1.3C

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Welcome to your assignment this week!

1   Classification task

In this task you are asked to build a simple Feed Forward Neural Network, train it and test it!

After this assignment you will be able to:

- Load a dataset.
- Train a Feed Forward Neural Network.
- Test a Feed Forward Neural Network.

Let's get started! Run the following cell to install all the packages you will need.

```
[7]: !pip install numpy
     !pip install keras
     !pip install tensorflow
     !pip install pandas
     !pip install matplotlib
```

Requirement already satisfied: numpy in ./opt/anaconda3/lib/python3.7/site-
packages (1.18.1)
Requirement already satisfied: keras in ./opt/anaconda3/lib/python3.7/site-
packages (2.3.1)
Requirement already satisfied: six>=1.9.0 in ./opt/anaconda3/lib/python3.7/site-
packages (from keras) (1.14.0)
Requirement already satisfied: keras-applications>=1.0.6 in
./opt/anaconda3/lib/python3.7/site-packages (from keras) (1.0.8)
Requirement already satisfied: keras-preprocessing>=1.0.5 in
./opt/anaconda3/lib/python3.7/site-packages (from keras) (1.1.0)
Requirement already satisfied: h5py in ./opt/anaconda3/lib/python3.7/site-
packages (from keras) (2.10.0)
Requirement already satisfied: pyyaml in ./opt/anaconda3/lib/python3.7/site-
packages (from keras) (5.3)
Requirement already satisfied: numpy>=1.9.1 in
./opt/anaconda3/lib/python3.7/site-packages (from keras) (1.18.1)
Requirement already satisfied: scipy>=0.14 in
./opt/anaconda3/lib/python3.7/site-packages (from keras) (1.4.1)

Requirement already satisfied: tensorflow in ./opt/anaconda3/lib/python3.7/site-packages (2.2.0)
Requirement already satisfied: astunparse==1.6.3 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (1.6.3)
Requirement already satisfied: grpcio>=1.8.6 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (1.28.1)
Requirement already satisfied: scipy==1.4.1; python_version >= "3" in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (1.4.1)
Requirement already satisfied: numpy<2.0,>=1.16.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (1.18.1)
Requirement already satisfied: gast==0.3.3 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (0.3.3)
Requirement already satisfied: wrapt>=1.11.1 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (1.11.2)
Requirement already satisfied: six>=1.12.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (1.14.0)
Requirement already satisfied: tensorflow-estimator<2.3.0,>=2.2.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (2.2.0)
Requirement already satisfied: tensorboard<2.3.0,>=2.2.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (2.2.1)
Requirement already satisfied: wheel>=0.26; python_version >= "3" in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (0.34.2)
Requirement already satisfied: termcolor>=1.1.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (1.1.0)
Requirement already satisfied: h5py<2.11.0,>=2.10.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (2.10.0)
Requirement already satisfied: keras-preprocessing>=1.1.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (1.1.0)
Requirement already satisfied: google-pasta>=0.1.8 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (0.2.0)
Requirement already satisfied: absl-py>=0.7.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (0.9.0)
Requirement already satisfied: opt-einsum>=2.3.2 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (3.2.1)
Requirement already satisfied: protobuf>=3.8.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorflow) (3.11.3)
Requirement already satisfied: google-auth-oauthlib<0.5,>=0.4.1 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorboard<2.3.0,>=2.2.0->tensorflow) (0.4.1)
Requirement already satisfied: setuptools>=41.0.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorboard<2.3.0,>=2.2.0->tensorflow) (46.0.0.post20200309)
Requirement already satisfied: tensorboard-plugin-wit>=1.6.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorboard<2.3.0,>=2.2.0->tensorflow) (1.6.0.post3)
Requirement already satisfied: requests<3,>=2.21.0 in ./opt/anaconda3/lib/python3.7/site-packages (from tensorboard<2.3.0,>=2.2.0->tensorflow) (2.22.0)

```
Requirement already satisfied: werkzeug>=0.11.15 in
./opt/anaconda3/lib/python3.7/site-packages (from
tensorboard<2.3.0,>=2.2.0->tensorflow) (1.0.0)
Requirement already satisfied: google-auth<2,>=1.6.3 in
./opt/anaconda3/lib/python3.7/site-packages (from
tensorboard<2.3.0,>=2.2.0->tensorflow) (1.14.2)
Requirement already satisfied: markdown>=2.6.8 in
./opt/anaconda3/lib/python3.7/site-packages (from
tensorboard<2.3.0,>=2.2.0->tensorflow) (3.2.2)
Requirement already satisfied: requests-oauthlib>=0.7.0 in
./opt/anaconda3/lib/python3.7/site-packages (from google-auth-
oauthlib<0.5,>=0.4.1->tensorboard<2.3.0,>=2.2.0->tensorflow) (1.3.0)
Requirement already satisfied: certifi>=2017.4.17 in
./opt/anaconda3/lib/python3.7/site-packages (from
requests<3,>=2.21.0->tensorboard<2.3.0,>=2.2.0->tensorflow) (2020.4.5.1)
Requirement already satisfied: idna<2.9,>=2.5 in
./opt/anaconda3/lib/python3.7/site-packages (from
requests<3,>=2.21.0->tensorboard<2.3.0,>=2.2.0->tensorflow) (2.8)
Requirement already satisfied: chardet<3.1.0,>=3.0.2 in
./opt/anaconda3/lib/python3.7/site-packages (from
requests<3,>=2.21.0->tensorboard<2.3.0,>=2.2.0->tensorflow) (3.0.4)
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in
./opt/anaconda3/lib/python3.7/site-packages (from
requests<3,>=2.21.0->tensorboard<2.3.0,>=2.2.0->tensorflow) (1.25.8)
Requirement already satisfied: cachetools<5.0,>=2.0.0 in
./opt/anaconda3/lib/python3.7/site-packages (from google-
auth<2,>=1.6.3->tensorboard<2.3.0,>=2.2.0->tensorflow) (4.1.0)
Requirement already satisfied: rsa<4.1,>=3.1.4 in
./opt/anaconda3/lib/python3.7/site-packages (from google-
auth<2,>=1.6.3->tensorboard<2.3.0,>=2.2.0->tensorflow) (4.0)
Requirement already satisfied: pyasn1-modules>=0.2.1 in
./opt/anaconda3/lib/python3.7/site-packages (from google-
auth<2,>=1.6.3->tensorboard<2.3.0,>=2.2.0->tensorflow) (0.2.8)
Requirement already satisfied: importlib-metadata; python_version < "3.8" in
./opt/anaconda3/lib/python3.7/site-packages (from
markdown>=2.6.8->tensorboard<2.3.0,>=2.2.0->tensorflow) (1.5.0)
Requirement already satisfied: oauthlib>=3.0.0 in
./opt/anaconda3/lib/python3.7/site-packages (from requests-
oauthlib>=0.7.0->google-auth-
oauthlib<0.5,>=0.4.1->tensorboard<2.3.0,>=2.2.0->tensorflow) (3.1.0)
Requirement already satisfied: pyasn1>=0.1.3 in
./opt/anaconda3/lib/python3.7/site-packages (from rsa<4.1,>=3.1.4->google-
auth<2,>=1.6.3->tensorboard<2.3.0,>=2.2.0->tensorflow) (0.4.8)
Requirement already satisfied: zipp>=0.5 in ./opt/anaconda3/lib/python3.7/site-
packages (from importlib-metadata; python_version <
"3.8"->markdown>=2.6.8->tensorboard<2.3.0,>=2.2.0->tensorflow) (2.2.0)
Requirement already satisfied: pandas in ./opt/anaconda3/lib/python3.7/site-
packages (1.0.1)
```

