SL Project - Fine-tuning

December 14, 2022

[1]:
```
import torchvision
import torch
import torch.nn as nn
from torchsummary import summary
```

[2]:
```
from torchvision import transforms, datasets
import matplotlib.pyplot as plt
from tqdm import tqdm
```

[3]:
```
import pandas as pd
```

[4]:
```
import os
import pickle
import seaborn as sns
import matplotlib.pyplot as plt
```

[5]:
```
sns.set_style("darkgrid")
```

[6]:
```
import cv2

image = cv2.imread("../data/asl_alphabet_train/A/A1.jpg")
print(image.shape)  # image dimensions
```

```
(200, 200, 3)
```

[7]:
```
transform = transforms.Compose([
    transforms.Resize(256),
    transforms.RandomCrop(224),
    transforms.ToTensor()
])
```

[8]:
```
PATH = "../data/asl_alphabet_train/"
```

[9]:
```
dataset = datasets.ImageFolder(PATH, transform=transform)
```

[10]:
```
n = len(dataset)
```

[11]:
```
print(n)
```

```
87000
```

[12]:
```
torch.manual_seed(1)
indices = torch.randperm(n)
```

[13]:
```
test_proportion = 0.2 # 20 percent of data used for testing
test_size = int(n * test_proportion)
```

[14]:
```
train_dataset = torch.utils.data.Subset(dataset, indices[test_size:])
test_dataset = torch.utils.data.Subset(dataset, indices[:test_size])
```

[15]:
```
len(train_dataset)
```

[15]:
```
69600
```

[16]:
```
len(test_dataset)
```

[16]:
```
17400
```

[17]:
```
train_dataloader = torch.utils.data.DataLoader(dataset=train_dataset,
                                               batch_size=32,
                                               shuffle=True,
                                               num_workers=4)

test_dataloader = torch.utils.data.DataLoader(dataset=test_dataset,
                                              batch_size=32,
                                              shuffle=False,
                                              num_workers=4)
```

[18]:
```
classes = dataset.classes
```

[19]:
```
cols = 10
rows = 2
fig, ax = plt.subplots(rows, cols, figsize=(20, 4))
i = 0
for img, label in train_dataloader:
    plt.subplot(rows, cols, i + 1)
    plt.imshow(img[0].permute(1, 2, 0))
    plt.xticks(())
    plt.yticks(())
    plt.title(classes[label[0]])
    i += 1
    if i == 20:
        break
```

```
[20]: model = torch.hub.load(repo_or_dir='pytorch/vision:v0.10.0', model='googlenet',
                             weights='GoogLeNet_Weights.IMAGENET1K_V1')
```

```
Using cache found in /home/rao.ans/.cache/torch/hub/pytorch_vision_v0.10.0
```

```
[21]: model.fc = torch.nn.Linear(model.fc.in_features, len(classes))
```

```
[22]: criterion = torch.nn.CrossEntropyLoss()
```

```
[23]: optimizer = torch.optim.Adam(model.parameters(), lr=3e-4, weight_decay=0.001)
```

```
[24]: device = torch.device('cuda' if torch.cuda.is_available() else 'cpu')
```

```
[25]: if torch.cuda.is_available():
          model.cuda()
```

```
[26]: summary(model, (3, 224, 224))
```

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1         [-1, 64, 112, 112]           9,408
       BatchNorm2d-2         [-1, 64, 112, 112]             128
       BasicConv2d-3         [-1, 64, 112, 112]               0
         MaxPool2d-4           [-1, 64, 56, 56]               0
            Conv2d-5           [-1, 64, 56, 56]           4,096
       BatchNorm2d-6           [-1, 64, 56, 56]             128
       BasicConv2d-7           [-1, 64, 56, 56]               0
            Conv2d-8          [-1, 192, 56, 56]         110,592
       BatchNorm2d-9          [-1, 192, 56, 56]             384
      BasicConv2d-10          [-1, 192, 56, 56]               0
        MaxPool2d-11          [-1, 192, 28, 28]               0
           Conv2d-12           [-1, 64, 28, 28]          12,288
      BatchNorm2d-13           [-1, 64, 28, 28]             128
      BasicConv2d-14           [-1, 64, 28, 28]               0
           Conv2d-15           [-1, 96, 28, 28]          18,432
      BatchNorm2d-16           [-1, 96, 28, 28]             192
      BasicConv2d-17           [-1, 96, 28, 28]               0
```

