.3589
Epoch [1/5], Step [300/391], Loss: 0.3651
Epoch [1/5] - Loss: 0.4961, Accuracy: 81.95%
Epoch [2/5], Step [100/391], Loss: 0.2894
Epoch [2/5], Step [200/391], Loss: 0.2846
Epoch [2/5], Step [300/391], Loss: 0.2823
Epoch [2/5] - Loss: 0.3459, Accuracy: 87.61%
Epoch [3/5], Step [100/391], Loss: 0.2716
Epoch [3/5], Step [200/391], Loss: 0.3100
Epoch [3/5], Step [300/391], Loss: 0.3763
Epoch [3/5] - Loss: 0.3223, Accuracy: 88.34%
Epoch [4/5], Step [100/391], Loss: 0.1752
Epoch [4/5], Step [200/391], Loss: 0.2606
Epoch [4/5], Step [300/391], Loss: 0.2913
Epoch [4/5] - Loss: 0.3045, Accuracy: 88.95%
Epoch [5/5], Step [100/391], Loss: 0.4153
Epoch [5/5], Step [200/391], Loss: 0.2127
Epoch [5/5], Step [300/391], Loss: 0.2228
```

```
Epoch [5/5] - Loss: 0.2974, Accuracy: 89.13%
Final accuracy: 0.90
Testing architecture: {'conv_channels': [16, 32], 'kernel_size': 3, 'fc_size':
128}
Initial accuracy: 0.11
Epoch [1/5], Step [100/391], Loss: 0.6252
Epoch [1/5], Step [200/391], Loss: 0.5313
Epoch [1/5], Step [300/391], Loss: 0.3325
Epoch [1/5] - Loss: 0.5195, Accuracy: 81.03%
Epoch [2/5], Step [100/391], Loss: 0.3809
Epoch [2/5], Step [200/391], Loss: 0.3743
Epoch [2/5], Step [300/391], Loss: 0.3179
Epoch [2/5] - Loss: 0.3581, Accuracy: 87.02%
Epoch [3/5], Step [100/391], Loss: 0.2859
Epoch [3/5], Step [200/391], Loss: 0.3096
Epoch [3/5], Step [300/391], Loss: 0.4571
Epoch [3/5] - Loss: 0.3306, Accuracy: 87.95%
Epoch [4/5], Step [100/391], Loss: 0.3472
Epoch [4/5], Step [200/391], Loss: 0.3263
Epoch [4/5], Step [300/391], Loss: 0.3443
Epoch [4/5] - Loss: 0.3246, Accuracy: 87.98%