Requirement already satisfied: python-dateutil>=2.6.1 in
./opt/anaconda3/lib/python3.7/site-packages (from pandas) (2.8.1)
Requirement already satisfied: pytz>=2017.2 in
./opt/anaconda3/lib/python3.7/site-packages (from pandas) (2019.3)
Requirement already satisfied: numpy>=1.13.3 in
./opt/anaconda3/lib/python3.7/site-packages (from pandas) (1.18.1)
Requirement already satisfied: six>=1.5 in ./opt/anaconda3/lib/python3.7/site-
packages (from python-dateutil>=2.6.1->pandas) (1.14.0)
Requirement already satisfied: matplotlib in ./opt/anaconda3/lib/python3.7/site-
packages (3.1.3)
Requirement already satisfied: python-dateutil>=2.1 in
./opt/anaconda3/lib/python3.7/site-packages (from matplotlib) (2.8.1)
Requirement already satisfied: cycler>=0.10 in
./opt/anaconda3/lib/python3.7/site-packages (from matplotlib) (0.10.0)
Requirement already satisfied: kiwisolver>=1.0.1 in
./opt/anaconda3/lib/python3.7/site-packages (from matplotlib) (1.1.0)
Requirement already satisfied: pyparsing!=2.0.4,!=2.1.2,!=2.1.6,>=2.0.1 in
./opt/anaconda3/lib/python3.7/site-packages (from matplotlib) (2.4.6)
Requirement already satisfied: numpy>=1.11 in
./opt/anaconda3/lib/python3.7/site-packages (from matplotlib) (1.18.1)
Requirement already satisfied: six>=1.5 in ./opt/anaconda3/lib/python3.7/site-
packages (from python-dateutil>=2.1->matplotlib) (1.14.0)
Requirement already satisfied: setuptools in ./opt/anaconda3/lib/python3.7/site-
packages (from kiwisolver>=1.0.1->matplotlib) (46.0.0.post20200309)

Run the following cell to load the packages you will need.

```
[8]: import numpy as np # linear algebra
import pandas as pd # data processing, CSV file I/O (e.g. pd.read_csv)
from sklearn.model_selection import train_test_split
import matplotlib.pyplot as plt
import keras
from keras.models import Sequential
from keras.layers import Dense
```

The dataset we will use consists of 4500 examples with 512 features. A label is given for each
example to indicate positive and negative instances.

