```
In [3]: !pip install d2l
```

```
Collecting d2l
  Downloading d2l-1.0.3-py3-none-any.whl.metadata (556 bytes)
Collecting jupyter==1.0.0 (from d2l)
  Downloading jupyter-1.0.0-py2.py3-none-any.whl.metadata (995 bytes)
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Collecting matplotlib==3.7.2 (from d2l)
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Installing collected packages: requests, qtpy, pyparsing, numpy, matplotlib-inline, jedi, scipy, pandas, matplot
lib, qtconsole, jupyter, d2l
  Attempting uninstall: requests
    Found existing installation: requests 2.32.3
    Uninstalling requests-2.32.3:
      Successfully uninstalled requests-2.32.3
  Attempting uninstall: pyparsing
    Found existing installation: pyparsing 3.1.4
    Uninstalling pyparsing-3.1.4:
      Successfully uninstalled pyparsing-3.1.4
  Attempting uninstall: numpy
    Found existing installation: numpy 1.26.4
    Uninstalling numpy-1.26.4:
      Successfully uninstalled numpy-1.26.4
  Attempting uninstall: matplotlib-inline
    Found existing installation: matplotlib-inline 0.1.7
    Uninstalling matplotlib-inline-0.1.7:
      Successfully uninstalled matplotlib-inline-0.1.7
  Attempting uninstall: scipy
    Found existing installation: scipy 1.13.1
    Uninstalling scipy-1.13.1:
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  Attempting uninstall: pandas
    Found existing installation: pandas 2.2.2
    Uninstalling pandas-2.2.2:
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  Attempting uninstall: matplotlib
    Found existing installation: matplotlib 3.7.1
    Uninstalling matplotlib-3.7.1:
      Successfully uninstalled matplotlib-3.7.1
ERROR: pip's dependency resolver does not currently take into account all the packages that are installed. This
behaviour is the source of the following dependency conflicts.
albucore 0.0.16 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatible.
albumentations 1.4.15 requires numpy>=1.24.4, but you have numpy 1.23.5 which is incompatible.
bigframes 1.19.0 requires numpy>=1.24.0, but you have numpy 1.23.5 which is incompatible.
chex 0.1.87 requires numpy>=1.24.1, but you have numpy 1.23.5 which is incompatible.
google-colab 1.0.0 requires pandas==2.2.2, but you have pandas 2.0.3 which is incompatible.
google-colab 1.0.0 requires requests==2.32.3, but you have requests 2.31.0 which is incompatible.
jax 0.4.33 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatible.
jaxlib 0.4.33 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatible.
mizani 0.11.4 requires pandas>=2.1.0, but you have pandas 2.0.3 which is incompatible.
plotnine 0.13.6 requires pandas<3.0.0,>=2.1.0, but you have pandas 2.0.3 which is incompatible.
xarray 2024.9.0 requires numpy>=1.24, but you have numpy 1.23.5 which is incompatible.
xarray 2024.9.0 requires pandas>=2.1, but you have pandas 2.0.3 which is incompatible.
Successfully installed d2l-1.0.3 jedi-0.19.1 jupyter-1.0.0 matplotlib-3.7.2 matplotlib-inline-0.1.6 numpy-1.23.5
pandas-2.0.3 pyparsing-3.0.9 qtconsole-5.6.0 qtpy-2.4.1 requests-2.31.0 scipy-1.10.1
```

```python
import torch
from torch import nn
from torch.nn import functional as F
```

```python
from d2l import torch as d2l
```

In [4]:
```python
class Residual(nn.Module):
    """The Residual block of ResNet models."""
    def __init__(self, num_channels, use_1x1conv=False, strides=1):
        super().__init__()
        self.conv1 = nn.LazyConv2d(num_channels, kernel_size=3, padding=1,
                                   stride=strides)
        self.conv2 = nn.LazyConv2d(num_channels, kernel_size=3, padding=1)
        if use_1x1conv:
            self.conv3 = nn.LazyConv2d(num_channels, kernel_size=1,
                                       stride=strides)
        else:
            self.conv3 = None
        self.bn1 = nn.LazyBatchNorm2d()
        self.bn2 = nn.LazyBatchNorm2d()

    def forward(self, X):
        Y = F.relu(self.bn1(self.conv1(X)))
        Y = self.bn2(self.conv2(Y))
        if self.conv3:
            X = self.conv3(X)
        Y += X
        return F.relu(Y)
```