Epoch [5/5], Step [100/391], Loss: 0.3452
Epoch [5/5], Step [200/391], Loss: 0.4301
Epoch [5/5], Step [300/391], Loss: 0.4237
Epoch [5/5] - Loss: 0.3143, Accuracy: 88.54%
Final accuracy: 0.88
Testing architecture: {'conv_channels': [32, 64], 'kernel_size': 5, 'fc_size':
128}
Initial accuracy: 0.07
Epoch [1/5], Step [100/391], Loss: 0.6502
Epoch [1/5], Step [200/391], Loss: 0.5616
Epoch [1/5], Step [300/391], Loss: 0.4712
Epoch [1/5] - Loss: 0.5335, Accuracy: 81.18%
Epoch [2/5], Step [100/391], Loss: 0.3825
Epoch [2/5], Step [200/391], Loss: 0.3091
Epoch [2/5], Step [300/391], Loss: 0.4531
Epoch [2/5] - Loss: 0.3670, Accuracy: 86.75%
Epoch [3/5], Step [100/391], Loss: 0.3813
Epoch [3/5], Step [200/391], Loss: 0.3803
Epoch [3/5], Step [300/391], Loss: 0.3532
Epoch [3/5] - Loss: 0.3379, Accuracy: 87.64%
Epoch [4/5], Step [100/391], Loss: 0.3026
Epoch [4/5], Step [200/391], Loss: 0.3686
Epoch [4/5], Step [300/391], Loss: 0.3926
Epoch [4/5] - Loss: 0.3268, Accuracy: 88.09%
Epoch [5/5], Step [100/391], Loss: 0.3103
Epoch [5/5], Step [200/391], Loss: 0.2955
Epoch [5/5], Step [300/391], Loss: 0.2464
```

```
Epoch [5/5] - Loss: 0.3166, Accuracy: 88.46%
Final accuracy: 0.90
Testing architecture: {'conv_channels': [32, 128], 'kernel_size': 5, 'fc_size':
256}
Initial accuracy: 0.12
Epoch [1/5], Step [100/391], Loss: 0.4200
Epoch [1/5], Step [200/391], Loss: 0.3113
Epoch [1/5], Step [300/391], Loss: 0.3817
Epoch [1/5] - Loss: 0.8555, Accuracy: 75.47%
Epoch [2/5], Step [100/391], Loss: 0.3825
Epoch [2/5], Step [200/391], Loss: 0.4202
Epoch [2/5], Step [300/391], Loss: 0.3434