Let's read the data.

```
[25]: df = pd.read_csv('data.csv')
df.set_index('id', inplace=True)
print(df)
```

```
          v1       v2       v3       v4       v5       v6       v7       v8  \
id
1    0.37797 -0.94808  0.01346  0.17893  0.37795  0.63571  0.13943 -0.25607
2    0.07609 -0.09774  0.39666 -0.39026  0.10606  0.52774  0.07105  0.33720
3    1.19391 -0.68707 -0.68422 -0.36378 -0.60847 -0.40118  1.45432  0.00592
```

```
4      1.34949 -0.31498 -1.30248   0.50278   1.66292 -1.06094 -0.70835 -0.24237
5     -0.03512 -0.34196  0.14230   1.50513  -0.14364  0.49429  0.07823 -0.04356
...      ...      ...      ...      ...      ...      ...      ...      ...
4496   0.54554  0.63002  1.99328  -0.73290  -0.28964  0.61707  0.69515  0.87060
4497  -0.26235  0.50776 -0.74164  -0.52717  -0.35846 -1.16202  0.21828  0.22305
4498  -0.81564 -0.46034 -0.40044   0.21816   0.75283 -0.58075 -0.38389  0.26561
4499   0.09764 -0.05440 -1.53883  -0.04827  -0.60092 -1.20086  0.54661 -0.45875
4500   0.48335  1.66099 -1.98407   0.04818  -0.17309  1.06795  0.30303 -0.45490

            v9       v10   ...      v504      v505      v506      v507      v508  \
id                          ...
1     -0.39341  1.08947   ... -0.03494   1.32443 -0.94570  0.02055 -1.23908
2      0.69917 -0.02842   ...  0.86624  -1.24953 -0.21511 -1.54146  1.04765
3      1.68940 -0.98205   ... -0.35893   0.02330  0.31548 -0.34923 -0.41772
4     -0.15509 -0.04532   ...  0.23942   0.20774  0.81792 -0.74814 -0.62521
5      0.42009 -0.88828   ... -1.78407   0.07465  1.50182 -0.41289 -0.55908
...      ...      ...   ... ...      ...      ...      ...      ...      ...
4496   0.18784 -0.53365   ... -0.91652   0.24407  1.02312 -1.06633  0.06479
4497  -0.78329  0.09361   ...  0.86871  -0.09672 -0.32991 -0.69076 -0.40691
4498  -0.80443  0.49042   ... -0.22298   0.14621 -0.45917  0.69664  0.08561
4499  -0.11255  0.42889   ... -0.39275  -0.47806  0.58785  0.59169 -0.05488
4500  -1.83532 -0.75861   ... -0.11633   0.71603  1.20805 -0.44330  1.13303

            v509      v510      v511      v512  label
id
1      0.43507  1.08635  1.69027  0.61609      0
2     -1.24035  0.00866 -1.27640 -0.60496      1
3     -0.58175 -0.60177  0.43555  0.41982      1
4      0.01689  0.83997 -0.46986  0.06755      0
5     -0.29702  0.83641  0.59756 -0.20298      0
...      ...      ...      ...      ...    ...
4496   0.80146  0.57461  1.69958  0.43941      0
4497  -0.56606 -0.33767 -0.01251  0.06872      0
4498  -0.42261  0.14222  0.10394 -0.33635      1
4499  -0.81097 -0.25393  0.84022 -0.13068      1
4500  -0.14939  0.06201 -2.24746  0.17192      0

[4500 rows x 513 columns]
```

Now, let's split the data into training and test sets.

```
[11]: X_train, X_test, y_train, y_test = train_test_split(
          df.index.values,
          df.label.values,
          test_size=0.15,
          random_state=17,
          stratify=df.label.values
      )
```

```
df['data_type'] = ['note_set']*df.shape[0]
df.loc[X_train, 'data_type'] = 'train'
df.loc[X_test, 'data_type'] = 'test'

## The data to use:

X_train = df[df['data_type']=='train'].iloc[:,:512].values
X_test = df[df['data_type']=='test'].iloc[:,:512].values
y_train = df[df['data_type']=='train'].iloc[:,512:513].values
y_test = df[df['data_type']=='test'].iloc[:,512:513].values
```

2   Task 1

Build a Feed Forward Neural Network to address this classification task using the Keras framework.

```
[22]: # START YOUR CODE HERE
      model = Sequential()
      model.add(Dense(512, activation='relu'))
      model.add(Dense(1, activation='sigmoid'))
      model.compile(loss='binary_crossentropy',
                    optimizer='adam',
                    metrics=['accuracy'])
```