```
        Conv2d-18          [-1, 128, 28, 28]         110,592
   BatchNorm2d-19          [-1, 128, 28, 28]             256
   BasicConv2d-20          [-1, 128, 28, 28]               0
        Conv2d-21           [-1, 16, 28, 28]           3,072
   BatchNorm2d-22           [-1, 16, 28, 28]              32
   BasicConv2d-23           [-1, 16, 28, 28]               0
        Conv2d-24           [-1, 32, 28, 28]           4,608
   BatchNorm2d-25           [-1, 32, 28, 28]              64
   BasicConv2d-26           [-1, 32, 28, 28]               0
     MaxPool2d-27          [-1, 192, 28, 28]               0
        Conv2d-28           [-1, 32, 28, 28]           6,144
   BatchNorm2d-29           [-1, 32, 28, 28]              64
   BasicConv2d-30           [-1, 32, 28, 28]               0
     Inception-31          [-1, 256, 28, 28]               0
        Conv2d-32          [-1, 128, 28, 28]          32,768
   BatchNorm2d-33          [-1, 128, 28, 28]             256
   BasicConv2d-34          [-1, 128, 28, 28]               0
        Conv2d-35          [-1, 128, 28, 28]          32,768
   BatchNorm2d-36          [-1, 128, 28, 28]             256
   BasicConv2d-37          [-1, 128, 28, 28]               0
        Conv2d-38          [-1, 192, 28, 28]         221,184
   BatchNorm2d-39          [-1, 192, 28, 28]             384
   BasicConv2d-40          [-1, 192, 28, 28]               0
        Conv2d-41           [-1, 32, 28, 28]           8,192
   BatchNorm2d-42           [-1, 32, 28, 28]              64
   BasicConv2d-43           [-1, 32, 28, 28]               0
        Conv2d-44           [-1, 96, 28, 28]          27,648
   BatchNorm2d-45           [-1, 96, 28, 28]             192
   BasicConv2d-46           [-1, 96, 28, 28]               0
     MaxPool2d-47          [-1, 256, 28, 28]               0
        Conv2d-48           [-1, 64, 28, 28]          16,384
   BatchNorm2d-49           [-1, 64, 28, 28]             128
   BasicConv2d-50           [-1, 64, 28, 28]               0
     Inception-51          [-1, 480, 28, 28]               0
     MaxPool2d-52          [-1, 480, 14, 14]               0
        Conv2d-53          [-1, 192, 14, 14]          92,160
   BatchNorm2d-54          [-1, 192, 14, 14]             384
   BasicConv2d-55          [-1, 192, 14, 14]               0
        Conv2d-56           [-1, 96, 14, 14]          46,080
   BatchNorm2d-57           [-1, 96, 14, 14]             192
   BasicConv2d-58           [-1, 96, 14, 14]               0
        Conv2d-59          [-1, 208, 14, 14]         179,712
   BatchNorm2d-60          [-1, 208, 14, 14]             416
   BasicConv2d-61          [-1, 208, 14, 14]               0
        Conv2d-62           [-1, 16, 14, 14]           7,680
   BatchNorm2d-63           [-1, 16, 14, 14]              32
   BasicConv2d-64           [-1, 16, 14, 14]               0
        Conv2d-65           [-1, 48, 14, 14]           6,912
```

