# bat hits

April 12, 2021

## 1 Loading and Viewing

[1]:

```
!pip install tensorflow
```

```
Requirement already satisfied: tensorflow in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (2.4.1)
Requirement already satisfied: numpy~=1.19.2 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (1.19.5)
Requirement already satisfied: tensorflow-estimator<2.5.0,>=2.4.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (2.4.0)
Requirement already satisfied: opt-einsum~=3.3.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (3.3.0)
Requirement already satisfied: absl-py~=0.10 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (0.12.0)
Requirement already satisfied: google-pasta~=0.2 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (0.2.0)
Requirement already satisfied: h5py~=2.10.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (2.10.0)
Requirement already satisfied: flatbuffers~=1.12.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (1.12)
Requirement already satisfied: termcolor~=1.1.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (1.1.0)
Requirement already satisfied: typing-extensions~=3.7.4 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (3.7.4.2)
Requirement already satisfied: wheel~=0.35 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (0.36.2)
Requirement already satisfied: wrapt~=1.12.1 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (1.12.1)
Requirement already satisfied: tensorboard~=2.4 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (2.4.1)
Requirement already satisfied: astunparse~=1.6.3 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (1.6.3)
Requirement already satisfied: protobuf>=3.9.2 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (3.15.8)
Requirement already satisfied: grpcio~=1.32.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (1.32.0)
Requirement already satisfied: keras-preprocessing~=1.1.2 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (1.1.2)
```

```
Requirement already satisfied: six~=1.15.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (1.15.0)
Requirement already satisfied: gast==0.3.3 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from tensorflow) (0.3.3)
Requirement already satisfied: werkzeug>=0.11.15 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
tensorboard~=2.4->tensorflow) (1.0.1)
Requirement already satisfied: tensorboard-plugin-wit>=1.6.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
tensorboard~=2.4->tensorflow) (1.8.0)
Requirement already satisfied: google-auth<2,>=1.6.3 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
tensorboard~=2.4->tensorflow) (1.28.1)
Requirement already satisfied: google-auth-oauthlib<0.5,>=0.4.1 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
tensorboard~=2.4->tensorflow) (0.4.4)
Requirement already satisfied: requests<3,>=2.21.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
tensorboard~=2.4->tensorflow) (2.24.0)
Requirement already satisfied: markdown>=2.6.8 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
tensorboard~=2.4->tensorflow) (3.3.4)
Requirement already satisfied: setuptools>=41.0.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
tensorboard~=2.4->tensorflow) (49.2.0.post20200714)
Requirement already satisfied: pyasn1-modules>=0.2.1 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from google-
auth<2,>=1.6.3->tensorboard~=2.4->tensorflow) (0.2.8)
Requirement already satisfied: cachetools<5.0,>=2.0.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from google-
auth<2,>=1.6.3->tensorboard~=2.4->tensorflow) (4.2.1)
Requirement already satisfied: rsa<5,>=3.1.4; python_version >= "3.6" in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from google-
auth<2,>=1.6.3->tensorboard~=2.4->tensorflow) (4.7.2)
Requirement already satisfied: requests-oauthlib>=0.7.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from google-auth-
oauthlib<0.5,>=0.4.1->tensorboard~=2.4->tensorflow) (1.3.0)
Requirement already satisfied: chardet<4,>=3.0.2 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
requests<3,>=2.21.0->tensorboard~=2.4->tensorflow) (3.0.4)
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
requests<3,>=2.21.0->tensorboard~=2.4->tensorflow) (1.25.9)
Requirement already satisfied: certifi>=2017.4.17 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
requests<3,>=2.21.0->tensorboard~=2.4->tensorflow) (2020.6.20)
Requirement already satisfied: idna<3,>=2.5 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
requests<3,>=2.21.0->tensorboard~=2.4->tensorflow) (2.10)
Requirement already satisfied: pyasn1<0.5.0,>=0.4.6 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from
pyasn1-modules>=0.2.1->google-auth<2,>=1.6.3->tensorboard~=2.4->tensorflow)
(0.4.8)
Requirement already satisfied: oauthlib>=3.0.0 in
/Users/oli/opt/anaconda3/lib/python3.8/site-packages (from requests-
oauthlib>=0.7.0->google-auth-oauthlib<0.5,>=0.4.1->tensorboard~=2.4->tensorflow)
(3.1.0)
```