3   Training

Now, let's start our training.

```
[23]: history = model.fit(X_train, y_train, epochs=200, batch_size=64, verbose=1)
```

```
Epoch 1/200
3825/3825 [==============================] - 0s 67us/step - loss: 0.1768 -
accuracy: 0.9273
Epoch 2/200
3825/3825 [==============================] - 0s 39us/step - loss: 0.0152 -
accuracy: 0.9995
Epoch 3/200
3825/3825 [==============================] - 0s 40us/step - loss: 0.0065 -
accuracy: 1.0000
Epoch 4/200
3825/3825 [==============================] - 0s 42us/step - loss: 0.0038 -
accuracy: 1.0000
Epoch 5/200
3825/3825 [==============================] - 0s 38us/step - loss: 0.0025 -
accuracy: 1.0000
Epoch 6/200
3825/3825 [==============================] - 0s 37us/step - loss: 0.0018 -
```

```
accuracy: 1.0000
Epoch 7/200
3825/3825 [==============================] - 0s 66us/step - loss: 0.0014 -
accuracy: 1.0000
Epoch 8/200
3825/3825 [==============================] - 0s 49us/step - loss: 0.0011 -
accuracy: 1.0000
Epoch 9/200
3825/3825 [==============================] - 0s 40us/step - loss: 8.5155e-04 -
accuracy: 1.0000
Epoch 10/200
3825/3825 [==============================] - 0s 39us/step - loss: 6.9925e-04 -
accuracy: 1.0000
Epoch 11/200
3825/3825 [==============================] - 0s 39us/step - loss: 5.8396e-04 -
accuracy: 1.0000
Epoch 12/200
3825/3825 [==============================] - 0s 43us/step - loss: 4.9445e-04 -
accuracy: 1.0000
Epoch 13/200
3825/3825 [==============================] - 0s 42us/step - loss: 4.2508e-04 -
accuracy: 1.0000
Epoch 14/200
3825/3825 [==============================] - 0s 38us/step - loss: 3.6868e-04 -
accuracy: 1.0000
Epoch 15/200
3825/3825 [==============================] - 0s 38us/step - loss: 3.2271e-04 -
accuracy: 1.0000
Epoch 16/200
3825/3825 [==============================] - 0s 39us/step - loss: 2.8470e-04 -
accuracy: 1.0000
Epoch 17/200
3825/3825 [==============================] - 0s 39us/step - loss: 2.5299e-04 -
accuracy: 1.0000
Epoch 18/200
3825/3825 [==============================] - 0s 38us/step - loss: 2.2615e-04 -
accuracy: 1.0000
Epoch 19/200
3825/3825 [==============================] - 0s 38us/step - loss: 2.0325e-04 -
accuracy: 1.0000
Epoch 20/200
3825/3825 [==============================] - 0s 39us/step - loss: 1.8370e-04 -
accuracy: 1.0000
Epoch 21/200
3825/3825 [==============================] - 0s 63us/step - loss: 1.6646e-04 -
accuracy: 1.0000
Epoch 22/200
3825/3825 [==============================] - 0s 42us/step - loss: 1.5165e-04 -
```

```
accuracy: 1.0000
Epoch 23/200
3825/3825 [==============================] - 0s 39us/step - loss: 1.3861e-04 -
accuracy: 1.0000
Epoch 24/200
3825/3825 [==============================] - 0s 39us/step - loss: 1.2711e-04 -
accuracy: 1.0000
Epoch 25/200
3825/3825 [==============================] - 0s 39us/step - loss: 1.1682e-04 -
accuracy: 1.0000
Epoch 26/200
3825/3825 [==============================] - 0s 39us/step - loss: 1.0776e-04 -
accuracy: 1.0000
Epoch 27/200
3825/3825 [==============================] - 0s 44us/step - loss: 9.9605e-05 -
accuracy: 1.0000
Epoch 28/200
3825/3825 [==============================] - 0s 41us/step - loss: 9.2288e-05 -
accuracy: 1.0000
Epoch 29/200
3825/3825 [==============================] - 0s 47us/step - loss: 8.5764e-05 -
accuracy: 1.0000
Epoch 30/200
3825/3825 [==============================] - 0s 61us/step - loss: 7.9765e-05 -
accuracy: 1.0000
Epoch 31/200
3825/3825 [==============================] - 0s 57us/step - loss: 7.4356e-05 -
accuracy: 1.0000
Epoch 32/200
3825/3825 [==============================] - 0s 56us/step - loss: 6.9472e-05 -
accuracy: 1.0000
Epoch 33/200
3825/3825 [==============================] - 0s 40us/step - loss: 6.4979e-05 -
accuracy: 1.0000
Epoch 34/200
3825/3825 [==============================] - 0s 39us/step - loss: 6.0869e-05 -
accuracy: 1.0000
Epoch 35/200
3825/3825 [==============================] - 0s 44us/step - loss: 5.7136e-05 -
accuracy: 1.0000
Epoch 36/200
3825/3825 [==============================] - 0s 52us/step - loss: 5.3658e-05 -
accuracy: 1.0000
Epoch 37/200
3825/3825 [==============================] - 0s 39us/step - loss: 5.0469e-05 -
accuracy: 1.0000
Epoch 38/200
3825/3825 [==============================] - 0s 39us/step - loss: 4.7545e-05 -
```

```
accuracy: 1.0000
Epoch 39/200
3825/3825 [==============================] - 0s 39us/step - loss: 4.4813e-05 -
accuracy: 1.0000
Epoch 40/200
3825/3825 [==============================] - 0s 42us/step - loss: 4.2325e-05 -
accuracy: 1.0000
Epoch 41/200
3825/3825 [==============================] - 0s 43us/step - loss: 3.9982e-05 -
accuracy: 1.0000
Epoch 42/200
3825/3825 [==============================] - 0s 38us/step - loss: 3.7806e-05 -
accuracy: 1.0000
Epoch 43/200
3825/3825 [==============================] - 0s 37us/step - loss: 3.5789e-05 -
accuracy: 1.0000
Epoch 44/200
3825/3825 [==============================] - 0s 37us/step - loss: 3.3905e-05 -
accuracy: 1.0000
Epoch 45/200
3825/3825 [==============================] - 0s 38us/step - loss: 3.2158e-05 -
accuracy: 1.0000
Epoch 46/200
3825/3825 [==============================] - 0s 37us/step - loss: 3.0493e-05 -
accuracy: 1.0000
Epoch 47/200
3825/3825 [==============================] - 0s 38us/step - loss: 2.8975e-05 -
accuracy: 1.0000
Epoch 48/200
3825/3825 [==============================] - 0s 37us/step - loss: 2.7525e-05 -
accuracy: 1.0000
Epoch 49/200
3825/3825 [==============================] - 0s 38us/step - loss: 2.6167e-05 -
accuracy: 1.0000
Epoch 50/200