Epoch [2/5] - Loss: 0.3716, Accuracy: 86.36%
Epoch [3/5], Step [100/391], Loss: 0.3296
Epoch [3/5], Step [200/391], Loss: 0.2441
Epoch [3/5], Step [300/391], Loss: 0.4808
Epoch [3/5] - Loss: 0.3435, Accuracy: 87.36%
Epoch [4/5], Step [100/391], Loss: 0.2894
Epoch [4/5], Step [200/391], Loss: 0.2525
Epoch [4/5], Step [300/391], Loss: 0.4302
Epoch [4/5] - Loss: 0.3381, Accuracy: 87.59%
Epoch [5/5], Step [100/391], Loss: 0.2498
Epoch [5/5], Step [200/391], Loss: 0.2961
Epoch [5/5], Step [300/391], Loss: 0.5788
Epoch [5/5] - Loss: 0.3324, Accuracy: 87.88%
Final accuracy: 0.88
Testing architecture: {'conv_channels': [8, 16, 32], 'kernel_size': 3,
'fc_size': 128}
Initial accuracy: 0.09
Epoch [1/5], Step [100/391], Loss: 0.5000
Epoch [1/5], Step [200/391], Loss: 0.4549
Epoch [1/5], Step [300/391], Loss: 0.4301
Epoch [1/5] - Loss: 0.5669, Accuracy: 78.94%
Epoch [2/5], Step [100/391], Loss: 0.4523
Epoch [2/5], Step [200/391], Loss: 0.2915
Epoch [2/5], Step [300/391], Loss: 0.3820
Epoch [2/5] - Loss: 0.3826, Accuracy: 86.03%
Epoch [3/5], Step [100/391], Loss: 0.2183
Epoch [3/5], Step [200/391], Loss: 0.1814
Epoch [3/5], Step [300/391], Loss: 0.2286
Epoch [3/5] - Loss: 0.3497, Accuracy: 87.20%
Epoch [4/5], Step [100/391], Loss: 0.4163
Epoch [4/5], Step [200/391], Loss: 0.2425
Epoch [4/5], Step [300/391], Loss: 0.3581
Epoch [4/5] - Loss: 0.3359, Accuracy: 87.76%
Epoch [5/5], Step [100/391], Loss: 0.3414
Epoch [5/5], Step [200/391], Loss: 0.3722
Epoch [5/5], Step [300/391], Loss: 0.3254
```

```
Epoch [5/5] - Loss: 0.3209, Accuracy: 88.24%
Final accuracy: 0.89
Testing architecture: {'conv_channels': [16, 32, 64], 'kernel_size': 3,
