dense_and_convolutional_nn

April 28, 2022

.

Pytorch. .

[1]:
```
import numpy as np

import seaborn as sns
from matplotlib import pyplot as plt

from sklearn.datasets import make_moons
from sklearn.model_selection import train_test_split

import torch
from torch import nn
from torchsummary import summary
from torch.nn import functional as F

from torch.utils.data import TensorDataset, DataLoader

sns.set(style="darkgrid", font_scale=1.4)
```

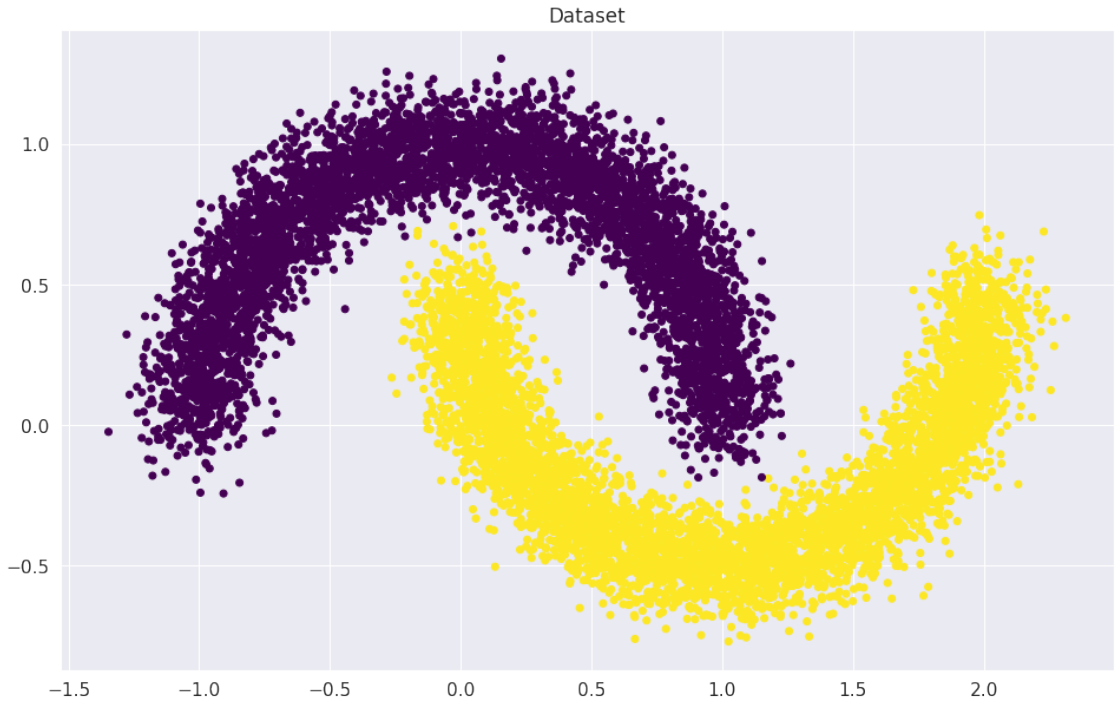
[2]:
```
device = "cuda" if torch.cuda.is_available() else "cpu"
```

1 1. moons

!

[3]:
```
X, y = make_moons(n_samples=10000, random_state=42, noise=0.1)
```

[4]:
```
plt.figure(figsize=(16, 10))
plt.title("Dataset")
plt.scatter(X[:, 0], X[:, 1], c=y, cmap="viridis")
plt.show()
```



train/test split

[5]:
```
X_train, X_val, y_train, y_val = train_test_split(X, y, random_state=42)
```

1.0.1

PyTorch ( ).
`Dataset` `DataLoader`.

1. `Dataset` .
2. `DataLoader` `Dataset` .

`TensorDataset`. , , numpy
`torch.float32`.

1.0.2 .

[6]:
```
X_train_t = torch.FloatTensor(X_train)
y_train_t = torch.FloatTensor(y_train).view(-1, 1)
X_val_t = torch.FloatTensor(X_val)
y_val_t = torch.FloatTensor(y_val).view(-1, 1)
```

`Dataset` `DataLoader`.

[7]:
```
train_dataset = TensorDataset(X_train_t, y_train_t)
val_dataset = TensorDataset(X_val_t, y_val_t)
train_dataloader = DataLoader(train_dataset, batch_size=128)
val_dataloader = DataLoader(val_dataset, batch_size=128)
```

1.1 Logistic regression is my profession

, . - X - y – $\{0, 1\}$. W b (bias), $XW + b$ - . $(-\infty; \infty)$.
" " (logits). $[0; 1]$,
, , , , $-\infty$ 0, $+\infty$ 1. .

$$\sigma(x) = \frac{1}{1 + e^{-x}}.$$

1.1.1 .

PyTorch $logits = XW + b$, W b – (`nn.Parameter`) .
, `nn.Linear` ( ).
(`torch.randn`).

[8]:
```
class LinearRegression(nn.Module):
    def __init__(self, in_features: int, out_features: int, bias: bool = True):
        super().__init__()
        self.weights = nn.Parameter(torch.randn(out_features, in_features),␣
↪requires_grad=True) # YOUR CODE GOES HERE
        self.bias = bias
        if bias:
            self.bias_term = nn.Parameter(torch.randn(out_features),␣
↪requires_grad=True) # YOUR CODE GOES HERE

    def forward(self, x):
        x = x @ self.weights.t() # YOUR CODE GOES HERE
        if self.bias:
            x += self.bias_term # YOUR CODE GOES HERE
        return x
```

[9]:
```
linear_regression = LinearRegression(2, 1)
loss_function = nn.BCEWithLogitsLoss()
optimizer = torch.optim.SGD(linear_regression.parameters(), lr=0.05)
```

[10]:
```
linear_regression.__dict__
```

[10]:
```
{'_backward_hooks': OrderedDict(),
 '_buffers': OrderedDict(),
 '_forward_hooks': OrderedDict(),
 '_forward_pre_hooks': OrderedDict(),
 '_is_full_backward_hook': None,
 '_load_state_dict_pre_hooks': OrderedDict(),
 '_modules': OrderedDict(),
 '_non_persistent_buffers_set': set(),
 '_parameters': OrderedDict([('weights', Parameter containing:
              tensor([[1.0379, 2.4760]], requires_grad=True)),
             ('bias_term', Parameter containing:
              tensor([-0.1329], requires_grad=True))]),
 '_state_dict_hooks': OrderedDict(),
 'bias': True,
 'training': True}
```

1. ? : 3. input (2, 1) LinearRegression(2, 1) : out_features * in_features ( ) + out_features ( ) = 3.

1.1.2 Train loop

, ,

```
for epoch in range(max_epochs):  # <-----------
    for x_batch, y_batch in dataset:  # <------  .  SGD  GD,
        optimizer.zero_grad()  # <-------------
        outp = model(x_batch)  # <-------------  " "
        loss = loss_func(outp, y_batch)  # <---  " "
        loss.backward()  # <-------------------
        optimizer.step()  # <-------------------
        if convergence:  # <-------------------
            break
```

accuracy loss.

1.1.3 .

[11]:
```
tol = 1e-3
losses = []
max_epochs = 100
prev_weights = torch.zeros_like(linear_regression.weights)
stop_it = False
for epoch in range(max_epochs):
    for it, (X_batch, y_batch) in enumerate(train_dataloader):
        optimizer.zero_grad()
        outp = linear_regression.forward(X_batch) # YOUR CODE. Use␣
↪linear_regression to get outputs
```

```
        loss = loss_function(outp, y_batch) # YOUR CODE. Compute loss
        loss.backward()
        losses.append(loss.detach().flatten()[0])
        optimizer.step()
        probabilities = torch.exp(outp) / torch.exp(outp).sum(dim=1,␣
↪keepdims=True) # YOUR CODE. Compute probabilities
        preds = (probabilities > 0.5).type(torch.long)
        batch_acc = (preds.flatten() == y_batch).type(torch.float32).sum() /␣
↪y_batch.size(0)

        if (it + epoch * len(train_dataloader)) % 100 == 0:
            print(f"Iteration: {it + epoch * len(train_dataloader)}\nBatch␣
↪accuracy: {batch_acc}")
        current_weights = linear_regression.weights.detach().clone()
        if (prev_weights - current_weights).abs().max() < tol:
            print(f"\nIteration: {it + epoch * len(train_dataloader)}.
↪Convergence. Stopping iterations.")
            stop_it = True
            break
        prev_weights = current_weights
    if stop_it:
        break
```