3825/3825 [==============================] - 0s 38us/step - loss: 2.4903e-05 -
accuracy: 1.0000
Epoch 51/200
3825/3825 [==============================] - 0s 38us/step - loss: 2.3708e-05 -
accuracy: 1.0000
Epoch 52/200
3825/3825 [==============================] - 0s 38us/step - loss: 2.2577e-05 -
accuracy: 1.0000
Epoch 53/200
3825/3825 [==============================] - 0s 55us/step - loss: 2.1526e-05 -
accuracy: 1.0000
Epoch 54/200
3825/3825 [==============================] - 0s 49us/step - loss: 2.0526e-05 -
```

```
accuracy: 1.0000
Epoch 55/200
3825/3825 [==============================] - 0s 43us/step - loss: 1.9584e-05 -
accuracy: 1.0000
Epoch 56/200
3825/3825 [==============================] - 0s 68us/step - loss: 1.8696e-05 -
accuracy: 1.0000
Epoch 57/200
3825/3825 [==============================] - 0s 38us/step - loss: 1.7854e-05 -
accuracy: 1.0000
Epoch 58/200
3825/3825 [==============================] - 0s 36us/step - loss: 1.7064e-05 -
accuracy: 1.0000
Epoch 59/200
3825/3825 [==============================] - 0s 35us/step - loss: 1.6312e-05 -
accuracy: 1.0000
Epoch 60/200
3825/3825 [==============================] - 0s 46us/step - loss: 1.5598e-05 -
accuracy: 1.0000
Epoch 61/200
3825/3825 [==============================] - 0s 58us/step - loss: 1.4920e-05 -
accuracy: 1.0000
Epoch 62/200
3825/3825 [==============================] - 0s 37us/step - loss: 1.4278e-05 -
accuracy: 1.0000
Epoch 63/200
3825/3825 [==============================] - 0s 36us/step - loss: 1.3674e-05 -
accuracy: 1.0000
Epoch 64/200
3825/3825 [==============================] - 0s 37us/step - loss: 1.3092e-05 -
accuracy: 1.0000
Epoch 65/200
3825/3825 [==============================] - 0s 40us/step - loss: 1.2548e-05 -
accuracy: 1.0000
Epoch 66/200
3825/3825 [==============================] - 0s 40us/step - loss: 1.2018e-05 -
accuracy: 1.0000
Epoch 67/200
3825/3825 [==============================] - 0s 38us/step - loss: 1.1522e-05 -
accuracy: 1.0000
Epoch 68/200
3825/3825 [==============================] - 0s 36us/step - loss: 1.1048e-05 -
accuracy: 1.0000
Epoch 69/200
3825/3825 [==============================] - 0s 36us/step - loss: 1.0602e-05 -
accuracy: 1.0000
Epoch 70/200
3825/3825 [==============================] - 0s 35us/step - loss: 1.0170e-05 -
```

```
accuracy: 1.0000
Epoch 71/200
3825/3825 [==============================] - 0s 37us/step - loss: 9.7612e-06 -
accuracy: 1.0000
Epoch 72/200
3825/3825 [==============================] - 0s 38us/step - loss: 9.3692e-06 -
accuracy: 1.0000
Epoch 73/200
3825/3825 [==============================] - 0s 39us/step - loss: 8.9992e-06 -
accuracy: 1.0000
Epoch 74/200
3825/3825 [==============================] - 0s 37us/step - loss: 8.6426e-06 -
accuracy: 1.0000
Epoch 75/200
3825/3825 [==============================] - 0s 39us/step - loss: 8.3008e-06 -
accuracy: 1.0000
Epoch 76/200
3825/3825 [==============================] - 0s 37us/step - loss: 7.9769e-06 -
accuracy: 1.0000
Epoch 77/200
3825/3825 [==============================] - 0s 35us/step - loss: 7.6678e-06 -
accuracy: 1.0000
Epoch 78/200
3825/3825 [==============================] - 0s 35us/step - loss: 7.3694e-06 -
accuracy: 1.0000
Epoch 79/200
3825/3825 [==============================] - 0s 34us/step - loss: 7.0861e-06 -
accuracy: 1.0000
Epoch 80/200
3825/3825 [==============================] - 0s 34us/step - loss: 6.8147e-06 -
accuracy: 1.0000
Epoch 81/200
3825/3825 [==============================] - 0s 33us/step - loss: 6.5560e-06 -
accuracy: 1.0000
Epoch 82/200
3825/3825 [==============================] - 0s 33us/step - loss: 6.3074e-06 -
accuracy: 1.0000
Epoch 83/200
3825/3825 [==============================] - 0s 33us/step - loss: 6.0677e-06 -
accuracy: 1.0000
Epoch 84/200
3825/3825 [==============================] - 0s 34us/step - loss: 5.8399e-06 -
accuracy: 1.0000
Epoch 85/200
3825/3825 [==============================] - 0s 34us/step - loss: 5.6212e-06 -
accuracy: 1.0000
Epoch 86/200
3825/3825 [==============================] - 0s 34us/step - loss: 5.4104e-06 -
```

```
accuracy: 1.0000
Epoch 87/200
3825/3825 [==============================] - 0s 33us/step - loss: 5.2112e-06 -
accuracy: 1.0000
Epoch 88/200
3825/3825 [==============================] - 0s 33us/step - loss: 5.0167e-06 -
accuracy: 1.0000
Epoch 89/200
3825/3825 [==============================] - 0s 33us/step - loss: 4.8327e-06 -
accuracy: 1.0000
Epoch 90/200
3825/3825 [==============================] - 0s 34us/step - loss: 4.6548e-06 -
accuracy: 1.0000
Epoch 91/200
3825/3825 [==============================] - 0s 33us/step - loss: 4.4847e-06 -
accuracy: 1.0000
Epoch 92/200
3825/3825 [==============================] - 0s 34us/step - loss: 4.3205e-06 -
accuracy: 1.0000
Epoch 93/200
3825/3825 [==============================] - 0s 34us/step - loss: 4.1656e-06 -
accuracy: 1.0000
Epoch 94/200
3825/3825 [==============================] - 0s 34us/step - loss: 4.0125e-06 -
accuracy: 1.0000
Epoch 95/200
3825/3825 [==============================] - 0s 33us/step - loss: 3.8687e-06 -
accuracy: 1.0000
Epoch 96/200
3825/3825 [==============================] - 0s 33us/step - loss: 3.7291e-06 -
accuracy: 1.0000
Epoch 97/200
3825/3825 [==============================] - 0s 33us/step - loss: 3.5947e-06 -
accuracy: 1.0000
Epoch 98/200
3825/3825 [==============================] - 0s 34us/step - loss: 3.4668e-06 -
accuracy: 1.0000
Epoch 99/200
3825/3825 [==============================] - 0s 34us/step - loss: 3.3437e-06 -
accuracy: 1.0000
Epoch 100/200