```
      BatchNorm2d-66           [-1, 48, 14, 14]              96
      BasicConv2d-67           [-1, 48, 14, 14]               0
        MaxPool2d-68          [-1, 480, 14, 14]               0
           Conv2d-69           [-1, 64, 14, 14]          30,720
      BatchNorm2d-70           [-1, 64, 14, 14]             128
      BasicConv2d-71           [-1, 64, 14, 14]               0
        Inception-72          [-1, 512, 14, 14]               0
           Conv2d-73          [-1, 160, 14, 14]          81,920
      BatchNorm2d-74          [-1, 160, 14, 14]             320
      BasicConv2d-75          [-1, 160, 14, 14]               0
           Conv2d-76          [-1, 112, 14, 14]          57,344
      BatchNorm2d-77          [-1, 112, 14, 14]             224
      BasicConv2d-78          [-1, 112, 14, 14]               0
           Conv2d-79          [-1, 224, 14, 14]         225,792
      BatchNorm2d-80          [-1, 224, 14, 14]             448
      BasicConv2d-81          [-1, 224, 14, 14]               0
           Conv2d-82           [-1, 24, 14, 14]          12,288
      BatchNorm2d-83           [-1, 24, 14, 14]              48
      BasicConv2d-84           [-1, 24, 14, 14]               0
           Conv2d-85           [-1, 64, 14, 14]          13,824
      BatchNorm2d-86           [-1, 64, 14, 14]             128
      BasicConv2d-87           [-1, 64, 14, 14]               0
        MaxPool2d-88          [-1, 512, 14, 14]               0
           Conv2d-89           [-1, 64, 14, 14]          32,768
      BatchNorm2d-90           [-1, 64, 14, 14]             128
      BasicConv2d-91           [-1, 64, 14, 14]               0
        Inception-92          [-1, 512, 14, 14]               0
           Conv2d-93          [-1, 128, 14, 14]          65,536
      BatchNorm2d-94          [-1, 128, 14, 14]             256
      BasicConv2d-95          [-1, 128, 14, 14]               0
           Conv2d-96          [-1, 128, 14, 14]          65,536
      BatchNorm2d-97          [-1, 128, 14, 14]             256
      BasicConv2d-98          [-1, 128, 14, 14]               0
           Conv2d-99          [-1, 256, 14, 14]         294,912
     BatchNorm2d-100          [-1, 256, 14, 14]             512
     BasicConv2d-101          [-1, 256, 14, 14]               0
          Conv2d-102           [-1, 24, 14, 14]          12,288
     BatchNorm2d-103           [-1, 24, 14, 14]              48
     BasicConv2d-104           [-1, 24, 14, 14]               0
          Conv2d-105           [-1, 64, 14, 14]          13,824
     BatchNorm2d-106           [-1, 64, 14, 14]             128
     BasicConv2d-107           [-1, 64, 14, 14]               0
       MaxPool2d-108          [-1, 512, 14, 14]               0
          Conv2d-109           [-1, 64, 14, 14]          32,768
     BatchNorm2d-110           [-1, 64, 14, 14]             128
     BasicConv2d-111           [-1, 64, 14, 14]               0
       Inception-112          [-1, 512, 14, 14]               0
          Conv2d-113          [-1, 112, 14, 14]          57,344
```