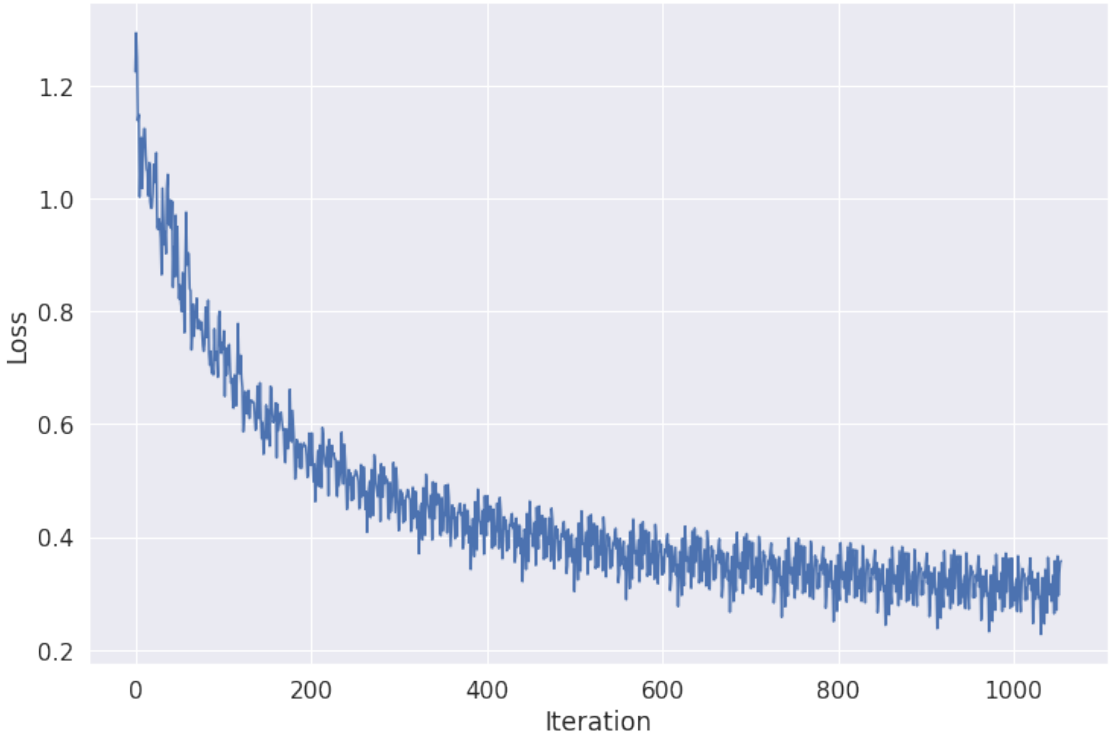
```
Iteration: 0
Batch accuracy: 62.0
Iteration: 100
Batch accuracy: 70.0
Iteration: 200
Batch accuracy: 59.0
Iteration: 300
Batch accuracy: 74.0
Iteration: 400
Batch accuracy: 61.0
Iteration: 500
Batch accuracy: 63.0
Iteration: 600
Batch accuracy: 52.0
Iteration: 700
Batch accuracy: 66.0
Iteration: 800
Batch accuracy: 68.0
Iteration: 900
Batch accuracy: 69.0
Iteration: 1000
Batch accuracy: 76.0

Iteration: 1054.Convergence. Stopping iterations.
```

2. , ?

: 519

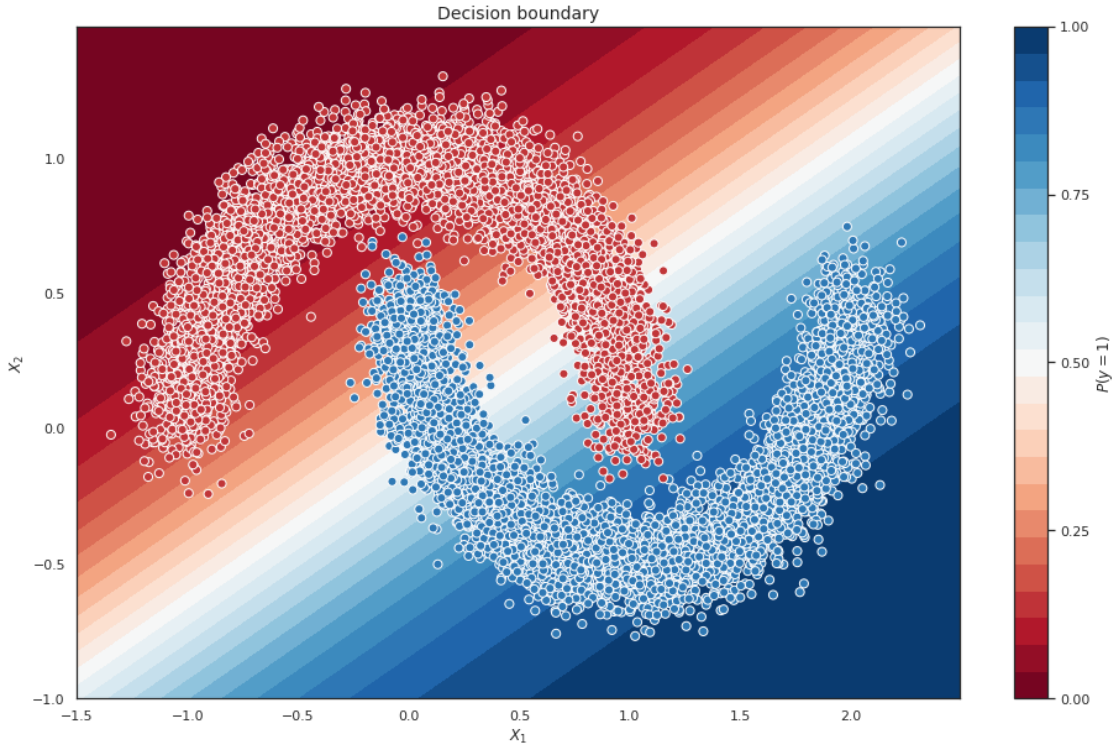
1.1.4

[12]:
```
plt.figure(figsize=(12, 8))
plt.plot(range(len(losses)), losses)
plt.xlabel("Iteration")
plt.ylabel("Loss")
plt.show()
```



[13]:
```
import numpy as np

sns.set(style="white")

xx, yy = np.mgrid[-1.5:2.5:.01, -1.:1.5:.01]
grid = np.c_[xx.ravel(), yy.ravel()]
batch = torch.from_numpy(grid).type(torch.float32)
with torch.no_grad():
    probs = torch.sigmoid(linear_regression(batch).reshape(xx.shape))
    probs = probs.numpy().reshape(xx.shape)
```

```
f, ax = plt.subplots(figsize=(16, 10))
ax.set_title("Decision boundary", fontsize=14)
contour = ax.contourf(xx, yy, probs, 25, cmap="RdBu",
                      vmin=0, vmax=1)
ax_c = f.colorbar(contour)
ax_c.set_label("$P(y = 1)$")
ax_c.set_ticks([0, .25, .5, .75, 1])

ax.scatter(X[100:,0], X[100:, 1], c=y[100:], s=50,
           cmap="RdBu", vmin=-.2, vmax=1.2,
           edgecolor="white", linewidth=1)

ax.set(xlabel="$X_1$", ylabel="$X_2$")
plt.show()
```



1.1.5 . predict accuracy test.

[14]:
```
@torch.no_grad()
def predict(dataloader, model):
    model.eval()
    predictions = np.array([])
    for x_batch, _ in dataloader:
```

```
        outp = model.forward(x_batch) #YOUR CODE. Compute predictions
        probabilities = torch.exp(outp) / torch.exp(outp).sum(dim=1,␣
↪keepdims=True)
        preds = (probabilities > 0.5).type(torch.long)
        predictions = np.hstack((predictions, preds.numpy().flatten()))
    return predictions.flatten()
```

[15]:
```
from sklearn.metrics import accuracy_score
predictions = predict(val_dataloader, linear_regression) # YOUR CODE. Compute␣
↪total accuracy
accuracy_score(y_val_t, predictions)
```

[15]:
```
0.4912
```

3

accuracy ?

: 0.4912

2 2. MNIST

MNIST . DataLoader- .

.

[16]:
```
import os
from torchvision.datasets import MNIST
import torchvision.transforms as tfs

data_tfs = tfs.Compose([
    tfs.ToTensor(),
    tfs.Normalize((0.5), (0.5))
])

# install for train and test
root = './'

train_dataset = MNIST(root, train=True,  transform=data_tfs, download=True)
val_dataset  = MNIST(root, train=False, transform=data_tfs, download=True)

train_dataloader = DataLoader(train_dataset, batch_size=128) # YOUR CODE GOES␣
↪HERE
valid_dataloader =  DataLoader(val_dataset, batch_size=128) # YOUR CODE GOES␣
↪HERE
```

2.1 2.1.

MNIST .

[17]:
```
class Identical(nn.Module):
    def forward(self, x):
        return x
```

2.1.1 .

Sequential. : * (nn.Flatten); * 128 nn.ELU; * 10 .

(-).

[18]:
```
activation = nn.ELU
```

[19]:
```
model = nn.Sequential(
    nn.Flatten(), #
    nn.Linear(784, 128),
    activation(),
    nn.Linear(128, 128),
    activation(),
    nn.Linear(128, 10) #YOUR CODE. Add layers to your sequential class
)
```

[20]:
```
criterion = nn.CrossEntropyLoss() #YOUR CODE. Select a loss function
optimizer = torch.optim.Adam(model.parameters())

loaders = {"train": train_dataloader, "valid": valid_dataloader}
```

2.1.2 Train loop (seriously)

, 90% .

```
for epoch in range(max_epochs):  # <---------------
    for k, dataloader in loaders.items():  # <-----       dataloader    train / valid / test
        for x_batch, y_batch in dataloader:  # <---                .                SGD     GD,
            if k == "train":
                model.train()  # <------------------                train
                optimizer.zero_grad()  # <---------
                outp = model(x_batch)
                loss = criterion(outp, y_batch) # <-     "   "
                loss.backward()  # <---------------
                optimizer.step()  # <--------------
            else:  # <---------------------------- test/eval
                model.eval()  # <------------------                eval
```

```
                with torch.no_grad():  # <---------
                    outp = model(x_batch)  # <-------------       "    "
                count_metrics(outp, y_batch)  # <--------------
```

2.1.3 . .