3825/3825 [==============================] - 0s 34us/step - loss: 3.2246e-06 -
accuracy: 1.0000
Epoch 101/200
3825/3825 [==============================] - 0s 34us/step - loss: 3.1095e-06 -
accuracy: 1.0000
Epoch 102/200
3825/3825 [==============================] - 0s 33us/step - loss: 2.9995e-06 -
```

```
accuracy: 1.0000
Epoch 103/200
3825/3825 [==============================] - 0s 34us/step - loss: 2.8943e-06 -
accuracy: 1.0000
Epoch 104/200
3825/3825 [==============================] - 0s 34us/step - loss: 2.7927e-06 -
accuracy: 1.0000
Epoch 105/200
3825/3825 [==============================] - 0s 33us/step - loss: 2.6944e-06 -
accuracy: 1.0000
Epoch 106/200
3825/3825 [==============================] - 0s 34us/step - loss: 2.6007e-06 -
accuracy: 1.0000
Epoch 107/200
3825/3825 [==============================] - 0s 34us/step - loss: 2.5096e-06 -
accuracy: 1.0000
Epoch 108/200
3825/3825 [==============================] - 0s 34us/step - loss: 2.4222e-06 -
accuracy: 1.0000
Epoch 109/200
3825/3825 [==============================] - 0s 34us/step - loss: 2.3383e-06 -
accuracy: 1.0000
Epoch 110/200
3825/3825 [==============================] - 0s 35us/step - loss: 2.2571e-06 -
accuracy: 1.0000
Epoch 111/200
3825/3825 [==============================] - 0s 37us/step - loss: 2.1791e-06 -
accuracy: 1.0000
Epoch 112/200
3825/3825 [==============================] - 0s 36us/step - loss: 2.1040e-06 -
accuracy: 1.0000
Epoch 113/200
3825/3825 [==============================] - 0s 36us/step - loss: 2.0315e-06 -
accuracy: 1.0000
Epoch 114/200
3825/3825 [==============================] - 0s 36us/step - loss: 1.9615e-06 -
accuracy: 1.0000
Epoch 115/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.8941e-06 -
accuracy: 1.0000
Epoch 116/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.8296e-06 -
accuracy: 1.0000
Epoch 117/200
3825/3825 [==============================] - 0s 35us/step - loss: 1.7670e-06 -
accuracy: 1.0000
Epoch 118/200
3825/3825 [==============================] - 0s 38us/step - loss: 1.7072e-06 -
```

```
accuracy: 1.0000
Epoch 119/200
3825/3825 [==============================] - 0s 35us/step - loss: 1.6485e-06 -
accuracy: 1.0000
Epoch 120/200
3825/3825 [==============================] - 0s 36us/step - loss: 1.5929e-06 -
accuracy: 1.0000
Epoch 121/200
3825/3825 [==============================] - 0s 35us/step - loss: 1.5388e-06 -
accuracy: 1.0000
Epoch 122/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.4869e-06 -
accuracy: 1.0000
Epoch 123/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.4363e-06 -
accuracy: 1.0000
Epoch 124/200
3825/3825 [==============================] - 0s 33us/step - loss: 1.3883e-06 -
accuracy: 1.0000
Epoch 125/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.3416e-06 -
accuracy: 1.0000
Epoch 126/200
3825/3825 [==============================] - 0s 35us/step - loss: 1.2965e-06 -
accuracy: 1.0000
Epoch 127/200
3825/3825 [==============================] - 0s 37us/step - loss: 1.2531e-06 -
accuracy: 1.0000
Epoch 128/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.2112e-06 -
accuracy: 1.0000
Epoch 129/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.1709e-06 -
accuracy: 1.0000
Epoch 130/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.1319e-06 -
accuracy: 1.0000
Epoch 131/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.0942e-06 -
accuracy: 1.0000
Epoch 132/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.0576e-06 -
accuracy: 1.0000
Epoch 133/200
3825/3825 [==============================] - 0s 34us/step - loss: 1.0227e-06 -
accuracy: 1.0000
Epoch 134/200
3825/3825 [==============================] - 0s 70us/step - loss: 9.8890e-07 -
```

```
accuracy: 1.0000
Epoch 135/200
3825/3825 [==============================] - 0s 68us/step - loss: 9.5619e-07 -
accuracy: 1.0000
Epoch 136/200
3825/3825 [==============================] - 0s 51us/step - loss: 9.2461e-07 -
accuracy: 1.0000
Epoch 137/200
3825/3825 [==============================] - 0s 40us/step - loss: 8.9418e-07 -
accuracy: 1.0000
Epoch 138/200
3825/3825 [==============================] - 0s 66us/step - loss: 8.6482e-07 -
accuracy: 1.0000
Epoch 139/200
3825/3825 [==============================] - 0s 39us/step - loss: 8.3633e-07 -
accuracy: 1.0000
Epoch 140/200
3825/3825 [==============================] - 0s 34us/step - loss: 8.0896e-07 -
accuracy: 1.0000
Epoch 141/200
3825/3825 [==============================] - 0s 40us/step - loss: 7.8250e-07 -
accuracy: 1.0000
Epoch 142/200
3825/3825 [==============================] - 0s 48us/step - loss: 7.5685e-07 -
accuracy: 1.0000
Epoch 143/200
3825/3825 [==============================] - 0s 47us/step - loss: 7.3206e-07 -
accuracy: 1.0000
Epoch 144/200
3825/3825 [==============================] - 0s 43us/step - loss: 7.0834e-07 -
accuracy: 1.0000
Epoch 145/200
3825/3825 [==============================] - 0s 45us/step - loss: 6.8511e-07 -
accuracy: 1.0000
Epoch 146/200
3825/3825 [==============================] - 0s 47us/step - loss: 6.6304e-07 -
accuracy: 1.0000
Epoch 147/200
3825/3825 [==============================] - 0s 47us/step - loss: 6.4146e-07 -
accuracy: 1.0000
Epoch 148/200
3825/3825 [==============================] - 0s 46us/step - loss: 6.2069e-07 -
accuracy: 1.0000
Epoch 149/200
3825/3825 [==============================] - 0s 46us/step - loss: 6.0059e-07 -
accuracy: 1.0000
Epoch 150/200
3825/3825 [==============================] - 0s 47us/step - loss: 5.8126e-07 -
```

```
accuracy: 1.0000
Epoch 151/200
