HW9 Solution

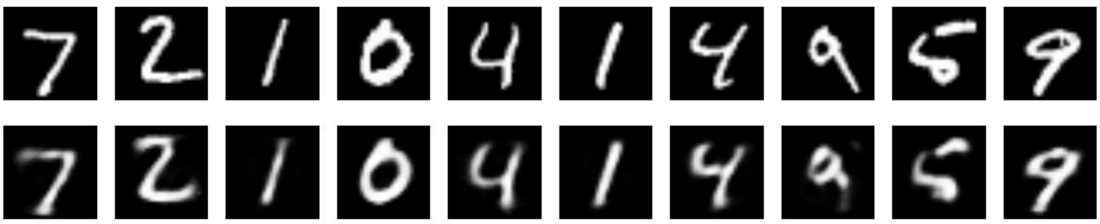
1. Let's build an autoencoder by Keras

```
from keras.layers import Input, Dense
from keras.models import Model

# this is the size of our encoded representations
encoding_dim = 32
# 32 floats -> compression of factor 24.5,
#assuming the input is 784 floats

# this is our input placeholder
input_img = Input(shape=(784,))
# "encoded" is the encoded representation of the input
encoded = Dense(encoding_dim, activation='relu')(input_img)
# "decoded" is the lossy reconstruction of the input
decoded = Dense(784, activation='sigmoid')(encoded)

# this model maps an input to its reconstruction
autoencoder = Model(input_img, decoded)

# this model maps an input to its encoded representation
encoder = Model(input_img, encoded)

# create a placeholder for an encoded (32-dimensional) input
encoded_input = Input(shape=(encoding_dim,))
# retrieve the last layer of the autoencoder model
decoder_layer = autoencoder.layers[-1]
# create the decoder model
decoder = Model(encoded_input, decoder_layer(encoded_input))

autoencoder.compile(optimizer='adadelta',
                    loss='binary_crossentropy')

from keras.datasets import mnist
import numpy as np
(x_train, _), (x_test, _) = mnist.load_data()

x_train = x_train.astype('float32') / 255.
x_test = x_test.astype('float32') / 255.
x_train = x_train.reshape((len(x_train),
                           np.prod(x_train.shape[1:])))
x_test = x_test.reshape((len(x_test),
```

```
                         np.prod(x_test.shape[1:])))
print(x_train.shape[0], 'train samples')
print(x_test.shape[0], 'test samples')

autoencoder.fit(x_train, x_train,
 epochs=50,
 batch_size=256,
 shuffle=True,
 validation_data=(x_test, x_test))

# encode and decode some digits
# note that we take them from the *test* set
encoded_imgs = encoder.predict(x_test)
decoded_imgs = decoder.predict(encoded_imgs)

# use Matplotlib (don't ask)
import matplotlib.pyplot as plt

n = 10 # how many digits we will display
plt.figure(figsize=(20, 4))
for i in range(n):
    # display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

    # display reconstruction
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(decoded_imgs[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
```

結果：

```
Epoch 50/50
60000/60000 [==============================] - 3s - loss: 0.1046 - val_loss: 0.1029
```



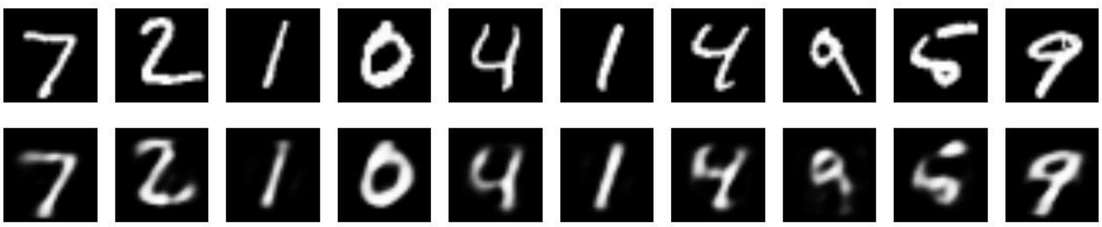
2. Adding a sparsity constraint on the encoded representations

```
from keras import regularizers
from keras.layers import Input, Dense
from keras.models import Model

encoding_dim = 32

input_img = Input(shape=(784,))
# add a Dense layer with a L1 activity regularizer
encoded = Dense(encoding_dim, activation='relu',
    activity_regularizer=regularizers.l1(10e-7))(input_img)
# "decoded" is the lossy reconstruction of the input
decoded = Dense(784, activation='sigmoid')(encoded)

# this model maps an input to its reconstruction
autoencoder = Model(input_img, decoded)

# this model maps an input to its encoded representation
encoder = Model(input_img, encoded)

# create a placeholder for an encoded (32-dimensional) input
encoded_input = Input(shape=(encoding_dim,))
# retrieve the last layer of the autoencoder model
decoder_layer = autoencoder.layers[-1]
# create the decoder model
decoder = Model(encoded_input, decoder_layer(encoded_input))

autoencoder.compile(optimizer='adadelta',
                    loss='binary_crossentropy')

from keras.datasets import mnist
import numpy as np
(x_train, _), (x_test, _) = mnist.load_data()

x_train = x_train.astype('float32') / 255.
x_test = x_test.astype('float32') / 255.
x_train = x_train.reshape((len(x_train),
                           np.prod(x_train.shape[1:])))
x_test = x_test.reshape((len(x_test),
                         np.prod(x_test.shape[1:])))
print(x_train.shape[0], 'train samples')
```

```python
print(x_test.shape[0], 'test samples')

autoencoder.fit(x_train, x_train,
 epochs=100,
 batch_size=256,
 shuffle=True,
 validation_data=(x_test, x_test))

# encode and decode some digits
# note that we take them from the *test* set
encoded_imgs = encoder.predict(x_test)
decoded_imgs = decoder.predict(encoded_imgs)

# use Matplotlib (don't ask)
import matplotlib.pyplot as plt

n = 10 # how many digits we will display
plt.figure(figsize=(20, 4))
for i in range(n):
    # display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

    # display reconstruction
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(decoded_imgs[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
```