'fc_size': 256}
Initial accuracy: 0.10
Epoch [1/5], Step [100/391], Loss: 0.4405
Epoch [1/5], Step [200/391], Loss: 0.3529
Epoch [1/5], Step [300/391], Loss: 0.3977
Epoch [1/5] - Loss: 0.5933, Accuracy: 78.03%
Epoch [2/5], Step [100/391], Loss: 0.4256
Epoch [2/5], Step [200/391], Loss: 0.4038
Epoch [2/5], Step [300/391], Loss: 0.3146
Epoch [2/5] - Loss: 0.4046, Accuracy: 85.14%
Epoch [3/5], Step [100/391], Loss: 0.3795
Epoch [3/5], Step [200/391], Loss: 0.3286
Epoch [3/5], Step [300/391], Loss: 0.2286
Epoch [3/5] - Loss: 0.3721, Accuracy: 86.21%
Epoch [4/5], Step [100/391], Loss: 0.4698
Epoch [4/5], Step [200/391], Loss: 0.3507
Epoch [4/5], Step [300/391], Loss: 0.4996
Epoch [4/5] - Loss: 0.3583, Accuracy: 86.90%
Epoch [5/5], Step [100/391], Loss: 0.3953
Epoch [5/5], Step [200/391], Loss: 0.2462
Epoch [5/5], Step [300/391], Loss: 0.4510
Epoch [5/5] - Loss: 0.3499, Accuracy: 87.06%
Final accuracy: 0.88
Testing architecture: {'conv_channels': [16, 32, 128], 'kernel_size': 5,
'fc_size': 256}
Initial accuracy: 0.10
Epoch [1/5], Step [100/391], Loss: 0.6413
Epoch [1/5], Step [200/391], Loss: 0.5520
Epoch [1/5], Step [300/391], Loss: 0.3026
Epoch [1/5] - Loss: 0.6272, Accuracy: 77.17%
Epoch [2/5], Step [100/391], Loss: 0.5112
Epoch [2/5], Step [200/391], Loss: 0.3273
Epoch [2/5], Step [300/391], Loss: 0.3440
Epoch [2/5] - Loss: 0.3991, Accuracy: 85.36%
Epoch [3/5], Step [100/391], Loss: 0.4714
Epoch [3/5], Step [200/391], Loss: 0.3159
Epoch [3/5], Step [300/391], Loss: 0.2785
Epoch [3/5] - Loss: 0.3695, Accuracy: 86.51%
Epoch [4/5], Step [100/391], Loss: 0.3712