```
   BatchNorm2d-114         [-1, 112, 14, 14]             224
  BasicConv2d-115          [-1, 112, 14, 14]               0
       Conv2d-116          [-1, 144, 14, 14]          73,728
  BatchNorm2d-117          [-1, 144, 14, 14]             288
  BasicConv2d-118          [-1, 144, 14, 14]               0
       Conv2d-119          [-1, 288, 14, 14]         373,248
  BatchNorm2d-120          [-1, 288, 14, 14]             576
  BasicConv2d-121          [-1, 288, 14, 14]               0
       Conv2d-122           [-1, 32, 14, 14]          16,384
  BatchNorm2d-123           [-1, 32, 14, 14]              64
  BasicConv2d-124           [-1, 32, 14, 14]               0
       Conv2d-125           [-1, 64, 14, 14]          18,432
  BatchNorm2d-126           [-1, 64, 14, 14]             128
  BasicConv2d-127           [-1, 64, 14, 14]               0
    MaxPool2d-128          [-1, 512, 14, 14]               0
       Conv2d-129           [-1, 64, 14, 14]          32,768
  BatchNorm2d-130           [-1, 64, 14, 14]             128
  BasicConv2d-131           [-1, 64, 14, 14]               0
    Inception-132          [-1, 528, 14, 14]               0
       Conv2d-133          [-1, 256, 14, 14]         135,168
  BatchNorm2d-134          [-1, 256, 14, 14]             512
  BasicConv2d-135          [-1, 256, 14, 14]               0
       Conv2d-136          [-1, 160, 14, 14]          84,480
  BatchNorm2d-137          [-1, 160, 14, 14]             320
  BasicConv2d-138          [-1, 160, 14, 14]               0
       Conv2d-139          [-1, 320, 14, 14]         460,800
  BatchNorm2d-140          [-1, 320, 14, 14]             640
  BasicConv2d-141          [-1, 320, 14, 14]               0
       Conv2d-142           [-1, 32, 14, 14]          16,896
  BatchNorm2d-143           [-1, 32, 14, 14]              64
  BasicConv2d-144           [-1, 32, 14, 14]               0
       Conv2d-145          [-1, 128, 14, 14]          36,864
  BatchNorm2d-146          [-1, 128, 14, 14]             256
  BasicConv2d-147          [-1, 128, 14, 14]               0
    MaxPool2d-148          [-1, 528, 14, 14]               0
       Conv2d-149          [-1, 128, 14, 14]          67,584
  BatchNorm2d-150          [-1, 128, 14, 14]             256
  BasicConv2d-151          [-1, 128, 14, 14]               0
    Inception-152          [-1, 832, 14, 14]               0
    MaxPool2d-153            [-1, 832, 7, 7]               0
       Conv2d-154            [-1, 256, 7, 7]         212,992
  BatchNorm2d-155            [-1, 256, 7, 7]             512
  BasicConv2d-156            [-1, 256, 7, 7]               0
       Conv2d-157            [-1, 160, 7, 7]         133,120
  BatchNorm2d-158            [-1, 160, 7, 7]             320
  BasicConv2d-159            [-1, 160, 7, 7]               0
       Conv2d-160            [-1, 320, 7, 7]         460,800
  BatchNorm2d-161            [-1, 320, 7, 7]             640
```

```
     BasicConv2d-162            [-1, 320, 7, 7]               0
          Conv2d-163             [-1, 32, 7, 7]          26,624
     BatchNorm2d-164             [-1, 32, 7, 7]              64
     BasicConv2d-165             [-1, 32, 7, 7]               0
          Conv2d-166            [-1, 128, 7, 7]          36,864
     BatchNorm2d-167            [-1, 128, 7, 7]             256
     BasicConv2d-168            [-1, 128, 7, 7]               0
       MaxPool2d-169            [-1, 832, 7, 7]               0
          Conv2d-170            [-1, 128, 7, 7]         106,496
     BatchNorm2d-171            [-1, 128, 7, 7]             256
     BasicConv2d-172            [-1, 128, 7, 7]               0
       Inception-173            [-1, 832, 7, 7]               0
          Conv2d-174            [-1, 384, 7, 7]         319,488
     BatchNorm2d-175            [-1, 384, 7, 7]             768
     BasicConv2d-176            [-1, 384, 7, 7]               0
          Conv2d-177            [-1, 192, 7, 7]         159,744
     BatchNorm2d-178            [-1, 192, 7, 7]             384
     BasicConv2d-179            [-1, 192, 7, 7]               0
          Conv2d-180            [-1, 384, 7, 7]         663,552
     BatchNorm2d-181            [-1, 384, 7, 7]             768
     BasicConv2d-182            [-1, 384, 7, 7]               0
          Conv2d-183             [-1, 48, 7, 7]          39,936
     BatchNorm2d-184             [-1, 48, 7, 7]              96
     BasicConv2d-185             [-1, 48, 7, 7]               0
          Conv2d-186            [-1, 128, 7, 7]          55,296
     BatchNorm2d-187            [-1, 128, 7, 7]             256
     BasicConv2d-188            [-1, 128, 7, 7]               0
       MaxPool2d-189            [-1, 832, 7, 7]               0
          Conv2d-190            [-1, 128, 7, 7]         106,496
     BatchNorm2d-191            [-1, 128, 7, 7]             256
     BasicConv2d-192            [-1, 128, 7, 7]               0
       Inception-193           [-1, 1024, 7, 7]               0
AdaptiveAvgPool2d-194           [-1, 1024, 1, 1]               0
         Dropout-195                 [-1, 1024]               0
          Linear-196                   [-1, 29]          29,725
================================================================
Total params: 5,629,629
Trainable params: 5,629,629
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.57
Forward/backward pass size (MB): 94.10
Params size (MB): 21.48
Estimated Total Size (MB): 116.15
----------------------------------------------------------------
```

[27]:
```
train_losses = []
train_accuracies = []
val_losses = []
val_accuracies = []
```

[28]:
```
step = 0
no_of_epochs = 10