結果：

```
Epoch 100/100
60000/60000 [==============================] - 4s - loss: 0.1303 - val_loss: 0.1287
```



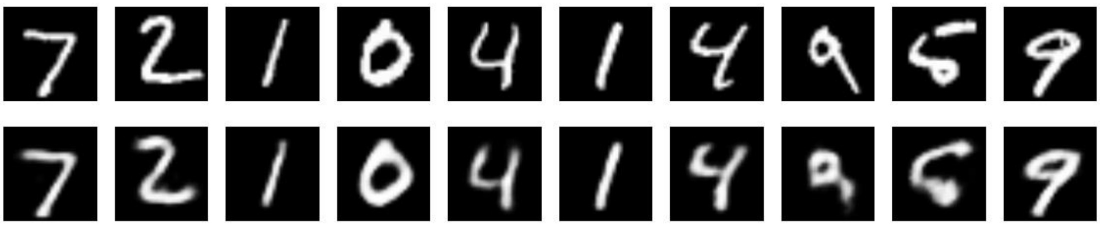
3. Deep autoencoder

```
from keras.layers import Input, Dense
from keras.models import Model

encoding_dim = 32

input_img = Input(shape=(784,))
encoded = Dense(128, activation='relu')(input_img)
encoded = Dense(64, activation='relu')(encoded)
encoded = Dense(32, activation='relu')(encoded)

decoded = Dense(64, activation='relu')(encoded)
decoded = Dense(128, activation='relu')(decoded)
decoded = Dense(784, activation='sigmoid')(decoded)

autoencoder = Model(input=input_img, output=decoded)
autoencoder.compile(optimizer='adadelta',
                    loss='binary_crossentropy')

# this model maps an input to its encoded representation
encoder = Model(input_img, encoded)
# create a placeholder for an encoded (32-dimensional) input
encoded_input = Input(shape=(encoding_dim,))
# retrieve the last layer of the autoencoder model
decoder_layer = autoencoder.layers[-1](
autoencoder.layers[-2](
autoencoder.layers[-3](encoded_input)))
# create the decoder model
decoder = Model(encoded_input,decoder_layer)

from keras.datasets import mnist
import numpy as np
(x_train, _), (x_test, _) = mnist.load_data()

x_train = x_train.astype('float32') / 255.
x_test = x_test.astype('float32') / 255.
x_train = x_train.reshape((len(x_train),
                           np.prod(x_train.shape[1:])))
x_test = x_test.reshape((len(x_test),
                         np.prod(x_test.shape[1:])))
print(x_train.shape[0], 'train samples')
```

```python
print(x_test.shape[0], 'test samples')

autoencoder.fit(x_train, x_train,
                nb_epoch=100,
                batch_size=256,
                shuffle=True,
                validation_data=(x_test, x_test))

# encode and decode some digits
# note that we take them from the *test* set
encoded_imgs = encoder.predict(x_test)
decoded_imgs = decoder.predict(encoded_imgs)

# use Matplotlib (don't ask)
import matplotlib.pyplot as plt

n = 10 # how many digits we will display
plt.figure(figsize=(20, 4))
for i in range(n):
    # display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

    # display reconstruction
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(decoded_imgs[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
```

結果：

```
Epoch 100/100
60000/60000 [==============================] - 3s - loss: 0.1005 - val_loss: 0.0990
```