3825/3825 [==============================] - 0s 46us/step - loss: 5.6248e-07 -
accuracy: 1.0000
Epoch 152/200
3825/3825 [==============================] - 0s 55us/step - loss: 5.4446e-07 -
accuracy: 1.0000
Epoch 153/200
3825/3825 [==============================] - 0s 59us/step - loss: 5.2686e-07 -
accuracy: 1.0000
Epoch 154/200
3825/3825 [==============================] - 0s 45us/step - loss: 5.1000e-07 -
accuracy: 1.0000
Epoch 155/200
3825/3825 [==============================] - 0s 41us/step - loss: 4.9360e-07 -
accuracy: 1.0000
Epoch 156/200
3825/3825 [==============================] - 0s 38us/step - loss: 4.7789e-07 -
accuracy: 1.0000
Epoch 157/200
3825/3825 [==============================] - 0s 37us/step - loss: 4.6258e-07 -
accuracy: 1.0000
Epoch 158/200
3825/3825 [==============================] - 0s 67us/step - loss: 4.4792e-07 -
accuracy: 1.0000
Epoch 159/200
3825/3825 [==============================] - 0s 71us/step - loss: 4.3364e-07 -
accuracy: 1.0000
Epoch 160/200
3825/3825 [==============================] - 0s 38us/step - loss: 4.1981e-07 -
accuracy: 1.0000
Epoch 161/200
3825/3825 [==============================] - 0s 36us/step - loss: 4.0665e-07 -
accuracy: 1.0000
Epoch 162/200
3825/3825 [==============================] - 0s 47us/step - loss: 3.9367e-07 -
accuracy: 1.0000
Epoch 163/200
3825/3825 [==============================] - 0s 50us/step - loss: 3.8125e-07 -
accuracy: 1.0000
Epoch 164/200
3825/3825 [==============================] - 0s 50us/step - loss: 3.6916e-07 -
accuracy: 1.0000
Epoch 165/200
3825/3825 [==============================] - 0s 50us/step - loss: 3.5749e-07 -
accuracy: 1.0000
Epoch 166/200
3825/3825 [==============================] - 0s 39us/step - loss: 3.4618e-07 -
```

```
accuracy: 1.0000
Epoch 167/200
3825/3825 [==============================] - 0s 37us/step - loss: 3.3542e-07 -
accuracy: 1.0000
Epoch 168/200
3825/3825 [==============================] - 0s 47us/step - loss: 3.2475e-07 -
accuracy: 1.0000
Epoch 169/200
3825/3825 [==============================] - 0s 80us/step - loss: 3.1450e-07 -
accuracy: 1.0000
Epoch 170/200
3825/3825 [==============================] - 0s 54us/step - loss: 3.0477e-07 -
accuracy: 1.0000
Epoch 171/200
3825/3825 [==============================] - 0s 36us/step - loss: 2.9515e-07 -
accuracy: 1.0000
Epoch 172/200
3825/3825 [==============================] - 0s 42us/step - loss: 2.8597e-07 -
accuracy: 1.0000
Epoch 173/200
3825/3825 [==============================] - 0s 49us/step - loss: 2.7708e-07 -
accuracy: 1.0000
Epoch 174/200
3825/3825 [==============================] - 0s 51us/step - loss: 2.6851e-07 -
accuracy: 1.0000
Epoch 175/200
3825/3825 [==============================] - 0s 64us/step - loss: 2.6008e-07 -
accuracy: 1.0000
Epoch 176/200
3825/3825 [==============================] - 0s 40us/step - loss: 2.5200e-07 -
accuracy: 1.0000
Epoch 177/200
3825/3825 [==============================] - 0s 45us/step - loss: 2.4419e-07 -
accuracy: 1.0000
Epoch 178/200
3825/3825 [==============================] - 0s 63us/step - loss: 2.3661e-07 -
accuracy: 1.0000
Epoch 179/200
3825/3825 [==============================] - 0s 42us/step - loss: 2.2935e-07 -
accuracy: 1.0000
Epoch 180/200
3825/3825 [==============================] - 0s 40us/step - loss: 2.2229e-07 -
accuracy: 1.0000
Epoch 181/200
3825/3825 [==============================] - 0s 40us/step - loss: 2.1544e-07 -
accuracy: 1.0000
Epoch 182/200
3825/3825 [==============================] - 0s 42us/step - loss: 2.0882e-07 -
```

```
accuracy: 1.0000
Epoch 183/200
3825/3825 [==============================] - 0s 43us/step - loss: 2.0239e-07 -
accuracy: 1.0000
Epoch 184/200
3825/3825 [==============================] - 0s 48us/step - loss: 1.9622e-07 -
accuracy: 1.0000
Epoch 185/200
3825/3825 [==============================] - 0s 76us/step - loss: 1.9022e-07 -
accuracy: 1.0000
Epoch 186/200
3825/3825 [==============================] - 0s 63us/step - loss: 1.8442e-07 -
accuracy: 1.0000
Epoch 187/200
3825/3825 [==============================] - 0s 40us/step - loss: 1.7883e-07 -
accuracy: 1.0000
Epoch 188/200
3825/3825 [==============================] - 0s 43us/step - loss: 1.7339e-07 -
accuracy: 1.0000
Epoch 189/200
3825/3825 [==============================] - 0s 69us/step - loss: 1.6813e-07 -
accuracy: 1.0000
Epoch 190/200
3825/3825 [==============================] - 0s 41us/step - loss: 1.6305e-07 -
accuracy: 1.0000
Epoch 191/200
3825/3825 [==============================] - 0s 36us/step - loss: 1.5812e-07 -
accuracy: 1.0000
Epoch 192/200
3825/3825 [==============================] - 0s 39us/step - loss: 1.5336e-07 -
accuracy: 1.0000
Epoch 193/200
3825/3825 [==============================] - 0s 52us/step - loss: 1.4873e-07 -
accuracy: 1.0000
Epoch 194/200
3825/3825 [==============================] - 0s 40us/step - loss: 1.4425e-07 -
accuracy: 1.0000
Epoch 195/200
3825/3825 [==============================] - 0s 36us/step - loss: 1.3995e-07 -
accuracy: 1.0000
Epoch 196/200
3825/3825 [==============================] - 0s 37us/step - loss: 1.3573e-07 -
accuracy: 1.0000
Epoch 197/200
3825/3825 [==============================] - 0s 47us/step - loss: 1.3167e-07 -
accuracy: 1.0000
Epoch 198/200
3825/3825 [==============================] - 0s 69us/step - loss: 1.2776e-07 -
```

```
accuracy: 1.0000
Epoch 199/200
3825/3825 [==============================] - 0s 62us/step - loss: 1.2395e-07 -
accuracy: 1.0000
Epoch 200/200
3825/3825 [==============================] - 0s 41us/step - loss: 1.2028e-07 -
accuracy: 1.0000
```

[24]:
```python
acc = history.history['accuracy']
loss = history.history['loss']
epochs = range(len(acc))
plt.plot(epochs, acc, 'b', label='Training accuracy')
plt.title('Training accuracy')
plt.figure()
plt.plot(epochs, loss, 'b', label='Training Loss')
plt.title('Training loss')
plt.legend()
plt.show()
```

Training loss
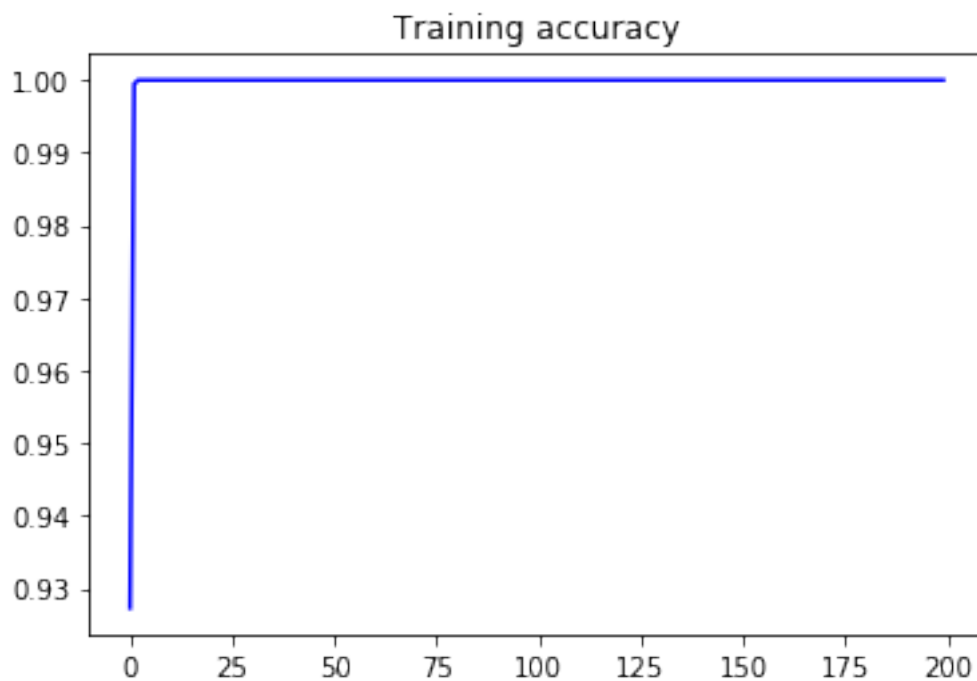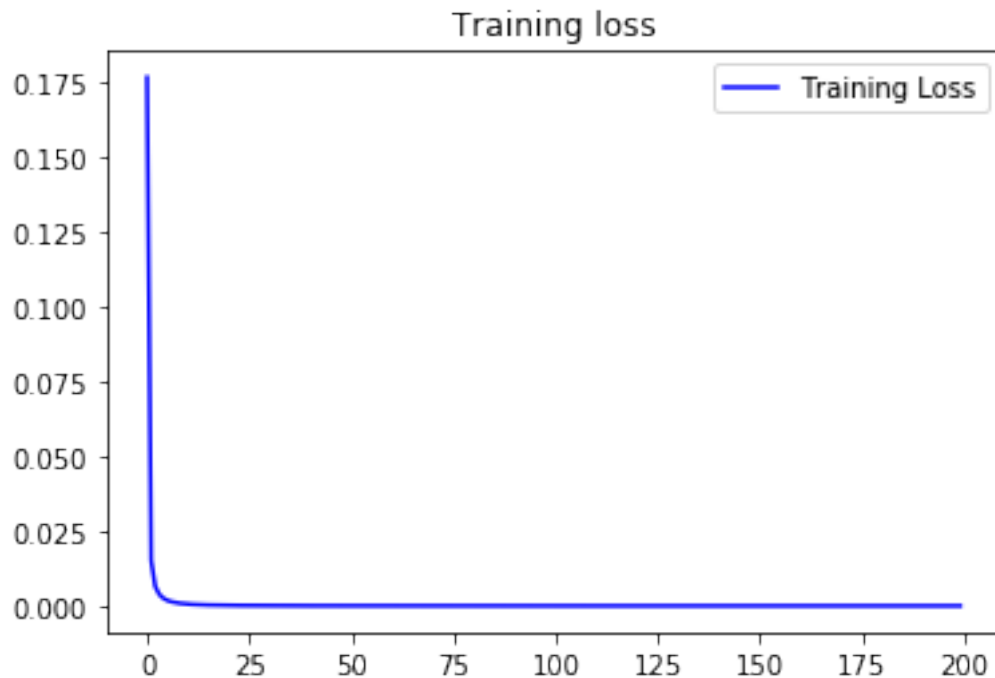
4 Task 2

Test the model on the test set.

```
[35]:  # START YOUR CODE HERE
       [test_loss, test_acc] = model.evaluate(X_test, y_test, verbose=0)
       print("Evaluation: Loss = {}, accuracy = {}".format(test_loss, test_acc))
```

Evaluation: Loss = 0.003374846804157035, accuracy = 0.9985185265541077

5 Congratulations!

You've come to the end of this assignment, and you have built your first neural network.

Congratulations on finishing this notebook!

```
[ ]:
```