for epoch in tqdm(range(no_of_epochs)):
    correct_train, total_train = 0, 0
    train_loss = 0
    model.train()
    for i, (images, labels) in enumerate(train_dataloader):
        step += 1
        images = images.to(device)
        labels = labels.to(device)
        optimizer.zero_grad()
        outputs = model(images)
        loss = criterion(outputs, labels)
        loss.backward()
        optimizer.step()

        total_train += labels.size(0)
        _, predicted = torch.max(outputs, dim=1)
        correct_train += (predicted == labels).sum().item()

        if step % 1000 == 0:
            print(f"epoch [{epoch + 1}]/[{no_of_epochs}]", end=" ")
            train_loss += loss.item()
            train_accuracy = (correct_train / total_train) * 100
            print(f"train accuracy: {train_accuracy}", end=" ")

            with torch.no_grad():
                correct_val, total_val = 0, 0
                val_loss = 0
                model.eval()
                for images, labels in test_dataloader:
                    images = images.to(device)
                    labels = labels.to(device)
                    outputs = model(images)

                    total_val += labels.size(0)
                    _, predicted = torch.max(outputs, dim=1)
                    correct_val += (predicted == labels).sum().item()

                    val_loss += loss.item()
        val_accuracy = (correct_val / total_val) * 100
        print(f"val accuracy: {val_accuracy}")
        train_losses.append(train_loss / total_train)
        val_losses.append(val_loss / total_val)
        train_accuracies.append(train_accuracy)
        val_accuracies.append(val_accuracy)
```

```
  0%|          | 0/10 [00:00<?, ?it/s]

epoch [1]/[10] train accuracy: 96.50937499999999 val accuracy: 99.0919540229885
epoch [1]/[10] train accuracy: 96.8703125 val accuracy: 99.56896551724138

 10%|         | 1/10 [04:25<39:50, 265.63s/it]

epoch [2]/[10] train accuracy: 99.84469696969697 val accuracy: 99.95402298850574
epoch [2]/[10] train accuracy: 98.59246575342466 val accuracy: 99.45977011494253

 20%|        | 2/10 [08:55<35:44, 268.10s/it]

epoch [3]/[10] train accuracy: 99.79326923076923 val accuracy: 99.7816091954023
epoch [3]/[10] train accuracy: 98.9659090909091 val accuracy: 99.50574712643679

 30%|       | 3/10 [13:25<31:21, 268.81s/it]

epoch [4]/[10] train accuracy: 99.84868421052632 val accuracy: 99.9080459770115
epoch [4]/[10] train accuracy: 99.00423728813558 val accuracy: 98.9655172413793

 40%|      | 4/10 [17:43<26:27, 264.66s/it]

epoch [5]/[10] train accuracy: 99.78125 val accuracy: 99.89655172413792
epoch [5]/[10] train accuracy: 99.0 val accuracy: 99.2816091954023

 50%|     | 5/10 [22:01<21:51, 262.33s/it]

epoch [6]/[10] train accuracy: 99.825 val accuracy: 99.91954022988506
epoch [6]/[10] train accuracy: 99.13888888888889 val accuracy: 99.4080459770115
epoch [6]/[10] train accuracy: 99.10441176470587 val accuracy: 99.22413793103448

 60%|    | 6/10 [26:51<18:07, 271.83s/it]

epoch [7]/[10] train accuracy: 99.8092105263158 val accuracy: 99.74712643678161
epoch [7]/[10] train accuracy: 99.2451923076923 val accuracy: 99.78735632183908