[21]:
```
model.to(device)
summary(model, (784,), batch_size=128)
```

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
           Flatten-1                  [128, 784]               0
            Linear-2                  [128, 128]         100,480
               ELU-3                  [128, 128]               0
            Linear-4                  [128, 128]          16,512
               ELU-5                  [128, 128]               0
            Linear-6                   [128, 10]           1,290
================================================================
Total params: 118,282
Trainable params: 118,282
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.38
Forward/backward pass size (MB): 1.28
Params size (MB): 0.45
Estimated Total Size (MB): 2.11
----------------------------------------------------------------
```

[22]:
```
max_epochs = 10
accuracy = {"train": [], "valid": []}
for epoch in range(max_epochs):
    for k, dataloader in loaders.items():
        epoch_correct = 0
        epoch_all = 0
        for x_batch, y_batch in dataloader:
            if k == "train":
                model.train()
                optimizer.zero_grad()
                outp = model(x_batch.to(device))
                loss = criterion(outp, y_batch.to(device))
                loss.backward()
                optimizer.step()
            else:
                model.eval()
                with torch.no_grad():
                    outp = model(x_batch.to(device))
```

```
            preds = outp.argmax(-1)
            correct = (preds.cpu().detach() == y_batch).sum()
            all = len(y_batch)
            epoch_correct += correct.item()
            epoch_all += all
        if k == "train":
            print(f"Epoch: {epoch+1}")
        print(f"Loader: {k}. Accuracy: {epoch_correct/epoch_all}")
        accuracy[k].append(epoch_correct/epoch_all)
```

```
Epoch: 1
Loader: train. Accuracy: 0.8824333333333333
Loader: valid. Accuracy: 0.9258
Epoch: 2
Loader: train. Accuracy: 0.9426166666666667
Loader: valid. Accuracy: 0.9504
Epoch: 3
Loader: train. Accuracy: 0.9599666666666666
Loader: valid. Accuracy: 0.9529
Epoch: 4
Loader: train. Accuracy: 0.9681833333333333
Loader: valid. Accuracy: 0.9564
Epoch: 5
Loader: train. Accuracy: 0.9737166666666667
Loader: valid. Accuracy: 0.9625
Epoch: 6
Loader: train. Accuracy: 0.9785166666666667
Loader: valid. Accuracy: 0.9698
Epoch: 7
Loader: train. Accuracy: 0.9817333333333333
Loader: valid. Accuracy: 0.9739
Epoch: 8
Loader: train. Accuracy: 0.98385
Loader: valid. Accuracy: 0.9743
Epoch: 9
Loader: train. Accuracy: 0.9853833333333334
Loader: valid. Accuracy: 0.9714
Epoch: 10
Loader: train. Accuracy: 0.9866666666666667
Loader: valid. Accuracy: 0.9579
```

2.1.4 . .

. validation accuracy.

, accuracies.

[23]:
```
elu_accuracy = accuracy["valid"]
```

[24]:
```
# YOUR CODE. Do the same thing with other activations (it's better to wrap into␣
↪a function that returns a list of accuracies)
def test_activation_function(activation):
    model = nn.Sequential(
        nn.Flatten(), #
        nn.Linear(784, 128),
        activation(),
        nn.Linear(128, 128),
        activation(),
        nn.Linear(128, 10) #YOUR CODE. Add layers to your sequential class
    )
    model.to(device) #      GPU
    criterion = nn.CrossEntropyLoss() #YOUR CODE. Select a loss function
    optimizer = torch.optim.Adam(model.parameters())
    # loaders = {"train": train_dataloader, "valid": valid_dataloader}
    max_epochs = 10
    accuracy = {"train": [], "valid": []}
    for epoch in range(max_epochs):
        for k, dataloader in loaders.items():
            epoch_correct = 0
            epoch_all = 0
            for x_batch, y_batch in dataloader:
                if k == "train":
                    model.train() #
                    optimizer.zero_grad()
                    outp = model(x_batch.to(device)) #input   output        GPU
                    loss = criterion(outp, y_batch.to(device)) #      GPU   ␣
↪       output
                    loss.backward()
                    optimizer.step()
                else:
                    model.eval() #
                    with torch.no_grad():
                        outp = model(x_batch.to(device))
                preds = outp.argmax(-1)
                correct = (preds.cpu().detach() == y_batch).sum()
                all = len(y_batch)
                epoch_correct += correct.item()
                epoch_all += all
            if k == "train":
                print(f"Epoch: {epoch+1}")
            print(f"Loader: {k}. Accuracy: {epoch_correct/epoch_all}")
            accuracy[k].append(epoch_correct/epoch_all)
    return accuracy
```

[25]:
```
plain_accuracy = test_activation_function(Identical)
relu_accuracy = test_activation_function(nn.ReLU)
```

```
leaky_relu_accuracy = test_activation_function(nn.LeakyReLU)
```

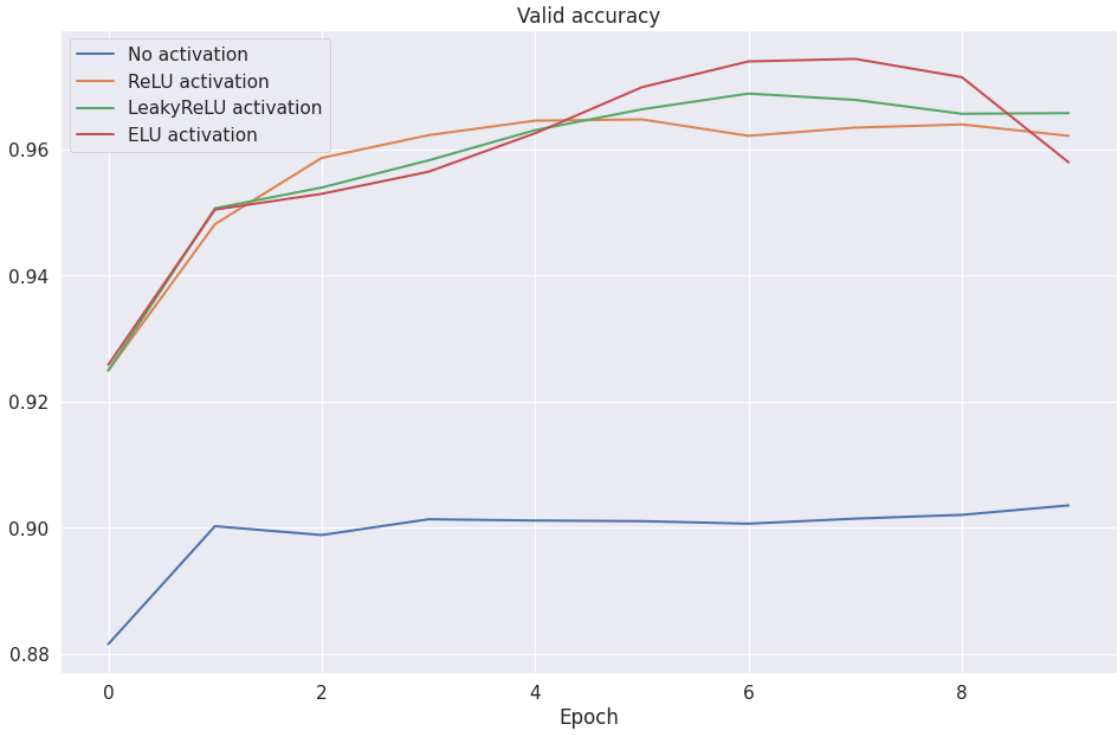
```
Epoch: 1
Loader: train. Accuracy: 0.8654
Loader: valid. Accuracy: 0.8815
Epoch: 2
Loader: train. Accuracy: 0.89655
Loader: valid. Accuracy: 0.9002
Epoch: 3
Loader: train. Accuracy: 0.9003
Loader: valid. Accuracy: 0.8988
Epoch: 4
Loader: train. Accuracy: 0.9023833333333333
Loader: valid. Accuracy: 0.9013
Epoch: 5
Loader: train. Accuracy: 0.90405
Loader: valid. Accuracy: 0.9011
Epoch: 6
Loader: train. Accuracy: 0.9052
Loader: valid. Accuracy: 0.901
Epoch: 7
Loader: train. Accuracy: 0.9066166666666666
Loader: valid. Accuracy: 0.9006
Epoch: 8
Loader: train. Accuracy: 0.9082
Loader: valid. Accuracy: 0.9014
Epoch: 9
Loader: train. Accuracy: 0.9086666666666666
Loader: valid. Accuracy: 0.902
Epoch: 10
Loader: train. Accuracy: 0.9098333333333334
Loader: valid. Accuracy: 0.9035
Epoch: 1
Loader: train. Accuracy: 0.8688666666666667
Loader: valid. Accuracy: 0.9249
Epoch: 2
Loader: train. Accuracy: 0.9339666666666666
Loader: valid. Accuracy: 0.9481
Epoch: 3
Loader: train. Accuracy: 0.9511833333333334
Loader: valid. Accuracy: 0.9586
Epoch: 4
Loader: train. Accuracy: 0.9613833333333334
Loader: valid. Accuracy: 0.9622
Epoch: 5
Loader: train. Accuracy: 0.9685666666666667
Loader: valid. Accuracy: 0.9645
```