4. Convolutional autoencoder

```
from keras.layers import Input, Dense, Conv2D, MaxPooling2D,
UpSampling2D
from keras.models import Model
from keras import backend as K
from keras.callbacks import TensorBoard

input_img = Input(shape=(28, 28, 1))
# adapt this if using `channels_first` image data format

x = Conv2D(16, (3, 3), activation='relu', padding='same')
(input_img)
x = MaxPooling2D((2, 2), padding='same')(x)
x = Conv2D(8, (3, 3), activation='relu', padding='same')(x)
x = MaxPooling2D((2, 2), padding='same')(x)
x = Conv2D(8, (3, 3), activation='relu', padding='same')(x)
encoded = MaxPooling2D((2, 2), padding='same')(x)

# at this point the representation is (4, 4, 8) i.e. 128-dimen

x = Conv2D(8, (3, 3), activation='relu', padding='same')
(encoded)
x = UpSampling2D((2, 2))(x)
x = Conv2D(8, (3, 3), activation='relu', padding='same')(x)
x = UpSampling2D((2, 2))(x)
x = Conv2D(16, (3, 3), activation='relu')(x)
x = UpSampling2D((2, 2))(x)
decoded = Conv2D(1, (3, 3), activation='sigmoid',
                 padding='same')(x)

autoencoder = Model(input_img, decoded)
autoencoder.compile(optimizer='adadelta',
                    loss='binary_crossentropy')

from keras.datasets import mnist
import numpy as np

(x_train, _), (x_test, _) = mnist.load_data()

x_train = x_train.astype('float32') / 255.
x_test = x_test.astype('float32') / 255.
```

```
x_train = np.reshape(x_train, (len(x_train), 28, 28, 1))
  # adapt this if using `channels_first` image data format
x_test = np.reshape(x_test, (len(x_test), 28, 28, 1))
# adapt this if using `channels_first` image data format

autoencoder.fit(x_train, x_train,
                epochs=50,
                batch_size=128,
                shuffle=True,
                validation_data=(x_test, x_test),
                callbacks=[TensorBoard
                           (log_dir='/tmp/autoencoder')])

# use Matplotlib
import matplotlib.pyplot as plt

decoded_imgs = autoencoder.predict(x_test)

n = 10
plt.figure(figsize=(20, 4))
for i in range(n):
    # display original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

    # display reconstruction
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(decoded_imgs[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()

# this model maps an input to its encoded representation
encoder = Model(input=input_img, output=encoded)
encoded_imgs = encoder.predict(x_test)

n = 10
plt.figure(figsize=(20, 8))
for i in range(n):
    ax = plt.subplot(1, n, i + 1)
    plt.imshow(encoded_imgs[i].reshape(4, 4 * 8).T)
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
```

結果：

5. Application to image denoising

```
import numpy as np
import matplotlib.pyplot as plt
from keras.layers import Input, Dense, Convolution2D,
MaxPooling2D, UpSampling2D
from keras.models import Model
from keras.datasets import mnist

input_img = Input(shape=(1, 28, 28))

x = Convolution2D(16, 3, 3, activation='relu',
                  border_mode='same')(input_img)
x = MaxPooling2D((2, 2), border_mode='same')(x)
x = Convolution2D(8, 3, 3, activation='relu',
                  border_mode='same')(x)
x = MaxPooling2D((2, 2), border_mode='same')(x)
x = Convolution2D(8, 3, 3, activation='relu',
                  border_mode='same')(x)
encoded = MaxPooling2D((2, 2), border_mode='same')(x)

encoder = Model(input_img, x)
# at this point the representation is (8, 4, 4)
#i.e. 128-dimensional

x = Convolution2D(8, 3, 3, activation='relu',
                  border_mode='same')(encoded)
x = UpSampling2D((2, 2))(x)
x = Convolution2D(8, 3, 3, activation='relu',
                  border_mode='same')(x)
x = UpSampling2D((2, 2))(x)
x = Convolution2D(16, 3, 3, activation='relu')(x)
x = UpSampling2D((2, 2))(x)
decoded = Convolution2D(1, 3, 3, activation='sigmoid',
                        border_mode='same')(x)

autoencoder = Model(input_img, decoded)
autoencoder.compile(optimizer='adadelta',
                    loss='binary_crossentropy')

(x_train, _), (x_test, _) = mnist.load_data()
```

```
x_train = x_train.astype('float32') / 255.
x_test = x_test.astype('float32') / 255.
x_train = np.reshape(x_train, (len(x_train), 1, 28, 28))
x_test = np.reshape(x_test, (len(x_test), 1, 28, 28))

noise_factor = 0.5
x_train_noisy = x_train + noise_factor
* np.random.normal(loc=0.0, scale=1.0, size=x_train.shape)
x_test_noisy = x_test + noise_factor
* np.random.normal(loc=0.0, scale=1.0, size=x_test.shape)

x_train_noisy = np.clip(x_train_noisy, 0., 1.)
x_test_noisy = np.clip(x_test_noisy, 0., 1.)

n = 10
plt.figure(figsize=(20, 2))
for i in range(n):
    ax = plt.subplot(1, n, i+1)
    plt.imshow(x_test_noisy[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
```

加了 noise 之後，如下圖