[2]:

```python
import numpy as np  # Arrays, matrices and functions on them. Required by Pandas, below
import pandas as pd # A data analysis library
from sklearn.model_selection import train_test_split # scikit-learn, machine learning tools
import matplotlib.pyplot as plt # A plotting library
import seaborn as sns # Built on matplotlib, facilitates aesthetically pleasing plots
import tensorflow as tf # Fast numerical computation for machine learning, computations on GPU or CPU
import tensorflow.keras as keras # High-level interface to TensorFlow, making it easier to create neural networks
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Activation
import time
```

[3]:

```python
# General settings
sns.set_style('whitegrid') # Plots will have a white grid
# Variables that will help us work with the classes
class_names = ['hit', 'miss']
class_colors = ['darkorange', 'steelblue']
```

[4]:

```python
def load_data(filename):
    hits_df = pd.read_csv(filename, header=None) # Use Pandas to load the data into a Pandas DataFrame
    print('Loaded from', filename)
    hits_data = hits_df.values # Convert from a Pandas DataFrame to a numpy array
    print('The shape of hits_data is', hits_data.shape)
    print('Number of samples of class 0 (hit)', (hits_data[:,0].astype(int) == 0).sum())
    print('Number of samples of class 1 (miss)', (hits_data[:,0].astype(int) == 1).sum())
    print('')
    return hits_data
```

[5]:
```
def plot_data_samples(data, labels, sample_numbers):
    ''' Plot the time series data relating to the input list of sample numbers␣
 ↪'''
    # Input format - a list, e.g. [1, 7, 22, 42]
    fig, ax = plt.subplots()

    for i in sample_numbers:
        plt.plot(data[i], label=class_names[labels[i]],␣
 ↪color=class_colors[labels[i]])
        print('sample', i, 'class', str(labels[i]), class_names[labels[i]])

    print('')
    plt.ylim([0, 7])
    plt.title('Orange : hit (class 0)\nBlue : miss (class 1)')
    ax.set_ylabel('Accelerometer data')
    ax.set_xlabel('Data point number')
```

[6]:
```
def plot_single_sample(data, sample_number):
    ''' Plot the time series data relating to this sample number. '''
    fig, ax = plt.subplots()
    plt.plot(data[sample_number], color='darkred')
    txt = 'Sample '+str(sample_number)+': Hit or miss?\nDo you recognise the␣
 ↪data\'s pattern?'
    plt.suptitle(txt)
    ax.set_ylabel('Standardised x-axis accelerometer data')
    ax.set_xlabel('Data point number')
```

[7]:
```
filename = 'BatHits_TSD.csv'
hits_data = load_data(filename) # This is a function that we created earlier in␣
 ↪this notebook
```

```
Loaded from BatHits_TSD.csv
The shape of hits_data is (39, 201)
Number of samples of class 0 (hit) 14
Number of samples of class 1 (miss) 25
```

[8]:
```
# Print information about the data's shape and size
print('The hits_data is a matrix. These are the first 7 rows and 5 columns of␣
 ↪hits_data:\n', hits_data[:7, :5], '\n')

labels = hits_data[:,0].astype(int)
data = hits_data[:,1:]
print('The shape of the data matrix is', data.shape)
print('The shape of the labels vector is', labels.shape)
```