```
Epoch: 6
Loader: train. Accuracy: 0.9734666666666667
Loader: valid. Accuracy: 0.9647
Epoch: 7
Loader: train. Accuracy: 0.9772166666666666
Loader: valid. Accuracy: 0.9621
Epoch: 8
Loader: train. Accuracy: 0.9803
Loader: valid. Accuracy: 0.9634
Epoch: 9
Loader: train. Accuracy: 0.9818833333333333
Loader: valid. Accuracy: 0.9639
Epoch: 10
Loader: train. Accuracy: 0.9837833333333333
Loader: valid. Accuracy: 0.9621
Epoch: 1
Loader: train. Accuracy: 0.8688
Loader: valid. Accuracy: 0.9249
Epoch: 2
Loader: train. Accuracy: 0.9376
Loader: valid. Accuracy: 0.9506
Epoch: 3
Loader: train. Accuracy: 0.9549333333333333
Loader: valid. Accuracy: 0.9539
Epoch: 4
Loader: train. Accuracy: 0.9634333333333334
Loader: valid. Accuracy: 0.9582
Epoch: 5
Loader: train. Accuracy: 0.96975
Loader: valid. Accuracy: 0.963
Epoch: 6
Loader: train. Accuracy: 0.9745833333333334
Loader: valid. Accuracy: 0.9663
Epoch: 7
Loader: train. Accuracy: 0.97735
Loader: valid. Accuracy: 0.9688
Epoch: 8
Loader: train. Accuracy: 0.97995
Loader: valid. Accuracy: 0.9678
Epoch: 9
Loader: train. Accuracy: 0.98145
Loader: valid. Accuracy: 0.9656
Epoch: 10
Loader: train. Accuracy: 0.9830666666666666
Loader: valid. Accuracy: 0.9657
```

2.1.5 Accuracy

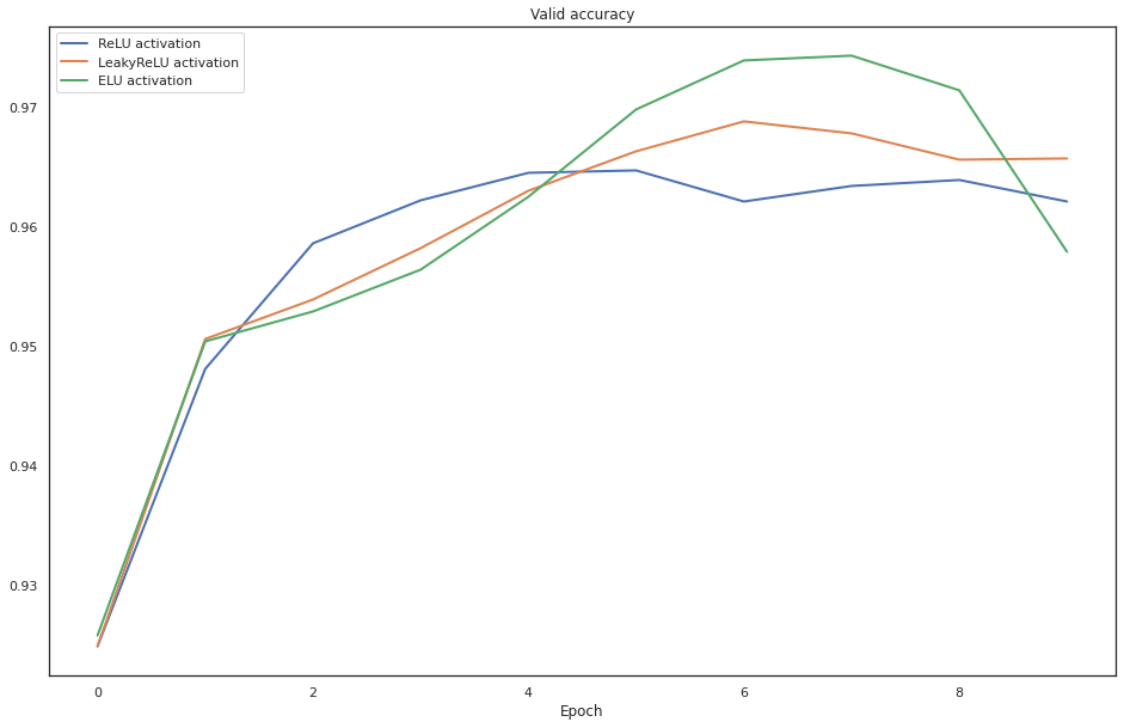
accuracy/epoch .

[26]:
```
sns.set(style="darkgrid", font_scale=1.4)

plt.figure(figsize=(16, 10))
plt.title("Valid accuracy")
plt.plot(range(max_epochs), plain_accuracy['valid'], label="No activation",␣
 ↪linewidth=2)
plt.plot(range(max_epochs), relu_accuracy['valid'], label="ReLU activation",␣
 ↪linewidth=2)
plt.plot(range(max_epochs), leaky_relu_accuracy['valid'], label="LeakyReLU␣
 ↪activation", linewidth=2)
plt.plot(range(max_epochs), elu_accuracy, label="ELU activation", linewidth=2)
plt.legend()
plt.xlabel("Epoch")
plt.show()
```



[39]:
```
plt.figure(figsize=(16, 10))
plt.title("Valid accuracy")
plt.plot(range(max_epochs), relu_accuracy['valid'], label="ReLU activation",␣
 ↪linewidth=2)
```

```
plt.plot(range(max_epochs), leaky_relu_accuracy['valid'], label="LeakyReLU␣
↪activation", linewidth=2)
plt.plot(range(max_epochs), elu_accuracy, label="ELU activation", linewidth=2)
plt.legend()
plt.xlabel("Epoch")
plt.show()
```



4. accuracy ?

: nn.ReLU

2.2 2.2

2.2.1

.

[28]:
```
!wget https://img.the-village.kz/the-village.com.kz/post-cover/
↪5x5-I6oiwjmq79dMCZMEbA-default.jpg -O sample_photo.jpg
```

```
--2022-04-28 08:58:51--  https://img.the-village.kz/the-village.com.kz/post-
cover/5x5-I6oiwjmq79dMCZMEbA-default.jpg
Resolving img.the-village.kz (img.the-village.kz)… 144.76.208.75
Connecting to img.the-village.kz (img.the-village.kz)|144.76.208.75|:443…
```

```
connected.
HTTP request sent, awaiting response… 301 Moved Permanently
Location: https://img.the-village-kz.com/the-village.com.kz/post-
cover/5x5-I6oiwjmq79dMCZMEbA-default.jpg [following]
--2022-04-28 08:58:52--  https://img.the-village-kz.com/the-village.com.kz/post-
cover/5x5-I6oiwjmq79dMCZMEbA-default.jpg
Resolving img.the-village-kz.com (img.the-village-kz.com)… 144.76.208.75
Connecting to img.the-village-kz.com (img.the-village-
kz.com)|144.76.208.75|:443… connected.
HTTP request sent, awaiting response… 200 OK
Length: 49337 (48K) [image/jpeg]
Saving to: ‘sample_photo.jpg’

sample_photo.jpg    100%[===================>]  48.18K   219KB/s    in 0.2s

2022-04-28 08:58:52 (219 KB/s) - ‘sample_photo.jpg’ saved [49337/49337]
```

[29]:
```
import cv2
sns.set(style="white")
img = cv2.imread("sample_photo.jpg")
RGB_img = cv2.cvtColor(img, cv2.COLOR_BGR2RGB)
plt.figure(figsize=(12, 8))
plt.imshow(RGB_img)
plt.show()
```

. , A)

```
[0, 0, 0],
[0, 1, 0],
[0, 0, 0]
```

)

```
[0, 1, 0],
[0, -2, 0],
[0, 1, 0]
```

)

```
[0, 0, 0],
[1, -2, 1],
[0, 0, 0]
```

)

```
[0, 1, 0],
[1, -4, 1],
[0, 1, 0]
```

)

```
[0, -1, 0],
[-1, 5, -1],
[0, -1, 0]
```

)

```
[0.0625, 0.125, 0.0625],
[0.125, 0.25, 0.125],
[0.0625, 0.125, 0.0625]
```

!

[30]:
```
img_t = torch.from_numpy(RGB_img).type(torch.float32).unsqueeze(0)
kernel = torch.tensor([
    [0, 0, 0],
[1, -2, 1],
[0, 0, 0]
]).reshape(1, 1, 3, 3).type(torch.float32)

kernel = kernel.repeat(3, 3, 1, 1)
img_t = img_t.permute(0, 3, 1, 2)  # [BS, H, W, C] -> [BS, C, H, W]
img_t = nn.ReflectionPad2d(1)(img_t)  # Pad Image for same output size

result = F.conv2d(img_t, kernel)[0]  #
```

[31]:
```
plt.figure(figsize=(12, 8))
result_np = result.permute(1, 2, 0).numpy() / 256 / 3