Epoch [4/5], Step [200/391], Loss: 0.3743
Epoch [4/5], Step [300/391], Loss: 0.3086
Epoch [4/5] - Loss: 0.3649, Accuracy: 86.50%
Epoch [5/5], Step [100/391], Loss: 0.4469
Epoch [5/5], Step [200/391], Loss: 0.2688
Epoch [5/5], Step [300/391], Loss: 0.4433
```

```
Epoch [5/5] - Loss: 0.3532, Accuracy: 86.94%
Final accuracy: 0.88
Testing architecture: {'conv_channels': [8, 16, 32, 64], 'kernel_size': 3,
'fc_size': 256}
Initial accuracy: 0.10
Epoch [1/5], Step [100/391], Loss: 0.6515
Epoch [1/5], Step [200/391], Loss: 0.5515
Epoch [1/5], Step [300/391], Loss: 0.4490
Epoch [1/5] - Loss: 0.5650, Accuracy: 78.80%
Epoch [2/5], Step [100/391], Loss: 0.4381
Epoch [2/5], Step [200/391], Loss: 0.2122
Epoch [2/5], Step [300/391], Loss: 0.3626
Epoch [2/5] - Loss: 0.3699, Accuracy: 86.49%
Epoch [3/5], Step [100/391], Loss: 0.2792
Epoch [3/5], Step [200/391], Loss: 0.2327
Epoch [3/5], Step [300/391], Loss: 0.2504
Epoch [3/5] - Loss: 0.3375, Accuracy: 87.73%
Epoch [4/5], Step [100/391], Loss: 0.3097
Epoch [4/5], Step [200/391], Loss: 0.2822
Epoch [4/5], Step [300/391], Loss: 0.4463
Epoch [4/5] - Loss: 0.3171, Accuracy: 88.39%
Epoch [5/5], Step [100/391], Loss: 0.2973
Epoch [5/5], Step [200/391], Loss: 0.2471
Epoch [5/5], Step [300/391], Loss: 0.1167
Epoch [5/5] - Loss: 0.3061, Accuracy: 88.81%
Final accuracy: 0.88
Testing architecture: {'conv_channels': [16, 32, 64, 128], 'kernel_size': 3,
'fc_size': 256}
Initial accuracy: 0.10
Epoch [1/5], Step [100/391], Loss: 0.5589
Epoch [1/5], Step [200/391], Loss: 0.5134
Epoch [1/5], Step [300/391], Loss: 0.4339
Epoch [1/5] - Loss: 0.5998, Accuracy: 77.30%