 70%|   | 7/10 [31:13<13:25, 268.42s/it]

epoch [8]/[10] train accuracy: 99.80645161290323 val accuracy: 99.93103448275862
epoch [8]/[10] train accuracy: 99.30281690140845 val accuracy: 98.94252873563218

 80%|  | 8/10 [35:33<08:51, 265.90s/it]

epoch [9]/[10] train accuracy: 99.84895833333334 val accuracy: 99.94827586206897
epoch [9]/[10] train accuracy: 99.35546875 val accuracy: 99.54597701149426

 90%| | 9/10 [39:56<04:24, 264.97s/it]
```

```
epoch [10]/[10] train accuracy: 99.83088235294117 val accuracy:
99.94252873563218
epoch [10]/[10] train accuracy: 99.3048245614035 val accuracy: 98.34482758620689

100%|          | 10/10 [44:20<00:00, 266.03s/it]
```

[29]:
```
SAVE_PATH = "../data/googlenet_asl_v2.pth"
```

[30]:
```
torch.save(model, SAVE_PATH)
```

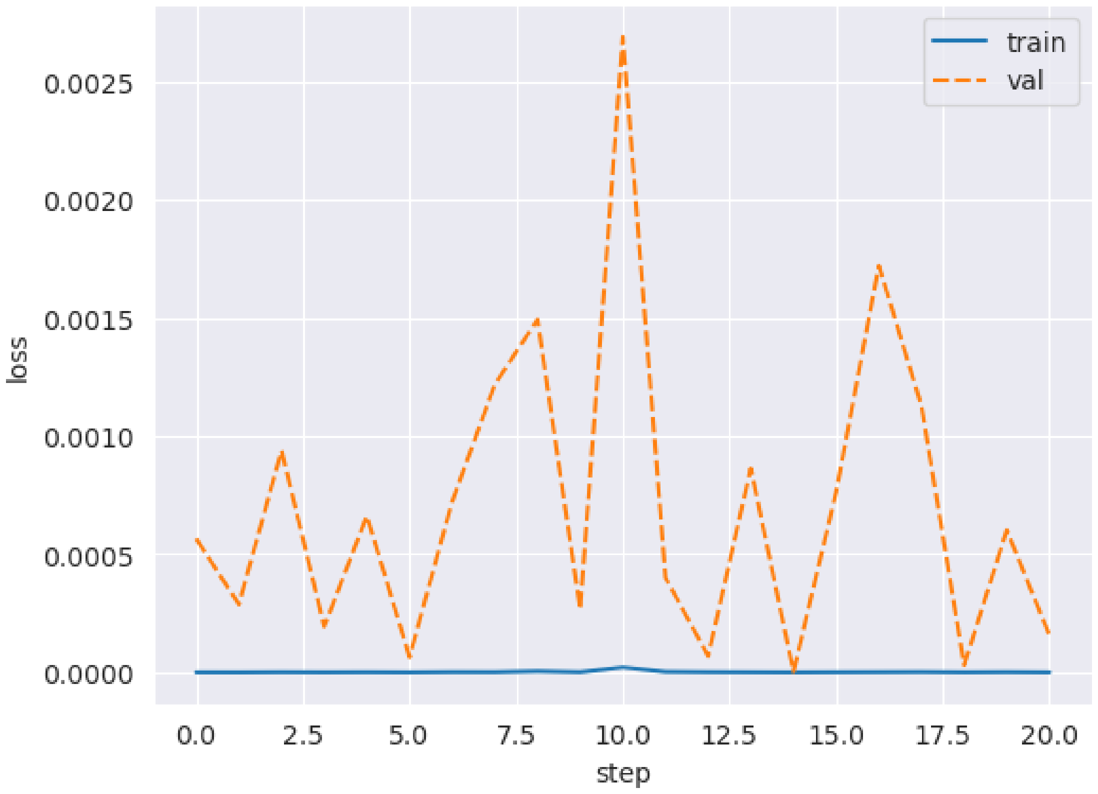
[31]:
```
with open('../data/googlenet_asl_v2_train_losses.pkl', 'wb') as f:
    pickle.dump(train_losses, f)
```

[32]:
```
with open('../data/googlenet_asl_v2_val_losses.pkl', 'wb') as f:
    pickle.dump(val_losses, f)
```

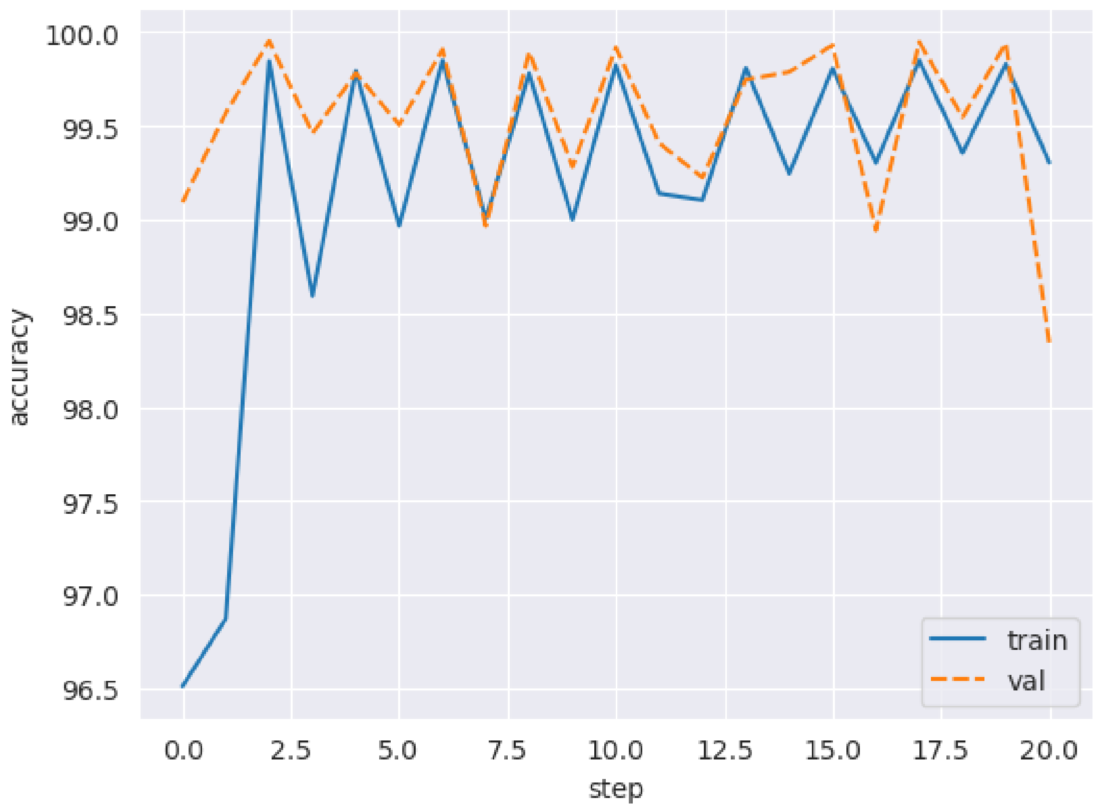
[33]:
```
with open('../data/googlenet_asl_v2_train_accuracies.pkl', 'wb') as f:
    pickle.dump(train_accuracies, f)
```

[34]:
```
with open('../data/googlenet_asl_v2_val_accuracies.pkl', 'wb') as f:
    pickle.dump(val_accuracies, f)
```

[35]:
```
loss = pd.DataFrame({'train': train_losses, 'val': val_losses})
sns.lineplot(loss)
plt.xlabel("step")
plt.ylabel("loss");
```



[36]:
```
accuracy = pd.DataFrame({'train': train_accuracies, 'val': val_accuracies})
sns.lineplot(accuracy)
plt.xlabel("step")
plt.ylabel("accuracy");
```



100.0
99.5
99.0
98.5
98.0
97.5
97.0
96.5
accuracy
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
step
train
val