plt.imshow(result_np)
plt.show()
```

```
Clipping input data to the valid range for imshow with RGB data ([0..1] for
floats or [0..255] for integers).
```

5. , ? .

1)

2)

3)

4)

5)

6)

: 3, 5, 4, 6, 2, 1

2.2.2 . LeNet

, . LeNet, 1998 ! (Sequential).

* 3x3 (1 , 6) ReLU; * MaxPooling- 2x2; * 3x3 (6 , 16) ReLU; * MaxPooling- 2x2; * (nn.Flatten); * 120 ReLU; * 84 ReLU; * 10 .

[32]:
```
class LeNet(nn.Module):
    def __init__(self):
        super(LeNet, self).__init__()
        # 1 input image channel, 6 output channels, 3x3 square conv kernel
        self.conv1 = nn.Conv2d(1, 6, 3)
        self.pool = nn.MaxPool2d(kernel_size=2, stride=2)
        self.conv2 = nn.Conv2d(6, 16, 3)
        self.fc1 = nn.Linear(5 * 5 * 16, 120)
        self.fc2 = nn.Linear(120, 84)
        self.fc3 = nn.Linear(84, 10)

    def forward(self, x):
        x = self.pool(F.relu(self.conv1(x)))
        x = self.pool(F.relu(self.conv2(x)))
        # print(x.shape)    flatten                                    5*5*16
        x = x.view(-1, 5 * 5 * 16)
        x = F.relu(self.fc1(x))
        x = F.relu(self.fc2(x))
        x = self.fc3(x)

        return x
```

[33]:
```
model = LeNet().to(device)

criterion = nn.CrossEntropyLoss()
optimizer = torch.optim.Adam(model.parameters())

loaders = {"train": train_dataloader, "valid": valid_dataloader}
```

2.2.3 . CNN

, .

[34]:
```
max_epochs = 10
accuracy = {"train": [], "valid": []}
for epoch in range(max_epochs):
    for k, dataloader in loaders.items():
```

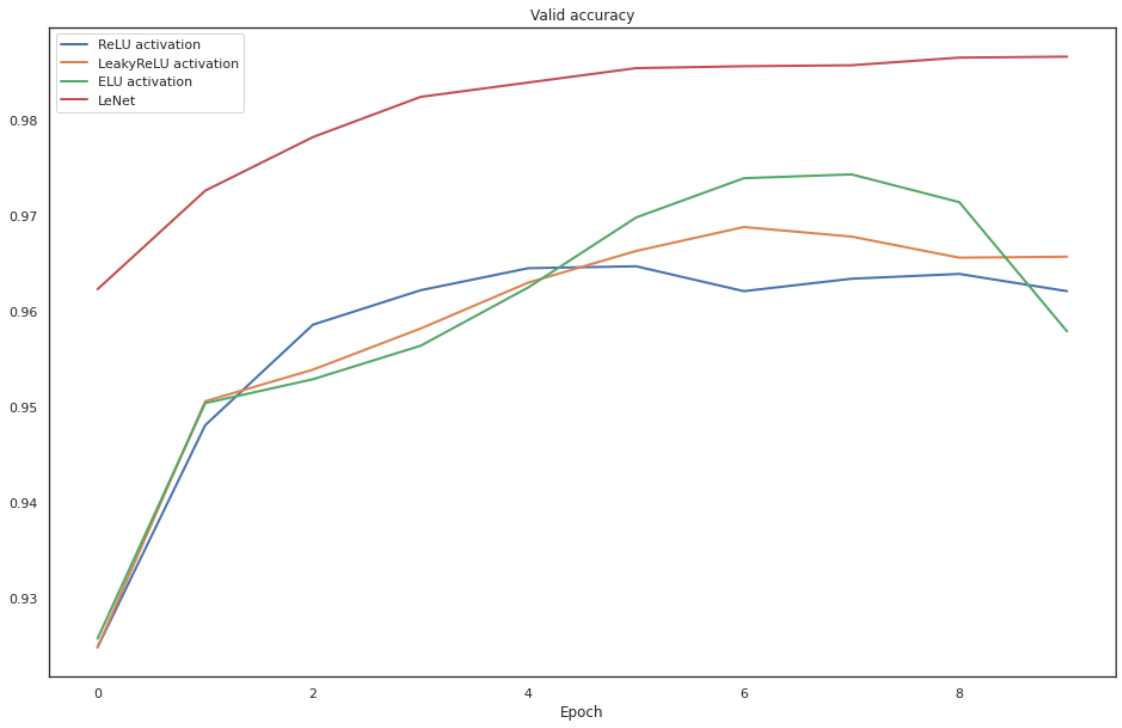
```
        epoch_correct = 0
        epoch_all = 0
        for x_batch, y_batch in dataloader:
            if k == "train":
                model.train()
                optimizer.zero_grad()
                outp = model(x_batch.to(device))
                loss = criterion(outp, y_batch.to(device))
                loss.backward()
                optimizer.step()
            else:
                model.eval()
                with torch.no_grad():
                    outp = model(x_batch.to(device))
            preds = outp.argmax(-1)
            correct = (preds.cpu().detach() == y_batch).sum()
            all = len(y_batch)
            epoch_correct += correct.item()
            epoch_all += all
        if k == "train":
            print(f"Epoch: {epoch+1}")
        print(f"Loader: {k}. Accuracy: {epoch_correct/epoch_all}")
        accuracy[k].append(epoch_correct/epoch_all)
```

```
Epoch: 1
Loader: train. Accuracy: 0.8760166666666667
Loader: valid. Accuracy: 0.9623
Epoch: 2
Loader: train. Accuracy: 0.9664
Loader: valid. Accuracy: 0.9726
Epoch: 3
Loader: train. Accuracy: 0.9773
Loader: valid. Accuracy: 0.9782
Epoch: 4
Loader: train. Accuracy: 0.9825
Loader: valid. Accuracy: 0.9824
Epoch: 5
Loader: train. Accuracy: 0.9854833333333334
Loader: valid. Accuracy: 0.9839
Epoch: 6
Loader: train. Accuracy: 0.9878666666666667
Loader: valid. Accuracy: 0.9854
Epoch: 7
Loader: train. Accuracy: 0.9897666666666667
Loader: valid. Accuracy: 0.9856
Epoch: 8
Loader: train. Accuracy: 0.9913333333333333
```

```
Loader: valid. Accuracy: 0.9857
Epoch: 9
Loader: train. Accuracy: 0.9924333333333333
Loader: valid. Accuracy: 0.9865
Epoch: 10
Loader: train. Accuracy: 0.9936666666666667
Loader: valid. Accuracy: 0.9866
```

[35]:
```
lenet_accuracy = accuracy["valid"]
```

[44]:
```
plt.figure(figsize=(16, 10))
plt.title("Valid accuracy")
plt.plot(range(max_epochs), relu_accuracy['valid'], label="ReLU activation",␣
 ↪linewidth=2)
plt.plot(range(max_epochs), leaky_relu_accuracy['valid'], label="LeakyReLU␣
 ↪activation", linewidth=2)
plt.plot(range(max_epochs), elu_accuracy, label="ELU activation", linewidth=2)
plt.plot(range(max_epochs), lenet_accuracy, label="LeNet", linewidth=2)
plt.legend()
plt.xlabel("Epoch")
plt.show()
```



6 accuracy ?

: 0.99

[45]:
```
!apt-get install texlive texlive-xetex texlive-latex-extra pandoc
!pip install pypandoc
```

```
Reading package lists… Done
Building dependency tree
Reading state information… Done
pandoc is already the newest version (1.19.2.4~dfsg-1build4).
pandoc set to manually installed.
The following additional packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcupsfilters1 libcupsimage2 libgs9 libgs9-common
  libijs-0.35 libjbig2dec0 libjs-jquery libkpathsea6 libpotrace0 libptexenc1
  libruby2.5 libsynctex1 libtexlua52 libtexluajit2 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-did-you-mean ruby-minitest
  ruby-net-telnet ruby-power-assert ruby-test-unit ruby2.5
  rubygems-integration t1utils tex-common tex-gyre texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-recommended texlive-pictures texlive-plain-generic tipa
Suggested packages:
  fonts-noto apache2 | lighttpd | httpd poppler-utils ghostscript
  fonts-japanese-mincho | fonts-ipafont-mincho fonts-japanese-gothic
  | fonts-ipafont-gothic fonts-arphic-ukai fonts-arphic-uming fonts-nanum ri
  ruby-dev bundler debhelper gv | postscript-viewer perl-tk xpdf-reader
  | pdf-viewer texlive-fonts-recommended-doc texlive-latex-base-doc
  python-pygments icc-profiles libfile-which-perl
  libspreadsheet-parseexcel-perl texlive-latex-extra-doc
  texlive-latex-recommended-doc texlive-pstricks dot2tex prerex ruby-tcltk
  | libtcltk-ruby texlive-pictures-doc vprerex
The following NEW packages will be installed:
  fonts-droid-fallback fonts-lato fonts-lmodern fonts-noto-mono fonts-texgyre
  javascript-common libcupsfilters1 libcupsimage2 libgs9 libgs9-common
  libijs-0.35 libjbig2dec0 libjs-jquery libkpathsea6 libpotrace0 libptexenc1
  libruby2.5 libsynctex1 libtexlua52 libtexluajit2 libzzip-0-13 lmodern
  poppler-data preview-latex-style rake ruby ruby-did-you-mean ruby-minitest
  ruby-net-telnet ruby-power-assert ruby-test-unit ruby2.5
  rubygems-integration t1utils tex-common tex-gyre texlive texlive-base
  texlive-binaries texlive-fonts-recommended texlive-latex-base
  texlive-latex-extra texlive-latex-recommended texlive-pictures
  texlive-plain-generic texlive-xetex tipa
0 upgraded, 47 newly installed, 0 to remove and 41 not upgraded.
Need to get 146 MB of archives.
After this operation, 460 MB of additional disk space will be used.
Get:1 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-droid-fallback
all 1:6.0.1r16-1.1 [1,805 kB]
Get:2 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-lato all 2.0-2
[2,698 kB]
```