Epoch [2/5], Step [100/391], Loss: 0.4366
Epoch [2/5], Step [200/391], Loss: 0.3899
Epoch [2/5], Step [300/391], Loss: 0.2504
Epoch [2/5] - Loss: 0.3790, Accuracy: 86.06%
Epoch [3/5], Step [100/391], Loss: 0.3497
Epoch [3/5], Step [200/391], Loss: 0.3458
Epoch [3/5], Step [300/391], Loss: 0.3171
Epoch [3/5] - Loss: 0.3447, Accuracy: 87.43%
Epoch [4/5], Step [100/391], Loss: 0.3295
Epoch [4/5], Step [200/391], Loss: 0.1892
Epoch [4/5], Step [300/391], Loss: 0.3939
Epoch [4/5] - Loss: 0.3228, Accuracy: 88.20%
Epoch [5/5], Step [100/391], Loss: 0.2682
Epoch [5/5], Step [200/391], Loss: 0.3719
Epoch [5/5], Step [300/391], Loss: 0.3468
```

```
Epoch [5/5] - Loss: 0.3224, Accuracy: 88.30%
Final accuracy: 0.89
Testing architecture: {'conv_channels': [16, 32, 64, 128], 'kernel_size': 5,
'fc_size': 256}
Initial accuracy: 0.10
Epoch [1/5], Step [100/391], Loss: 0.8628
Epoch [1/5], Step [200/391], Loss: 0.7326
Epoch [1/5], Step [300/391], Loss: 0.5651
Epoch [1/5] - Loss: 0.9575, Accuracy: 62.76%
Epoch [2/5], Step [100/391], Loss: 0.3649
Epoch [2/5], Step [200/391], Loss: 0.3942
Epoch [2/5], Step [300/391], Loss: 0.4608
Epoch [2/5] - Loss: 0.4760, Accuracy: 82.50%
Epoch [3/5], Step [100/391], Loss: 0.3162
Epoch [3/5], Step [200/391], Loss: 0.4044
Epoch [3/5], Step [300/391], Loss: 0.4841
Epoch [3/5] - Loss: 0.4405, Accuracy: 83.82%
Epoch [4/5], Step [100/391], Loss: 0.3238
Epoch [4/5], Step [200/391], Loss: 0.3368
Epoch [4/5], Step [300/391], Loss: 0.3994
Epoch [4/5] - Loss: 0.4110, Accuracy: 84.89%
Epoch [5/5], Step [100/391], Loss: 0.4570
Epoch [5/5], Step [200/391], Loss: 0.3203
