```
# Replace the average pooling with max-pooling.
# Replace the softmax layer with ReLU.
# Adjust the number of fully connected layers.
```

```
import torch
!pip install d2l==1.0.0a0
```

```
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.8/dist-packages (from requests->d2l==1.0.0a0) (2.10)
Requirement already satisfied: chardet<5,>=3.0.2 in /usr/local/lib/python3.8/dist-packages (from requests->d2l==1.0.0a0) (4.0.0)
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Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.8/dist-packages (from importlib-metadata>=4.8.0->gym->d2l==1.0.0
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.8/dist-packages (from python-dateutil>=2.1->matplotlib->d2l==1.0.
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Requirement already satisfied: parso<0.9.0,>=0.8.0 in /usr/local/lib/python3.8/dist-packages (from jedi>=0.10->ipython>=5.0.0->ipyk
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Installing collected packages: qtpy, jedi, qtconsole, jupyter, d2l
Successfully installed d2l-1.0.0a0 jedi-0.18.2 jupyter-1.0.0 qtconsole-5.4.0 qtpy-2.3.0
```

```
!pip install matplotlib
%matplotlib inline
!pip install matplotlib-inline
import sys
!{sys.executable} -m pip install matplotlib
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Requirement already satisfied: matplotlib in /usr/local/lib/python3.8/dist-packages (3.2.2)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.8/dist-packages (from matplotlib) (0.11.0)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.8/dist-packages (from matplotlib) (1.4.4)
Requirement already satisfied: numpy>=1.11 in /usr/local/lib/python3.8/dist-packages (from matplotlib) (1.21.6)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 in /usr/local/lib/python3.8/dist-packages (from matplotlib) (3.0
Requirement already satisfied: python-dateutil>=2.1 in /usr/local/lib/python3.8/dist-packages (from matplotlib) (2.8.2)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.8/dist-packages (from python-dateutil>=2.1->matplotlib) (1.15.0)
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting matplotlib-inline
  Downloading matplotlib_inline-0.1.6-py3-none-any.whl (9.4 kB)
Requirement already satisfied: traitlets in /usr/local/lib/python3.8/dist-packages (from matplotlib-inline) (5.7.1)
Installing collected packages: matplotlib-inline
Successfully installed matplotlib-inline-0.1.6
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Requirement already satisfied: matplotlib in /usr/local/lib/python3.8/dist-packages (3.2.2)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python3.8/dist-packages (from matplotlib) (1.4.4)
Requirement already satisfied: python-dateutil>=2.1 in /usr/local/lib/python3.8/dist-packages (from matplotlib) (2.8.2)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.8/dist-packages (from matplotlib) (0.11.0)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 in /usr/local/lib/python3.8/dist-packages (from matplotlib) (3.0
Requirement already satisfied: numpy>=1.11 in /usr/local/lib/python3.8/dist-packages (from matplotlib) (1.21.6)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.8/dist-packages (from python-dateutil>=2.1->matplotlib) (1.15.0)
```

```
import time
import numpy as np
import torch
import torchvision
from torchvision import transforms
from torch import nn
from d2l import torch as d2l
from torch.optim import lr_scheduler
```

```
def LeNet(num_classes=10):
    net = nn.Sequential(nn.LazyConv2d(6, kernel_size=5, padding=2),
          nn.ReLU(),
          nn.MaxPool2d(kernel_size=2, stride=2),
          nn.LazyConv2d(16, kernel_size=5),
          nn.ReLU(),
          nn.MaxPool2d(kernel_size=2, stride=2),
          nn.Flatten(),
          nn.Linear(400, 256),
          nn.ReLU(),
          nn.Linear(256, 128),
          nn.ReLU(),
          nn.Linear(128, 64),
          nn.ReLU(),
          nn.Linear(64, num_classes))
    return net
```

```
def train(model, train_loader, test_loader, num_epochs, loss_fn, trainer):

    animator = d2l.Animator(xlabel='epoch', xlim=[0, num_epochs], legend=['train loss', 'train accuracy', 'test accuracy'])
    for epoch in range(num_epochs):
        metric = d2l.Accumulator(3)
        for i, (X, y) in enumerate(train_loader):
            net.train()
            trainer.zero_grad()
            y_hat = net(X)
            l = loss_fn(y_hat, y)
            l.backward()
            trainer.step()
            with torch.no_grad():
                metric.add(l * X.shape[0], d2l.accuracy(y_hat, y), X.shape[0])
            train_loss = metric[0] / metric[2]
            train_acc = metric[1] / metric[2]
            if (i + 1) % 50 == 0:
                animator.add(epoch + i / len(train_loader),
                             (train_loss, train_acc, None))

        test_acc = d2l.evaluate_accuracy_gpu(model, test_loader)
        animator.add(epoch+1, (None, None, test_acc))

    print(f'train loss {train_loss:.3f}, train accuracy {train_acc:.3f}, 'f'test accuracy {test_acc:.3f}')
```

```
loss = nn.CrossEntropyLoss()
batch_size = 256
num_epochs = 10
lr=0.01
```

```
train_loader, test_loader = d2l.load_data_fashion_mnist(batch_size=batch_size)
net= LeNet(num_classes=10)
```

```
3 trainer = torch.optim.Adam(net.parameters(), lr=lr)
```

```
Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train-images-idx3-ubyte.gz
Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train-images-idx3-ubyte.gz to ../data/FashionMNIST/raw/train-imag
100%                                      26421880/26421880 [00:01<00:00, 23844638.73it/s]
Extracting ../data/FashionMNIST/raw/train-images-idx3-ubyte.gz to ../data/FashionMNIST/raw

Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/train-labels-idx1-ubyte.gz
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Extracting ../data/FashionMNIST/raw/train-labels-idx1-ubyte.gz to ../data/FashionMNIST/raw

Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/t10k-images-idx3-ubyte.gz
Downloading http://fashion-mnist.s3-website.eu-central-1.amazonaws.com/t10k-images-idx3-ubyte.gz to ../data/FashionMNIST/raw/t10k-images
100%                                      4422102/4422102 [00:00<00:00, 8516007.46it/s]
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100%                                      5148/5148 [00:00<00:00, 112494.93it/s]
Extracting ../data/FashionMNIST/raw/t10k-labels-idx1-ubyte.gz to ../data/FashionMNIST/raw

/usr/local/lib/python3.8/dist-packages/torch/utils/data/dataloader.py:554: UserWarning: This DataLoader will create 4 worker processes i
  warnings.warn(_create_warning_msg(
/usr/local/lib/python3.8/dist-packages/torch/nn/modules/lazy.py:180: UserWarning: Lazy modules are a new feature under heavy development
  warnings.warn('Lazy modules are a new feature under heavy development '
```
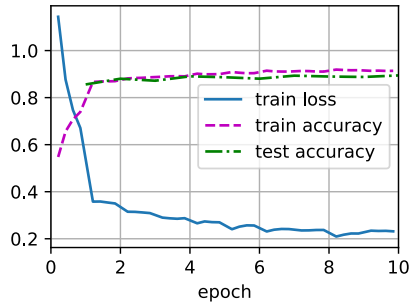

```
1 train(net, train_loader, test_loader, num_epochs, loss, trainer)
```

```
train loss 0.230, train accuracy 0.914, test accuracy 0.894
```




```
1 # Measuring and comparing theoretical computation complexity (number of operations and parameters size)
```

```
1 pip install torchinfo
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting torchinfo
  Downloading torchinfo-1.7.2-py3-none-any.whl (22 kB)
Installing collected packages: torchinfo
Successfully installed torchinfo-1.7.2
```

```
1  from torchinfo import summary
2
3  model = LeNet()
4  batch_size = 256
5  summary(model, input_size=(batch_size, 1, 28, 28))
```

```
==========================================================================================
Layer (type:depth-idx)                   Output Shape              Param #
==========================================================================================
Sequential                               [256, 10]                 --
├─Conv2d: 1-1                            [256, 6, 28, 28]          156
├─ReLU: 1-2                              [256, 6, 28, 28]          --
├─MaxPool2d: 1-3                         [256, 6, 14, 14]          --
├─Conv2d: 1-4                            [256, 16, 10, 10]         2,416
├─ReLU: 1-5                              [256, 16, 10, 10]         --
├─MaxPool2d: 1-6                         [256, 16, 5, 5]           --
├─Flatten: 1-7                           [256, 400]                --
├─Linear: 1-8                            [256, 256]                102,656
├─ReLU: 1-9                              [256, 256]                --
├─Linear: 1-10                           [256, 128]                32,896
├─ReLU: 1-11                             [256, 128]                --
```

```
├─Linear: 1-12                           [256, 64]                 8,256
├─ReLU: 1-13                             [256, 64]                 --
├─Linear: 1-14                           [256, 10]                 650
==========================================================================================
Total params: 147,030
Trainable params: 147,030
Non-trainable params: 0
Total mult-adds (M): 130.14
==========================================================================================
Input size (MB): 0.80
Forward/backward pass size (MB): 13.85
Params size (MB): 0.59
Estimated Total Size (MB): 15.24
==========================================================================================
```

✓ 11s completed at 8:30 PM