```
Get:3 http://archive.ubuntu.com/ubuntu bionic/main amd64 poppler-data all
0.4.8-2 [1,479 kB]
Get:4 http://archive.ubuntu.com/ubuntu bionic/main amd64 tex-common all 6.09
[33.0 kB]
Get:5 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-lmodern all
2.004.5-3 [4,551 kB]
Get:6 http://archive.ubuntu.com/ubuntu bionic/main amd64 fonts-noto-mono all
20171026-2 [75.5 kB]
Get:7 http://archive.ubuntu.com/ubuntu bionic/universe amd64 fonts-texgyre all
20160520-1 [8,761 kB]
Get:8 http://archive.ubuntu.com/ubuntu bionic/main amd64 javascript-common all
11 [6,066 B]
Get:9 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsfilters1
amd64 1.20.2-0ubuntu3.1 [108 kB]
Get:10 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libcupsimage2
amd64 2.2.7-1ubuntu2.8 [18.6 kB]
Get:11 http://archive.ubuntu.com/ubuntu bionic/main amd64 libijs-0.35 amd64
0.35-13 [15.5 kB]
Get:12 http://archive.ubuntu.com/ubuntu bionic/main amd64 libjbig2dec0 amd64
0.13-6 [55.9 kB]
Get:13 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9-common
all 9.26~dfsg+0-0ubuntu0.18.04.15 [5,092 kB]
Get:14 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libgs9 amd64
9.26~dfsg+0-0ubuntu0.18.04.15 [2,265 kB]
Get:15 http://archive.ubuntu.com/ubuntu bionic/main amd64 libjs-jquery all
3.2.1-1 [152 kB]
Get:16 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libkpathsea6
amd64 2017.20170613.44572-8ubuntu0.1 [54.9 kB]
Get:17 http://archive.ubuntu.com/ubuntu bionic/main amd64 libpotrace0 amd64
1.14-2 [17.4 kB]
Get:18 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libptexenc1
amd64 2017.20170613.44572-8ubuntu0.1 [34.5 kB]
Get:19 http://archive.ubuntu.com/ubuntu bionic/main amd64 rubygems-integration
all 1.11 [4,994 B]
Get:20 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 ruby2.5 amd64
2.5.1-1ubuntu1.11 [48.6 kB]
Get:21 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby amd64 1:2.5.1
[5,712 B]
Get:22 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 rake all
12.3.1-1ubuntu0.1 [44.9 kB]
Get:23 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-did-you-mean all
1.2.0-2 [9,700 B]
Get:24 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-minitest all
5.10.3-1 [38.6 kB]
Get:25 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-net-telnet all
0.1.1-2 [12.6 kB]
Get:26 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-power-assert all
0.3.0-1 [7,952 B]
```

```
Get:27 http://archive.ubuntu.com/ubuntu bionic/main amd64 ruby-test-unit all
3.2.5-1 [61.1 kB]
Get:28 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libruby2.5
amd64 2.5.1-1ubuntu1.11 [3,072 kB]
Get:29 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libsynctex1
amd64 2017.20170613.44572-8ubuntu0.1 [41.4 kB]
Get:30 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtexlua52
amd64 2017.20170613.44572-8ubuntu0.1 [91.2 kB]
Get:31 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libtexluajit2
amd64 2017.20170613.44572-8ubuntu0.1 [230 kB]
Get:32 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 libzzip-0-13
amd64 0.13.62-3.1ubuntu0.18.04.1 [26.0 kB]
Get:33 http://archive.ubuntu.com/ubuntu bionic/main amd64 lmodern all 2.004.5-3
[9,631 kB]
Get:34 http://archive.ubuntu.com/ubuntu bionic/main amd64 preview-latex-style
all 11.91-1ubuntu1 [185 kB]
Get:35 http://archive.ubuntu.com/ubuntu bionic/main amd64 t1utils amd64 1.41-2
[56.0 kB]
Get:36 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tex-gyre all
20160520-1 [4,998 kB]
Get:37 http://archive.ubuntu.com/ubuntu bionic-updates/main amd64 texlive-
binaries amd64 2017.20170613.44572-8ubuntu0.1 [8,179 kB]
Get:38 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-base all
2017.20180305-1 [18.7 MB]
Get:39 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-fonts-
recommended all 2017.20180305-1 [5,262 kB]
Get:40 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-base all
2017.20180305-1 [951 kB]
Get:41 http://archive.ubuntu.com/ubuntu bionic/main amd64 texlive-latex-
recommended all 2017.20180305-1 [14.9 MB]
Get:42 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive all
2017.20180305-1 [14.4 kB]
Get:43 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-pictures
all 2017.20180305-1 [4,026 kB]
Get:44 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-latex-
extra all 2017.20180305-2 [10.6 MB]
Get:45 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-plain-
generic all 2017.20180305-2 [23.6 MB]
Get:46 http://archive.ubuntu.com/ubuntu bionic/universe amd64 tipa all 2:1.3-20
[2,978 kB]
Get:47 http://archive.ubuntu.com/ubuntu bionic/universe amd64 texlive-xetex all
2017.20180305-1 [10.7 MB]
Fetched 146 MB in 3s (55.8 MB/s)
Extracting templates from packages: 100%
Preconfiguring packages …
Selecting previously unselected package fonts-droid-fallback.
(Reading database … 155514 files and directories currently installed.)
Preparing to unpack …/00-fonts-droid-fallback_1%3a6.0.1r16-1.1_all.deb …
```

```
Unpacking fonts-droid-fallback (1:6.0.1r16-1.1) …
Selecting previously unselected package fonts-lato.
Preparing to unpack …/01-fonts-lato_2.0-2_all.deb …
Unpacking fonts-lato (2.0-2) …
Selecting previously unselected package poppler-data.
Preparing to unpack …/02-poppler-data_0.4.8-2_all.deb …
Unpacking poppler-data (0.4.8-2) …
Selecting previously unselected package tex-common.
Preparing to unpack …/03-tex-common_6.09_all.deb …
Unpacking tex-common (6.09) …
Selecting previously unselected package fonts-lmodern.
Preparing to unpack …/04-fonts-lmodern_2.004.5-3_all.deb …
Unpacking fonts-lmodern (2.004.5-3) …
Selecting previously unselected package fonts-noto-mono.
Preparing to unpack …/05-fonts-noto-mono_20171026-2_all.deb …
Unpacking fonts-noto-mono (20171026-2) …
Selecting previously unselected package fonts-texgyre.
Preparing to unpack …/06-fonts-texgyre_20160520-1_all.deb …
Unpacking fonts-texgyre (20160520-1) …
Selecting previously unselected package javascript-common.
Preparing to unpack …/07-javascript-common_11_all.deb …
Unpacking javascript-common (11) …
Selecting previously unselected package libcupsfilters1:amd64.
Preparing to unpack …/08-libcupsfilters1_1.20.2-0ubuntu3.1_amd64.deb …
Unpacking libcupsfilters1:amd64 (1.20.2-0ubuntu3.1) …
Selecting previously unselected package libcupsimage2:amd64.
Preparing to unpack …/09-libcupsimage2_2.2.7-1ubuntu2.8_amd64.deb …
Unpacking libcupsimage2:amd64 (2.2.7-1ubuntu2.8) …
Selecting previously unselected package libijs-0.35:amd64.
Preparing to unpack …/10-libijs-0.35_0.35-13_amd64.deb …
Unpacking libijs-0.35:amd64 (0.35-13) …
Selecting previously unselected package libjbig2dec0:amd64.
Preparing to unpack …/11-libjbig2dec0_0.13-6_amd64.deb …
Unpacking libjbig2dec0:amd64 (0.13-6) …
Selecting previously unselected package libgs9-common.
Preparing to unpack …/12-libgs9-common_9.26~dfsg+0-0ubuntu0.18.04.15_all.deb
…
Unpacking libgs9-common (9.26~dfsg+0-0ubuntu0.18.04.15) …
Selecting previously unselected package libgs9:amd64.
Preparing to unpack …/13-libgs9_9.26~dfsg+0-0ubuntu0.18.04.15_amd64.deb …
Unpacking libgs9:amd64 (9.26~dfsg+0-0ubuntu0.18.04.15) …
Selecting previously unselected package libjs-jquery.
Preparing to unpack …/14-libjs-jquery_3.2.1-1_all.deb …
Unpacking libjs-jquery (3.2.1-1) …
Selecting previously unselected package libkpathsea6:amd64.
Preparing to unpack …/15-libkpathsea6_2017.20170613.44572-8ubuntu0.1_amd64.deb
…
Unpacking libkpathsea6:amd64 (2017.20170613.44572-8ubuntu0.1) …
```