Epoch [5/5], Step [300/391], Loss: 0.3062
Epoch [5/5] - Loss: 0.4009, Accuracy: 85.27%
Final accuracy: 0.85
```

[13]:

```python
import matplotlib.pyplot as plt

print(results)

for result in results:
    plt.plot(result['accuracies'], label='Accuracy')
    plt.title(f"Accuracy per Epoch ({result['config']})")
    plt.xlabel("Epoch")
    plt.ylabel("Accuracy (%)")
    plt.legend()

    plt.show()
```

```
[{'config': {'conv_channels': [8, 16], 'kernel_size': 3, 'fc_size': 64},
'initial_accuracy': 0.12446, 'final_accuracy': 0.89696, 'accuracies': [0.12446,
81.952, 87.606, 88.338, 88.946, 89.128]}, {'config': {'conv_channels': [16, 32],
'kernel_size': 3, 'fc_size': 128}, 'initial_accuracy': 0.11168,
'final_accuracy': 0.88472, 'accuracies': [0.11168, 81.032, 87.016, 87.952,
87.984, 88.538]}, {'config': {'conv_channels': [32, 64], 'kernel_size': 5,
'fc_size': 128}, 'initial_accuracy': 0.06554, 'final_accuracy': 0.8955,
'accuracies': [0.06554, 81.182, 86.75, 87.638, 88.094, 88.458]}, {'config':
```

{'conv_channels': [32, 128], 'kernel_size': 5, 'fc_size': 256},
'initial_accuracy': 0.12448, 'final_accuracy': 0.88238, 'accuracies': [0.12448,
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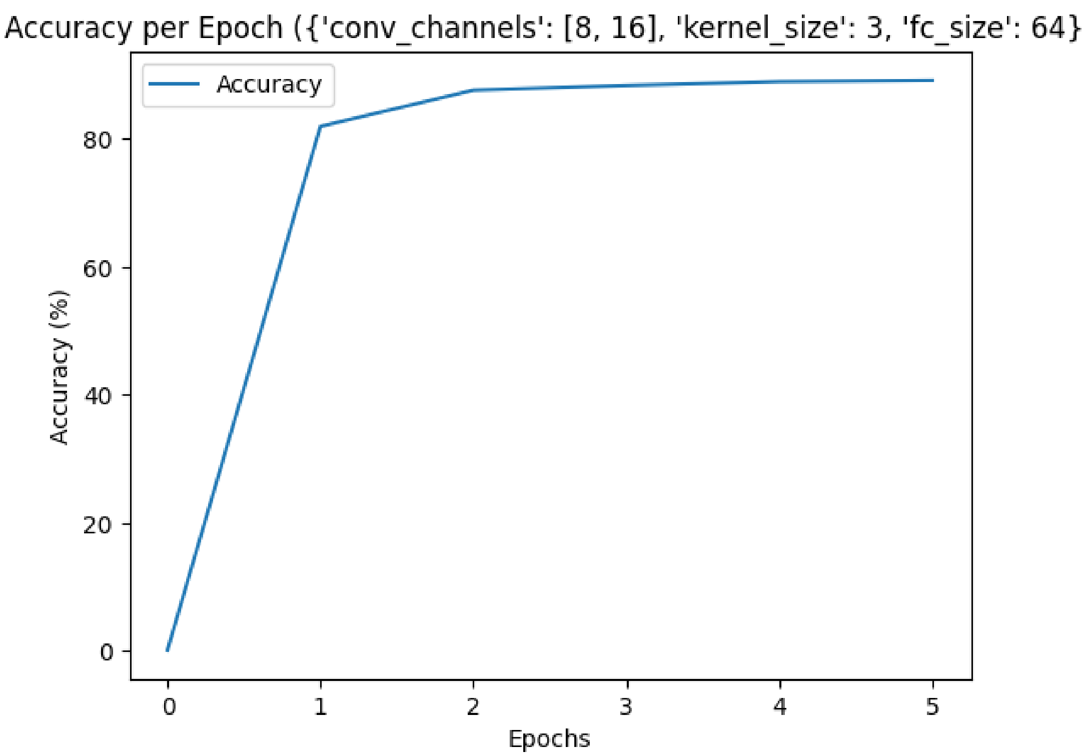
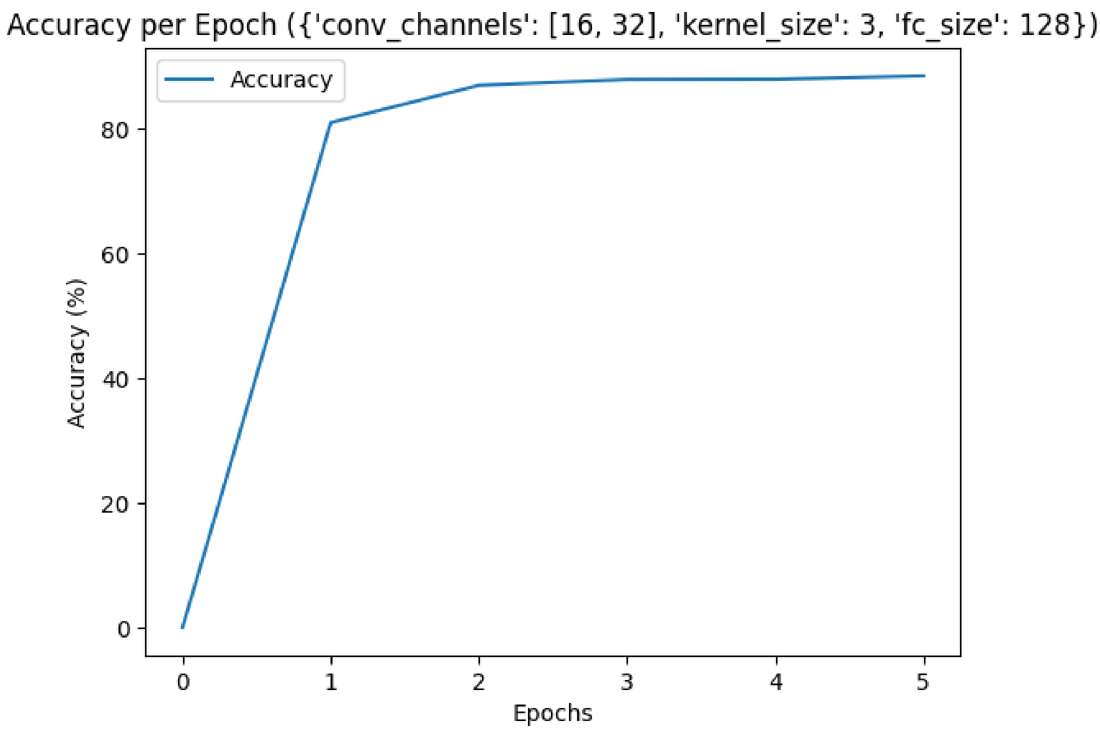
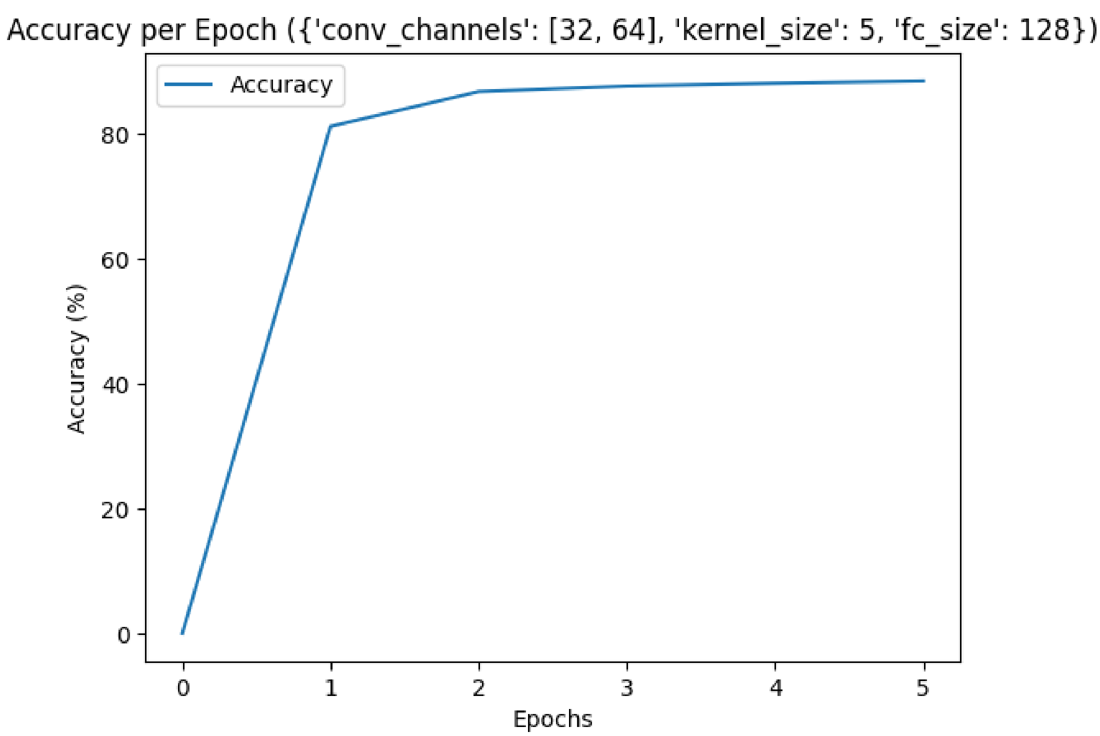
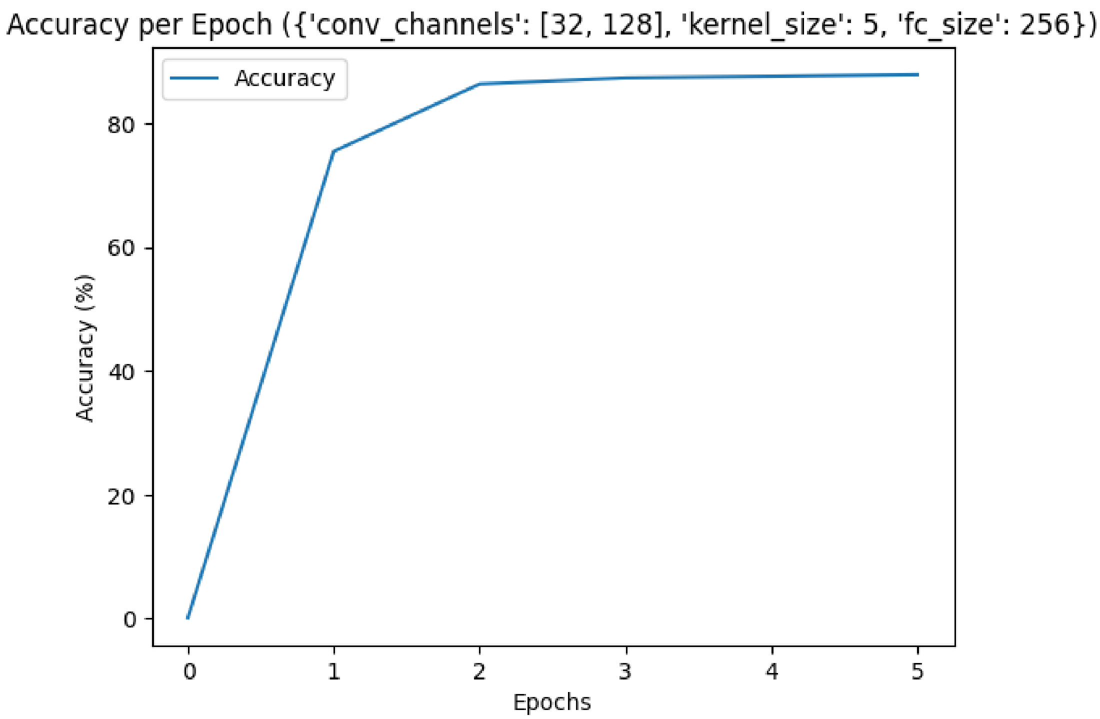
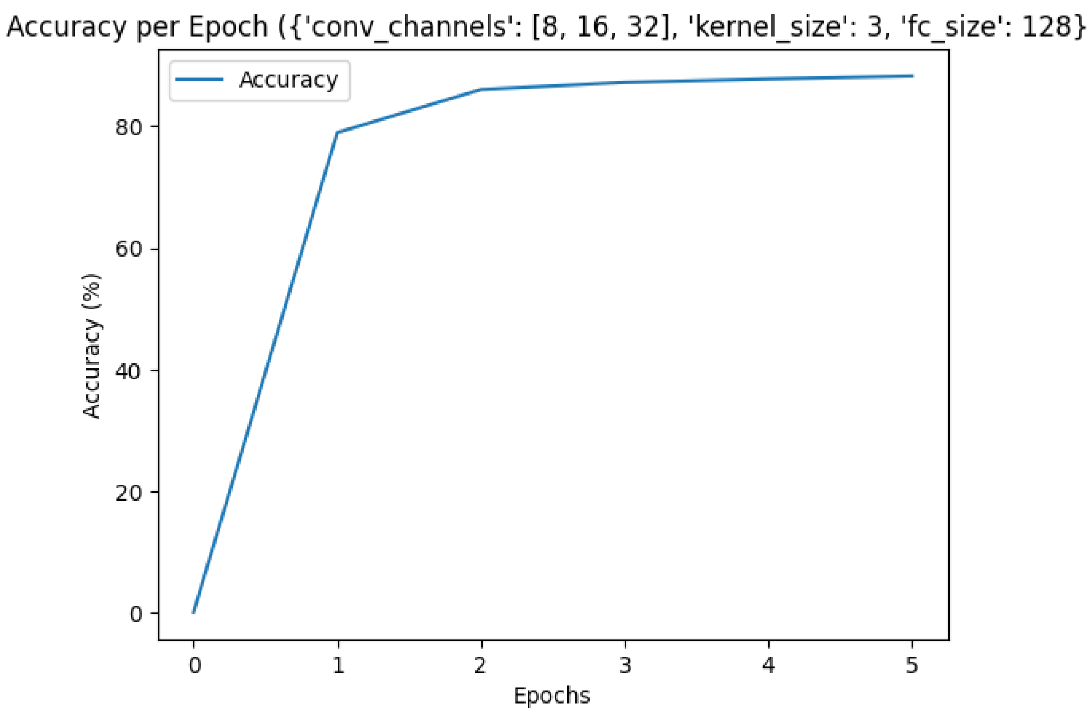
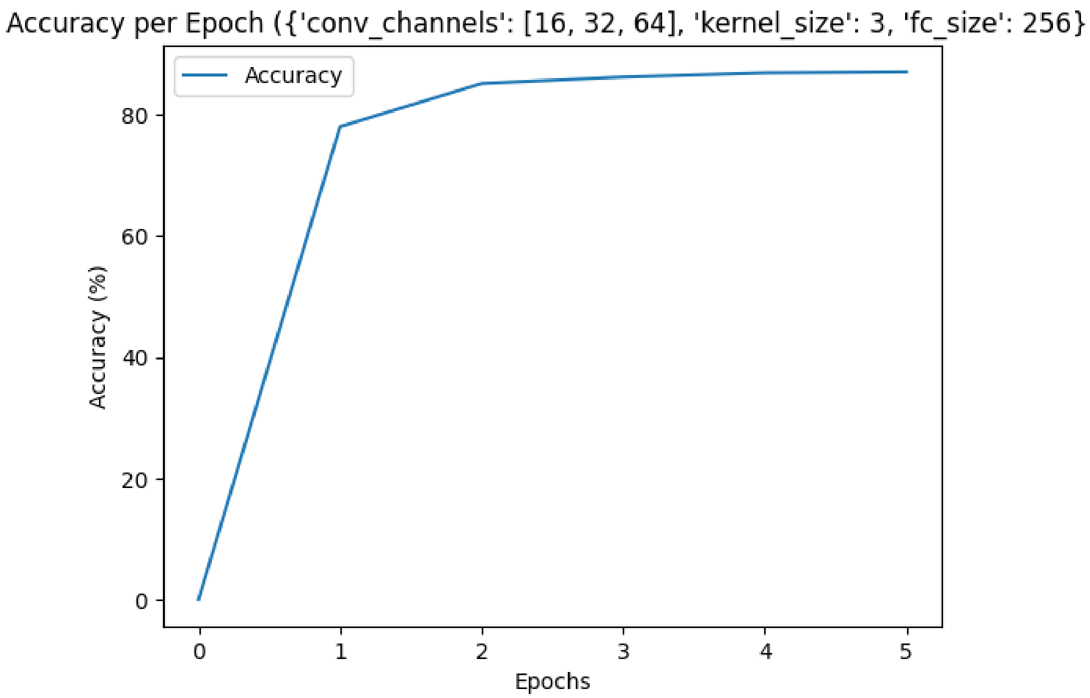


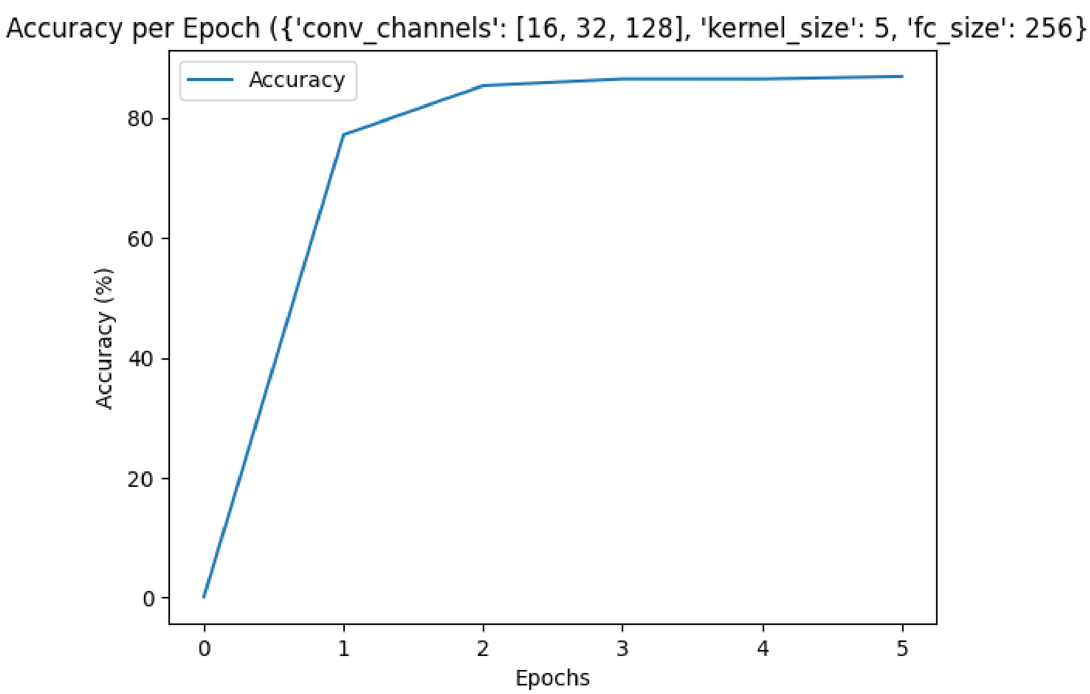

Accuracy per Epoch ({'conv_channels': [16, 32], 'kernel_size': 3, 'fc_size': 128})
Accuracy
Accuracy (%)
Epochs
0
20
40
60
80
0
1
2
3
4
5

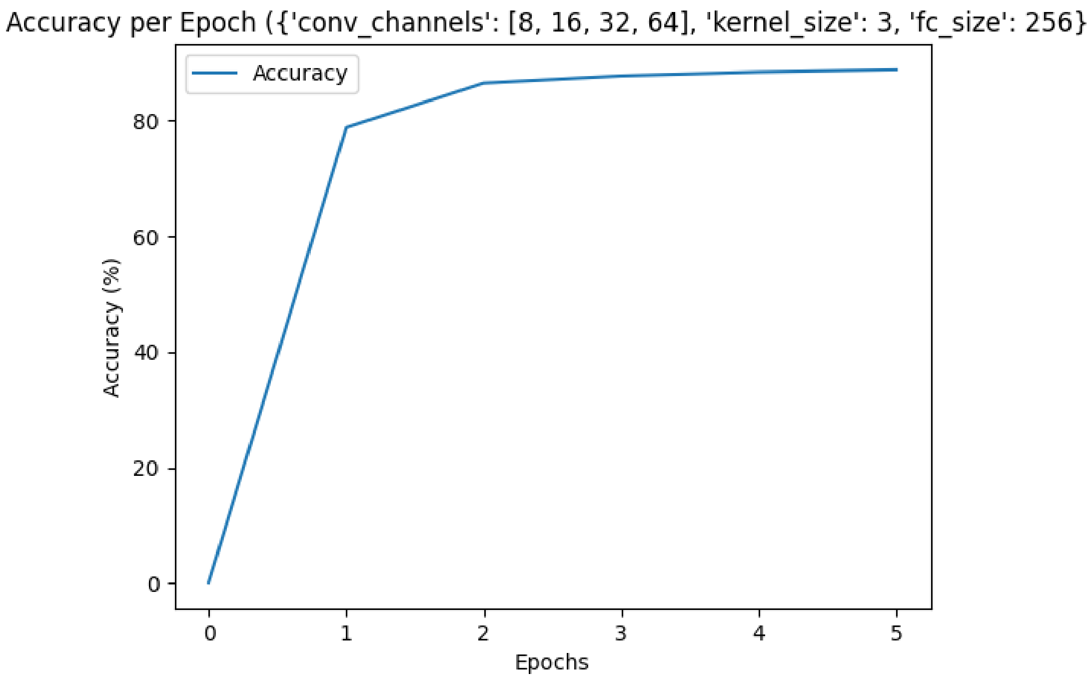

Accuracy per Epoch ({'conv_channels': [32, 64], 'kernel_size': 5, 'fc_size': 128})
Accuracy
Accuracy (%)
Epochs
0
20
40
60
80
0
1
2
3
4
5

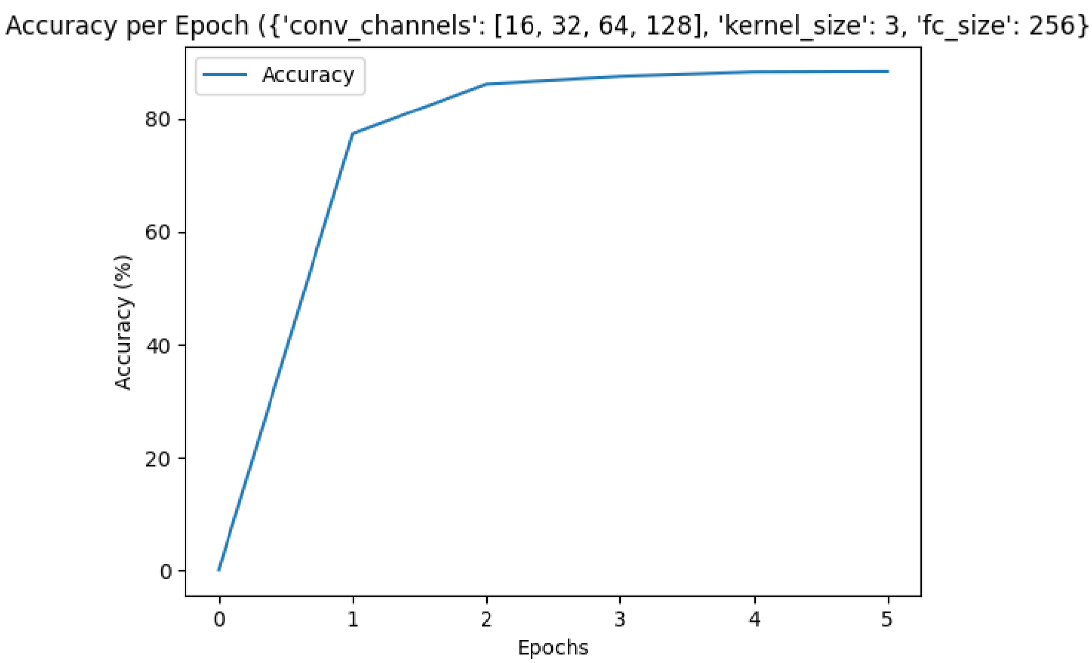

Accuracy per Epoch ({'conv_channels': [32, 128], 'kernel_size': 5, 'fc_size': 256})
Accuracy
Accuracy (%)
Epochs
0
20
40
60
80
0
1
2
3
4
5

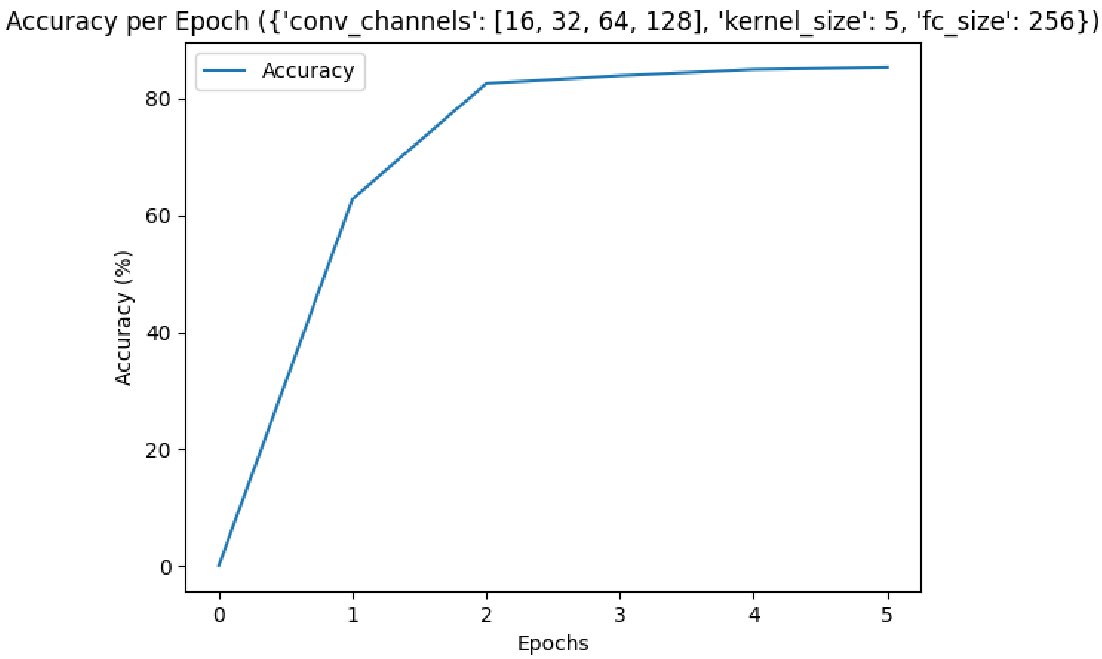

Accuracy per Epoch ({'conv_channels': [8, 16, 32], 'kernel_size': 3, 'fc_size': 128})
Accuracy
Accuracy (%)
Epochs
0
20
40
60
80
0
1
2
3
4
5


Accuracy per Epoch ({'conv_channels': [16, 32, 64], 'kernel_size': 3, 'fc_size': 256})
Accuracy
Accuracy (%)
Epochs
0
20
40
60
80
0
1
2
3
4
5


Accuracy per Epoch ({'conv_channels': [16, 32, 128], 'kernel_size': 5, 'fc_size': 256})
Accuracy
Accuracy (%)
Epochs
0
20
40
60
80
0
1
2
3
4
5


Accuracy per Epoch ({'conv_channels': [8, 16, 32, 64], 'kernel_size': 3, 'fc_size': 256})
Accuracy
Accuracy (%)
0
20
40
60
80
0
1
2
3
4
5
Epochs


Accuracy per Epoch ({'conv_channels': [16, 32, 64, 128], 'kernel_size': 3, 'fc_size': 256})
Accuracy
Accuracy (%)
0
20
40
60
80
0
1
2
3
4
5
Epochs



[16]:
```python
best_model = max(results, key=lambda x: x['final_accuracy'])

print("Best architecture:")
print(f"Config: {best_model['config']}")
print(f"Initial accuracy: {best_model['initial_accuracy']:.4f}")
print(f"Final accuracy: {best_model['final_accuracy']:.4f}")
```

```
Best architecture:
Config: {'conv_channels': [8, 16], 'kernel_size': 3, 'fc_size': 64}
Initial accuracy: 0.1245
Final accuracy: 0.8970
```