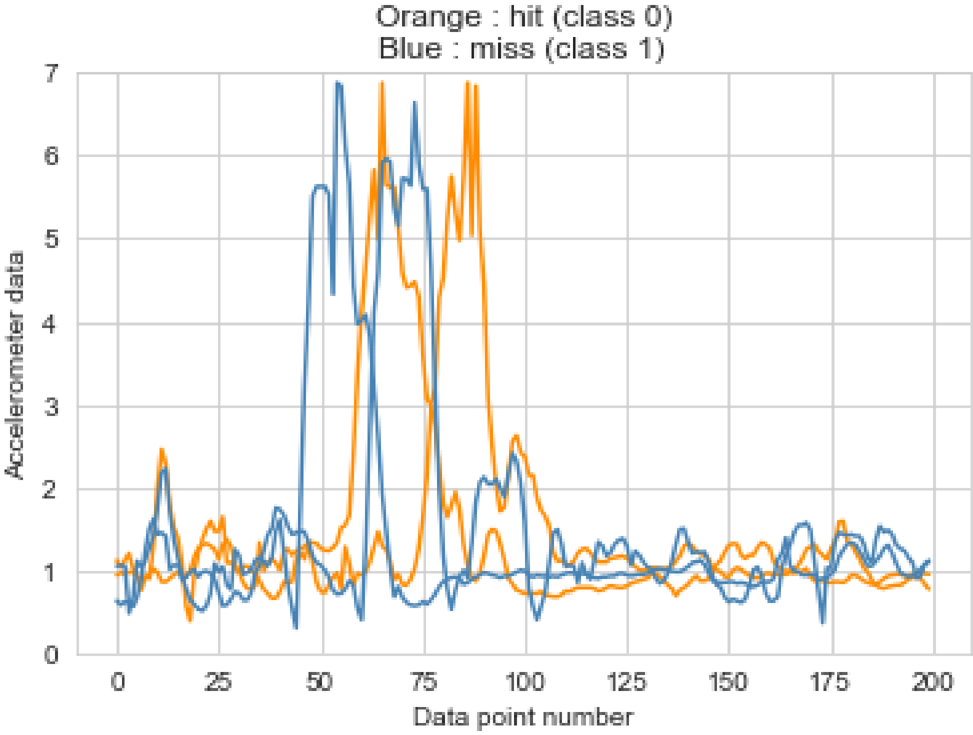
```
The hits_data is a matrix. These are the first 7 rows and 5 columns of
hits_data:
 [[0.   0.94 0.97 0.95 0.98]
 [0.   1.12 1.03 1.12 1.2 ]
 [0.   1.11 1.06 0.99 0.98]
 [0.   1.13 1.19 1.15 1.34]
 [0.   1.   1.12 0.58 0.27]
 [0.   1.16 1.17 1.19 1.21]
 [1.   1.05 1.06 1.05 0.48]]

The shape of the data matrix is (39, 200)
The shape of the labels vector is (39,)
```

[9]:

```
plot_data_samples(data, labels, [0, 1, 6, 7]) ### CHANGE PARAMETER HERE ###
```

```
sample 0 class 0 hit
sample 1 class 0 hit
sample 6 class 1 miss
sample 7 class 1 miss
```



[10]:

```
test_size = 10 ### CHANGE PARAMETER HERE ###

data_train, data_test, labels_train, labels_test = train_test_split(
    data, labels, test_size=test_size, random_state=21, stratify=labels)
```

```
print('The shape of train_data is', data_train.shape)
print('The shape of test_data is', data_test.shape)
print('Training data:')
print('Number of samples of class 0', (labels_train == 0).sum())
print('Number of samples of class 1', (labels_train == 1).sum())
print('Test data:')
print('Number of samples of class 0', (labels_test == 0).sum())
print('Number of samples of class 1', (labels_test == 1).sum())
```

```
The shape of train_data is (29, 200)
The shape of test_data is (10, 200)
Training data:
Number of samples of class 0 10
Number of samples of class 1 19
Test data:
Number of samples of class 0 4
Number of samples of class 1 6
```

## 2 Building and Training

[11]:

```
def plot_comparison(data_train, labels_train, data_test, labels_test,␣
 ↪test_sample):
    ''' Plot the given test sample alongside a few training samples of the same␣
 ↪class '''
    # Determine the true class of the given sample
    print('Test sample', test_sample, 'true class',␣
 ↪str(labels_test[test_sample]), class_names[labels_test[test_sample]])
    true_class = labels_test[test_sample]

    # Plot data samples that are in the same class
    fig, ax = plt.subplots()
    count = 0
    for i in range(100):
        if labels_train[i] == true_class:
            plt.plot(data_train[i], color=class_colors[labels_train[i]])
            print('Training sample', i, 'class', str(labels_train[i]),␣
 ↪class_names[labels_train[i]])
            count = count + 1
            if count > 4:
                break
    plt.ylim([-3.5, 3.5])
    plt.title('Walking on  '+class_names[true_class])
    ax.set_ylabel('Accelerometer data')
    ax.set_xlabel('Data point number')
    # Plot the test data sample
    plt.plot(data_test[test_sample], color='darkred')
```

[12]:

```
def plot_loss(log):
    ''' Plot the loss recorded in the log during model training '''
    ax = log[['loss', 'val_loss']].plot(title='Loss function during training',␣
 ↪color=class_colors)
    ax.set_xlabel("Model training epoch")
    ax.set_ylabel("Loss")
    ax.legend(["training", "validation"]);
```

[13]:

```
def plot_accuracy(log):
    ''' Plot the accuracy recorded in the log during model training '''
    ax = log[['accuracy', 'val_accuracy']].plot(title='Accuracy during␣
 ↪training', color=class_colors)
    ax.set_xlabel("Model training epoch")
    ax.set_ylabel("Accuracy")
    ax.legend(["training", "validation"]);
```

[14]:

```
def build_model(print_summary=False):
    ''' Return a model with randomly initialised weights '''
    model = Sequential([
        Dense(8, input_dim=input_dim, activation='relu', name='Layer1'),
        Dense(4, activation='relu', name='Layer2'),
        Dense(1, activation='sigmoid', name='OutputLayer')
    ])

    optimizer = keras.optimizers.Adam()
    model.compile(loss='binary_crossentropy', optimizer=optimizer,␣
 ↪metrics=['accuracy'])
    if print_summary:
        print(model.summary())
    return model
```

[15]:

```
# The size of the input vector
input_dim = data_train.shape[1]
model = build_model(True)
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
Layer1 (Dense)               (None, 8)                 1608
_________________________________________________________________
Layer2 (Dense)               (None, 4)                 36
_________________________________________________________________
OutputLayer (Dense)          (None, 1)                 5
=================================================================
Total params: 1,649
Trainable params: 1,649
Non-trainable params: 0

_________________________________________________________________
None
```

[16]:

```
result = model.evaluate(data_test, labels_test, batch_size=5)
print('Pre-training, validation accuracy is', result[1])
```

```
2/2 [==============================] - 0s 1ms/step - loss: 0.6072 - accuracy:
0.3333
Pre-training, validation accuracy is 0.4000000059604645
```

[17]:

```
batch_size = 8 ### CHANGE PARAMETER HERE ###
epochs = 10 ### CHANGE PARAMETER HERE ###

model = build_model() # This re-initialises the model with random weights each␣
 ↪time before we train it.

# Train
start = time.time()
hist = model.fit(data_train, labels_train, batch_size=batch_size, epochs=epochs,
                 validation_data=(data_test, labels_test), verbose=1)
end = time.time()
log = pd.DataFrame(hist.history)
print('Training complete in', round(end-start), 'seconds')
```

```
Epoch 1/10
4/4 [==============================] - 1s 165ms/step - loss: 0.6999 - accuracy:
0.6579 - val_loss: 0.6719 - val_accuracy: 0.6000
Epoch 2/10
4/4 [==============================] - 0s 12ms/step - loss: 0.6843 - accuracy:
0.6454 - val_loss: 0.6565 - val_accuracy: 0.6000
Epoch 3/10
4/4 [==============================] - 0s 12ms/step - loss: 0.6079 - accuracy:
0.7162 - val_loss: 0.6525 - val_accuracy: 0.6000
Epoch 4/10
4/4 [==============================] - 0s 12ms/step - loss: 0.6482 - accuracy:
0.6579 - val_loss: 0.6474 - val_accuracy: 0.6000
Epoch 5/10
4/4 [==============================] - 0s 13ms/step - loss: 0.6315 - accuracy:
0.6800 - val_loss: 0.6416 - val_accuracy: 0.5000
Epoch 6/10
4/4 [==============================] - 0s 12ms/step - loss: 0.6292 - accuracy:
0.6496 - val_loss: 0.6445 - val_accuracy: 0.5000
Epoch 7/10
4/4 [==============================] - 0s 11ms/step - loss: 0.6488 - accuracy:
0.6079 - val_loss: 0.6461 - val_accuracy: 0.5000
Epoch 8/10
```

```
4/4 [==============================] - 0s 12ms/step - loss: 0.5897 - accuracy:
0.6246 - val_loss: 0.6428 - val_accuracy: 0.5000
Epoch 9/10
4/4 [==============================] - 0s 12ms/step - loss: 0.5879 - accuracy:
0.6871 - val_loss: 0.6422 - val_accuracy: 0.5000
Epoch 10/10
4/4 [==============================] - 0s 12ms/step - loss: 0.5852 - accuracy:
0.7175 - val_loss: 0.6454 - val_accuracy: 0.6000
Training complete in 1 seconds
```

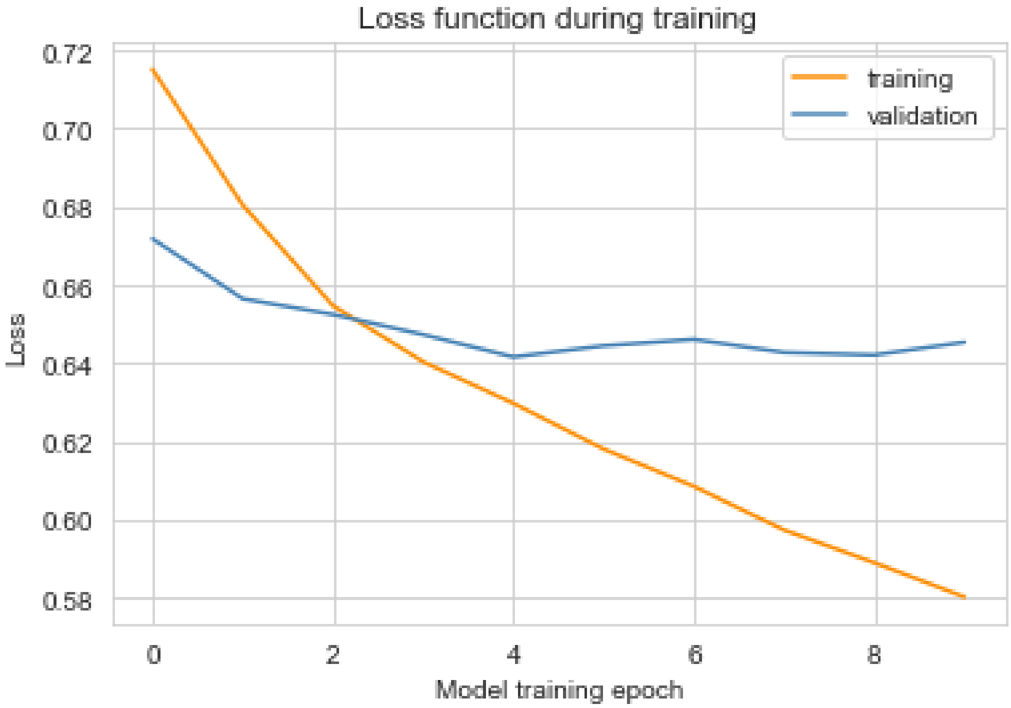
[18]:

```python
# Use the trained model to classify the test dataset.
result = model.evaluate(data_test, labels_test, batch_size=batch_size)
print('Validation accuracy:\t', result[1])
print('Validation loss:\t', result[0])
print('test_size:\t', test_size)
print('batch_size:\t', batch_size)
print('epochs:\t\t', epochs)
```

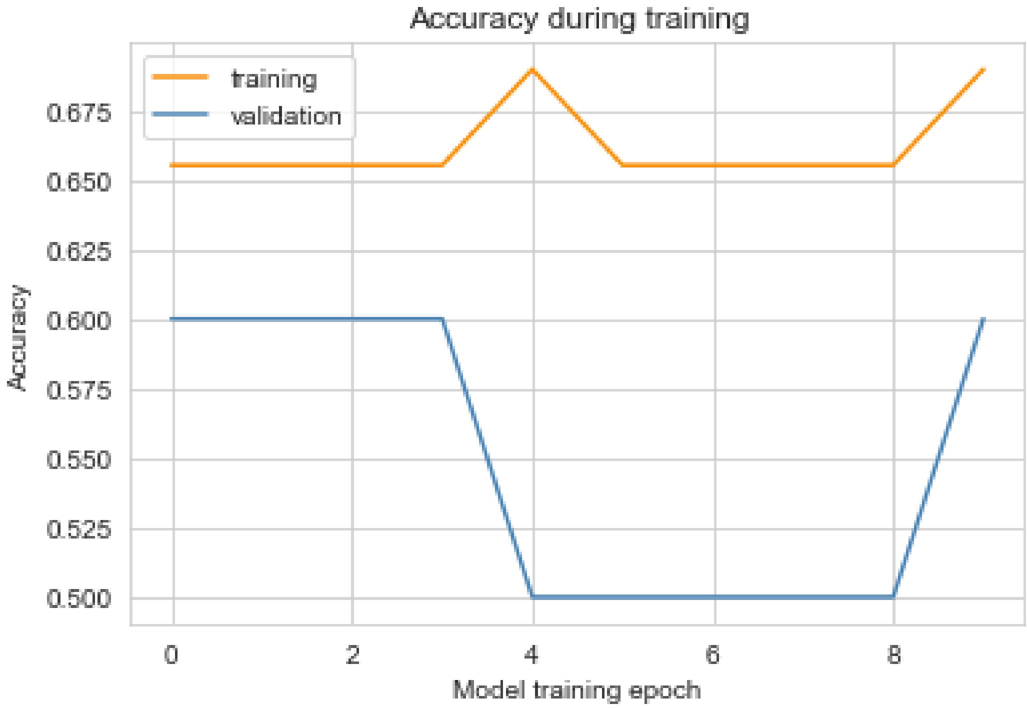
```
2/2 [==============================] - 0s 2ms/step - loss: 0.6454 - accuracy:
0.6000
Validation accuracy:     0.6000000238418579
Validation loss:         0.6454225778579712
test_size:       10
batch_size:      8
epochs:          10
```

[19]:

```python
# Plot the training log's loss dxata.
plot_loss(log)
```



[20]:
```
# Plot the training log's accuracy data.
plot_accuracy(log)
```



```
[21]: sample_num = 3 ### CHANGE PARAMETER HERE ###
      data_sample = data_test[sample_num]
      data_sample = np.array( [data_sample,] ) # Convert the data sample into the␣
       ↪shape expected by the MLP
      probability = model.predict(data_sample)
      print('Model: probability of belonging to class 1:', probability[0][0])
      print('Predicted class:\t', (np.round(probability)[0][0].astype(int))) # \t␣
       ↪inserts a tab space into the text
      print('True class:\t\t', labels_test[sample_num])
```

```
Model: probability of belonging to class 1: 0.50909096
Predicted class:         1
True class:              1
```

```
[ ]:
```