```
Selecting previously unselected package libpotrace0.
Preparing to unpack …/16-libpotrace0_1.14-2_amd64.deb …
Unpacking libpotrace0 (1.14-2) …
Selecting previously unselected package libptexenc1:amd64.
Preparing to unpack …/17-libptexenc1_2017.20170613.44572-8ubuntu0.1_amd64.deb
…
Unpacking libptexenc1:amd64 (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package rubygems-integration.
Preparing to unpack …/18-rubygems-integration_1.11_all.deb …
Unpacking rubygems-integration (1.11) …
Selecting previously unselected package ruby2.5.
Preparing to unpack …/19-ruby2.5_2.5.1-1ubuntu1.11_amd64.deb …
Unpacking ruby2.5 (2.5.1-1ubuntu1.11) …
Selecting previously unselected package ruby.
Preparing to unpack …/20-ruby_1%3a2.5.1_amd64.deb …
Unpacking ruby (1:2.5.1) …
Selecting previously unselected package rake.
Preparing to unpack …/21-rake_12.3.1-1ubuntu0.1_all.deb …
Unpacking rake (12.3.1-1ubuntu0.1) …
Selecting previously unselected package ruby-did-you-mean.
Preparing to unpack …/22-ruby-did-you-mean_1.2.0-2_all.deb …
Unpacking ruby-did-you-mean (1.2.0-2) …
Selecting previously unselected package ruby-minitest.
Preparing to unpack …/23-ruby-minitest_5.10.3-1_all.deb …
Unpacking ruby-minitest (5.10.3-1) …
Selecting previously unselected package ruby-net-telnet.
Preparing to unpack …/24-ruby-net-telnet_0.1.1-2_all.deb …
Unpacking ruby-net-telnet (0.1.1-2) …
Selecting previously unselected package ruby-power-assert.
Preparing to unpack …/25-ruby-power-assert_0.3.0-1_all.deb …
Unpacking ruby-power-assert (0.3.0-1) …
Selecting previously unselected package ruby-test-unit.
Preparing to unpack …/26-ruby-test-unit_3.2.5-1_all.deb …
Unpacking ruby-test-unit (3.2.5-1) …
Selecting previously unselected package libruby2.5:amd64.
Preparing to unpack …/27-libruby2.5_2.5.1-1ubuntu1.11_amd64.deb …
Unpacking libruby2.5:amd64 (2.5.1-1ubuntu1.11) …
Selecting previously unselected package libsynctex1:amd64.
Preparing to unpack …/28-libsynctex1_2017.20170613.44572-8ubuntu0.1_amd64.deb
…
Unpacking libsynctex1:amd64 (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package libtexlua52:amd64.
Preparing to unpack …/29-libtexlua52_2017.20170613.44572-8ubuntu0.1_amd64.deb
…
Unpacking libtexlua52:amd64 (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package libtexluajit2:amd64.
Preparing to unpack
…/30-libtexluajit2_2017.20170613.44572-8ubuntu0.1_amd64.deb …
```

```
Unpacking libtexluajit2:amd64 (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package libzzip-0-13:amd64.
Preparing to unpack …/31-libzzip-0-13_0.13.62-3.1ubuntu0.18.04.1_amd64.deb …
Unpacking libzzip-0-13:amd64 (0.13.62-3.1ubuntu0.18.04.1) …
Selecting previously unselected package lmodern.
Preparing to unpack …/32-lmodern_2.004.5-3_all.deb …
Unpacking lmodern (2.004.5-3) …
Selecting previously unselected package preview-latex-style.
Preparing to unpack …/33-preview-latex-style_11.91-1ubuntu1_all.deb …
Unpacking preview-latex-style (11.91-1ubuntu1) …
Selecting previously unselected package t1utils.
Preparing to unpack …/34-t1utils_1.41-2_amd64.deb …
Unpacking t1utils (1.41-2) …
Selecting previously unselected package tex-gyre.
Preparing to unpack …/35-tex-gyre_20160520-1_all.deb …
Unpacking tex-gyre (20160520-1) …
Selecting previously unselected package texlive-binaries.
Preparing to unpack …/36-texlive-
binaries_2017.20170613.44572-8ubuntu0.1_amd64.deb …
Unpacking texlive-binaries (2017.20170613.44572-8ubuntu0.1) …
Selecting previously unselected package texlive-base.
Preparing to unpack …/37-texlive-base_2017.20180305-1_all.deb …
Unpacking texlive-base (2017.20180305-1) …
Selecting previously unselected package texlive-fonts-recommended.
Preparing to unpack …/38-texlive-fonts-recommended_2017.20180305-1_all.deb …
Unpacking texlive-fonts-recommended (2017.20180305-1) …
Selecting previously unselected package texlive-latex-base.
Preparing to unpack …/39-texlive-latex-base_2017.20180305-1_all.deb …
Unpacking texlive-latex-base (2017.20180305-1) …
Selecting previously unselected package texlive-latex-recommended.
Preparing to unpack …/40-texlive-latex-recommended_2017.20180305-1_all.deb …
Unpacking texlive-latex-recommended (2017.20180305-1) …
Selecting previously unselected package texlive.
Preparing to unpack …/41-texlive_2017.20180305-1_all.deb …
Unpacking texlive (2017.20180305-1) …
Selecting previously unselected package texlive-pictures.
Preparing to unpack …/42-texlive-pictures_2017.20180305-1_all.deb …
Unpacking texlive-pictures (2017.20180305-1) …
Selecting previously unselected package texlive-latex-extra.
Preparing to unpack …/43-texlive-latex-extra_2017.20180305-2_all.deb …
Unpacking texlive-latex-extra (2017.20180305-2) …
Selecting previously unselected package texlive-plain-generic.
Preparing to unpack …/44-texlive-plain-generic_2017.20180305-2_all.deb …
Unpacking texlive-plain-generic (2017.20180305-2) …
Selecting previously unselected package tipa.
Preparing to unpack …/45-tipa_2%3a1.3-20_all.deb …
Unpacking tipa (2:1.3-20) …
Selecting previously unselected package texlive-xetex.
```

```
Preparing to unpack …/46-texlive-xetex_2017.20180305-1_all.deb …
Unpacking texlive-xetex (2017.20180305-1) …
Setting up libgs9-common (9.26~dfsg+0-0ubuntu0.18.04.15) …
Setting up libkpathsea6:amd64 (2017.20170613.44572-8ubuntu0.1) …
Setting up libjs-jquery (3.2.1-1) …
Setting up libtexlua52:amd64 (2017.20170613.44572-8ubuntu0.1) …
Setting up fonts-droid-fallback (1:6.0.1r16-1.1) …
Setting up libsynctex1:amd64 (2017.20170613.44572-8ubuntu0.1) …
Setting up libptexenc1:amd64 (2017.20170613.44572-8ubuntu0.1) …
Setting up tex-common (6.09) …
update-language: texlive-base not installed and configured, doing nothing!
Setting up poppler-data (0.4.8-2) …
Setting up tex-gyre (20160520-1) …
Setting up preview-latex-style (11.91-1ubuntu1) …
Setting up fonts-texgyre (20160520-1) …
Setting up fonts-noto-mono (20171026-2) …
Setting up fonts-lato (2.0-2) …
Setting up libcupsfilters1:amd64 (1.20.2-0ubuntu3.1) …
Setting up libcupsimage2:amd64 (2.2.7-1ubuntu2.8) …
Setting up libjbig2dec0:amd64 (0.13-6) …
Setting up ruby-did-you-mean (1.2.0-2) …
Setting up t1utils (1.41-2) …
Setting up ruby-net-telnet (0.1.1-2) …
Setting up libijs-0.35:amd64 (0.35-13) …
Setting up rubygems-integration (1.11) …
Setting up libpotrace0 (1.14-2) …
Setting up javascript-common (11) …
Setting up ruby-minitest (5.10.3-1) …
Setting up libzzip-0-13:amd64 (0.13.62-3.1ubuntu0.18.04.1) …
Setting up libgs9:amd64 (9.26~dfsg+0-0ubuntu0.18.04.15) …
Setting up libtexluajit2:amd64 (2017.20170613.44572-8ubuntu0.1) …
Setting up fonts-lmodern (2.004.5-3) …
Setting up ruby-power-assert (0.3.0-1) …
Setting up texlive-binaries (2017.20170613.44572-8ubuntu0.1) …
update-alternatives: using /usr/bin/xdvi-xaw to provide /usr/bin/xdvi.bin
(xdvi.bin) in auto mode
update-alternatives: using /usr/bin/bibtex.original to provide /usr/bin/bibtex
(bibtex) in auto mode
Setting up texlive-base (2017.20180305-1) …
mktexlsr: Updating /var/lib/texmf/ls-R-TEXLIVEDIST…
mktexlsr: Updating /var/lib/texmf/ls-R-TEXMFMAIN…
mktexlsr: Updating /var/lib/texmf/ls-R…
mktexlsr: Done.
tl-paper: setting paper size for dvips to a4:
/var/lib/texmf/dvips/config/config-paper.ps
tl-paper: setting paper size for dvipdfmx to a4:
/var/lib/texmf/dvipdfmx/dvipdfmx-paper.cfg
tl-paper: setting paper size for xdvi to a4: /var/lib/texmf/xdvi/XDvi-paper
```