In [5]:
```python
blk = Residual(3)
X = torch.randn(4, 3, 6, 6)
blk(X).shape
```

Out[5]: torch.Size([4, 3, 6, 6])

In [6]:
```python
blk = Residual(6, use_1x1conv=True, strides=2)
blk(X).shape
```

Out[6]: torch.Size([4, 6, 3, 3])

In [7]:
```python
class ResNet(d2l.Classifier):
    def b1(self):
        return nn.Sequential(
            nn.LazyConv2d(64, kernel_size=7, stride=2, padding=3),
            nn.LazyBatchNorm2d(), nn.ReLU(),
            nn.MaxPool2d(kernel_size=3, stride=2, padding=1))
```

In [8]:
```python
@d2l.add_to_class(ResNet)
def block(self, num_residuals, num_channels, first_block=False):
    blk = []
    for i in range(num_residuals):
        if i == 0 and not first_block:
            blk.append(Residual(num_channels, use_1x1conv=True, strides=2))
        else:
            blk.append(Residual(num_channels))
    return nn.Sequential(*blk)
```

In [9]:
```python
@d2l.add_to_class(ResNet)
def __init__(self, arch, lr=0.1, num_classes=10):
    super(ResNet, self).__init__()
    self.save_hyperparameters()
    self.net = nn.Sequential(self.b1())
    for i, b in enumerate(arch):
        self.net.add_module(f'b{i+2}', self.block(*b, first_block=(i==0)))
    self.net.add_module('last', nn.Sequential(
        nn.AdaptiveAvgPool2d((1, 1)), nn.Flatten(),
        nn.LazyLinear(num_classes)))
    self.net.apply(d2l.init_cnn)
```
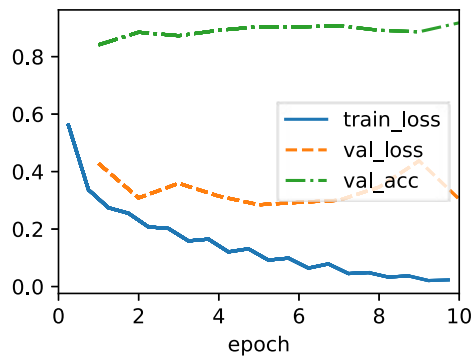
In [10]:
```python
class ResNet18(ResNet):
    def __init__(self, lr=0.1, num_classes=10):
        super().__init__(((2, 64), (2, 128), (2, 256), (2, 512)),
                         lr, num_classes)

ResNet18().layer_summary((1, 1, 96, 96))
```

```
Sequential output shape:        torch.Size([1, 64, 24, 24])
Sequential output shape:        torch.Size([1, 64, 24, 24])
Sequential output shape:        torch.Size([1, 128, 12, 12])
Sequential output shape:        torch.Size([1, 256, 6, 6])
Sequential output shape:        torch.Size([1, 512, 3, 3])
Sequential output shape:        torch.Size([1, 10])
```

In [11]:
```python
model = ResNet18(lr=0.01)
trainer = d2l.Trainer(max_epochs=10, num_gpus=1)
data = d2l.FashionMNIST(batch_size=128, resize=(96, 96))
```

```
model.apply_init([next(iter(data.get_dataloader(True)))[0]], d2l.init_cnn)
trainer.fit(model, data)
```


Discussion: 이 단원에서 배운 ResNet은, Residual connection(잔차 연결) 이라는 딥러닝에서 중요한 개념 중 하나를 도입한 네트워크이다. 깊은 신경망의 설계에서, 깊이가 너무 깊다면 학습이 어렵거나 성능이 떨어지는 문제점이 생기는데, 이럴 때 일부 층을 건너뛰는 방식인 잔차 연결을 이용하여 최소한의 성능을 보장하고 성능이 떨어지는 것을 막는다.이 방법은 네트워크가 입력과 출력의 잔차(residual)을 학습하게 된다.

이번 단원 역시 학습하는데 시간이 너무 걸려서, colab으로 진행하였다. 앞으로는 매번 pip install같은 것을 해야하는 문제가 있지만 gpu를 사용할 수 있는 colab을 사용해야 할 것 같다.

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