```
tl-paper: setting paper size for pdftex to a4:
/var/lib/texmf/tex/generic/config/pdftexconfig.tex
Setting up texlive-fonts-recommended (2017.20180305-1) …
Setting up texlive-plain-generic (2017.20180305-2) …
Setting up texlive-latex-base (2017.20180305-1) …
Setting up lmodern (2.004.5-3) …
Setting up texlive-latex-recommended (2017.20180305-1) …
Setting up texlive-pictures (2017.20180305-1) …
Setting up tipa (2:1.3-20) …
Regenerating '/var/lib/texmf/fmtutil.cnf-DEBIAN'… done.
Regenerating '/var/lib/texmf/fmtutil.cnf-TEXLIVEDIST'… done.
update-fmtutil has updated the following file(s):
        /var/lib/texmf/fmtutil.cnf-DEBIAN
        /var/lib/texmf/fmtutil.cnf-TEXLIVEDIST
If you want to activate the changes in the above file(s),
you should run fmtutil-sys or fmtutil.
Setting up texlive (2017.20180305-1) …
Setting up texlive-latex-extra (2017.20180305-2) …
Setting up texlive-xetex (2017.20180305-1) …
Setting up ruby2.5 (2.5.1-1ubuntu1.11) …
Setting up ruby (1:2.5.1) …
Setting up ruby-test-unit (3.2.5-1) …
Setting up rake (12.3.1-1ubuntu0.1) …
Setting up libruby2.5:amd64 (2.5.1-1ubuntu1.11) …
Processing triggers for mime-support (3.60ubuntu1) …
Processing triggers for libc-bin (2.27-3ubuntu1.3) …
/sbin/ldconfig.real: /usr/local/lib/python3.7/dist-
packages/ideep4py/lib/libmkldnn.so.0 is not a symbolic link

Processing triggers for man-db (2.8.3-2ubuntu0.1) …
Processing triggers for fontconfig (2.12.6-0ubuntu2) …
Processing triggers for tex-common (6.09) …
Running updmap-sys. This may take some time… done.
Running mktexlsr /var/lib/texmf … done.
Building format(s) --all.
        This may take some time… done.
Collecting pypandoc
  Downloading pypandoc-1.7.5.tar.gz (23.2 MB)
     |                  | 23.2 MB 1.6 MB/s
  Installing build dependencies … done
  Getting requirements to build wheel … done
    Preparing wheel metadata … done
Building wheels for collected packages: pypandoc
  Building wheel for pypandoc (PEP 517) … done
  Created wheel for pypandoc: filename=pypandoc-1.7.5-py2.py3-none-any.whl
size=23503245
sha256=30db4c714479d602458695dd2cb69f87918fcc2d53b05b8e3b3b855879464e87
  Stored in directory: /root/.cache/pip/wheels/df/fc/e9/4e92342cc30e3b25f26f37fc
```

```
a8b9bcd3f847f51a41ed01f122
Successfully built pypandoc
Installing collected packages: pypandoc
Successfully installed pypandoc-1.7.5
```

[46]:
```
from google.colab import drive
drive.mount('/content/drive')
```

```
Mounted at /content/drive
```

[47]:
```
!cp /content/drive/MyDrive/[homework]dense_and_convolutional_nn.ipynb
```

```
cp: missing destination file operand after
'/content/drive/MyDrive/[homework]dense_and_convolutional_nn.ipynb'
Try 'cp --help' for more information.
```

[49]:
```
!jupyter nbconvert --to PDF "[homework]dense_and_convolutional_nn.ipynb"
```

```
[NbConvertApp] WARNING | pattern '[homework]dense_and_convolutional_nn.ipynb'
matched no files
This application is used to convert notebook files (*.ipynb)
        to various other formats.

        WARNING: THE COMMANDLINE INTERFACE MAY CHANGE IN FUTURE RELEASES.

Options
=======
The options below are convenience aliases to configurable class-options,
as listed in the "Equivalent to" description-line of the aliases.
To see all configurable class-options for some <cmd>, use:
    <cmd> --help-all

--debug
    set log level to logging.DEBUG (maximize logging output)
    Equivalent to: [--Application.log_level=10]
--show-config
    Show the application's configuration (human-readable format)
    Equivalent to: [--Application.show_config=True]
--show-config-json
    Show the application's configuration (json format)
    Equivalent to: [--Application.show_config_json=True]
--generate-config
    generate default config file
    Equivalent to: [--JupyterApp.generate_config=True]
-y
    Answer yes to any questions instead of prompting.
    Equivalent to: [--JupyterApp.answer_yes=True]
--execute
```

```
    Execute the notebook prior to export.
    Equivalent to: [--ExecutePreprocessor.enabled=True]
--allow-errors
    Continue notebook execution even if one of the cells throws an error and
include the error message in the cell output (the default behaviour is to abort
conversion). This flag is only relevant if '--execute' was specified, too.
    Equivalent to: [--ExecutePreprocessor.allow_errors=True]
--stdin
    read a single notebook file from stdin. Write the resulting notebook with
default basename 'notebook.*'
    Equivalent to: [--NbConvertApp.from_stdin=True]
--stdout
    Write notebook output to stdout instead of files.
    Equivalent to: [--NbConvertApp.writer_class=StdoutWriter]
--inplace
    Run nbconvert in place, overwriting the existing notebook (only
            relevant when converting to notebook format)
    Equivalent to: [--NbConvertApp.use_output_suffix=False
--NbConvertApp.export_format=notebook --FilesWriter.build_directory=]
--clear-output
    Clear output of current file and save in place,
            overwriting the existing notebook.
    Equivalent to: [--NbConvertApp.use_output_suffix=False
--NbConvertApp.export_format=notebook --FilesWriter.build_directory=
--ClearOutputPreprocessor.enabled=True]
--no-prompt
    Exclude input and output prompts from converted document.
    Equivalent to: [--TemplateExporter.exclude_input_prompt=True
--TemplateExporter.exclude_output_prompt=True]
--no-input
    Exclude input cells and output prompts from converted document.
            This mode is ideal for generating code-free reports.
    Equivalent to: [--TemplateExporter.exclude_output_prompt=True
--TemplateExporter.exclude_input=True]
--log-level=<Enum>
    Set the log level by value or name.
    Choices: any of [0, 10, 20, 30, 40, 50, 'DEBUG', 'INFO', 'WARN', 'ERROR',
'CRITICAL']
    Default: 30
    Equivalent to: [--Application.log_level]
--config=<Unicode>
    Full path of a config file.
    Default: ''
    Equivalent to: [--JupyterApp.config_file]
--to=<Unicode>
    The export format to be used, either one of the built-in formats
            ['asciidoc', 'custom', 'html', 'latex', 'markdown', 'notebook',
'pdf', 'python', 'rst', 'script', 'slides']
```

```
            or a dotted object name that represents the import path for an
            `Exporter` class
    Default: 'html'
    Equivalent to: [--NbConvertApp.export_format]
--template=<Unicode>
    Name of the template file to use
    Default: ''
    Equivalent to: [--TemplateExporter.template_file]
--writer=<DottedObjectName>
    Writer class used to write the
                                        results of the conversion
    Default: 'FilesWriter'
    Equivalent to: [--NbConvertApp.writer_class]
--post=<DottedOrNone>
    PostProcessor class used to write the
                                        results of the conversion
    Default: ''
    Equivalent to: [--NbConvertApp.postprocessor_class]
--output=<Unicode>
    overwrite base name use for output files.
                can only be used when converting one notebook at a time.
    Default: ''
    Equivalent to: [--NbConvertApp.output_base]
--output-dir=<Unicode>
    Directory to write output(s) to. Defaults
                                    to output to the directory of each notebook.
To recover
                                    previous default behaviour (outputting to the
current
                                    working directory) use . as the flag value.
    Default: ''
    Equivalent to: [--FilesWriter.build_directory]
--reveal-prefix=<Unicode>
    The URL prefix for reveal.js (version 3.x).
            This defaults to the reveal CDN, but can be any url pointing to a
copy
            of reveal.js.
            For speaker notes to work, this must be a relative path to a local
            copy of reveal.js: e.g., "reveal.js".
            If a relative path is given, it must be a subdirectory of the
            current directory (from which the server is run).
            See the usage documentation
            (https://nbconvert.readthedocs.io/en/latest/usage.html#reveal-js-
html-slideshow)
            for more details.
    Default: ''
    Equivalent to: [--SlidesExporter.reveal_url_prefix]
--nbformat=<Enum>
```

```
    The nbformat version to write.
            Use this to downgrade notebooks.
    Choices: any of [1, 2, 3, 4]
    Default: 4
    Equivalent to: [--NotebookExporter.nbformat_version]

Examples
--------

    The simplest way to use nbconvert is

            > jupyter nbconvert mynotebook.ipynb

            which will convert mynotebook.ipynb to the default format (probably
HTML).

            You can specify the export format with `--to`.
            Options include ['asciidoc', 'custom', 'html', 'latex', 'markdown',
'notebook', 'pdf', 'python', 'rst', 'script', 'slides'].

            > jupyter nbconvert --to latex mynotebook.ipynb

            Both HTML and LaTeX support multiple output templates. LaTeX
includes
            'base', 'article' and 'report'.  HTML includes 'basic' and 'full'.
You
            can specify the flavor of the format used.

            > jupyter nbconvert --to html --template basic mynotebook.ipynb

            You can also pipe the output to stdout, rather than a file

            > jupyter nbconvert mynotebook.ipynb --stdout

            PDF is generated via latex

            > jupyter nbconvert mynotebook.ipynb --to pdf

            You can get (and serve) a Reveal.js-powered slideshow

            > jupyter nbconvert myslides.ipynb --to slides --post serve

            Multiple notebooks can be given at the command line in a couple of
            different ways:

            > jupyter nbconvert notebook*.ipynb
            > jupyter nbconvert notebook1.ipynb notebook2.ipynb
```

```
            or you can specify the notebooks list in a config file, containing::

                c.NbConvertApp.notebooks = ["my_notebook.ipynb"]

            > jupyter nbconvert --config mycfg.py

To see all available configurables, use `--help-all`.
```

[ ]: