DNN_Lab

March 3, 2025

1 Deep Neural Networks Laboration

1.0.1 Quick introduction to jupyter notebooks

- Each cell in this notebook contains either code or text.
- You can run a cell by pressing Ctrl-Enter, or run and advance to the next cell with Shift-Enter.
- Code cells will print their output, including images, below the cell. Running it again deletes the previous output, so be careful if you want to save some results.
- You don't have to rerun all cells to test changes, just rerun the cell you have made changes to. Some exceptions might apply, for example if you overwrite variables from previous cells, but in general this will work.
- If all else fails, use the "Kernel" menu and select "Restart Kernel and Clear All Output". You can also use this menu to run all cells.
- A useful debug tool is the console. You can right-click anywhere in the notebook and select "New console for notebook". This opens a python console which shares the environment with the notebook, which let's you easily print variables or test commands.

[1]:
```
# Setups
# Automatically reload modules when changed
%reload_ext autoreload
%autoreload 2
```

1.0.2 Your task

Your task is to make a DNN that can classify benign or malicious networks attacks using the Mirai dataset (see below).

You need to answer all the questions in the notebook. Also, for all classification tasks that you will explore, you should always answer these two questions: - How good classification accuracy can a naive classifier obtain? The naive classifier will assume that all examples belong to one class. - What is random chance classification accuracy if you randomly guess the label of each (test) example? For a balanced dataset and binary classification this is easy (50%), but in many cases it is more complicated and a Monte Carlo simulation may be required to estimate random chance accuracy.

If your classifier cannot perform better than a naive classifier or a random classifier, you are doing something wrong.

If the training is too slow on your own computer, use the smaller datasets (*half or* quarter).

Dense networks are not optimal for tabular datasets like the one used here, but here the main goal is to explore and get a a hands-on experience with deep learning.

2 Part 1: The Dataset

Data used in this laboration are from the Kitsune Network Attack Datase. We will focus on the 'Mirai' part of the dataset. Your task is to make a DNN that can classify if each attack is benign or malicious. The dataset has 116 covariates, but to make it a bit more difficult we will remove the first 24 covariates.

2.0.1 1.1 Load the data

Complete and run the following cell to to load the the `Mirai_data.npy` and the `Mirai_labels.npy` files and remove the first 24 covariances to make the classification task harder.

[2]:
```
import os
from numpy import genfromtxt # ! Not needed if you load data from numpy arrays !
import numpy as np

# Load data from numpy arrays, choose reduced files if the training takes too␣
 ↪long
# Load the dataset
X = np.load('Mirai_data.npy')
Y = np.load('Mirai_labels.npy')

# ------------------------------------------
# === Your code here =======================
# ------------------------------------------
# Remove the first 24 covariates (columns)
X = X[:,24:]
Y = Y

# Print the size of the covariates and labels
print(np.shape(X))
print(np.shape(Y))
# ==========================================
```

```
(764137, 92)
(764137,)
```

2.0.2 1.2 Explore the data (NaNs)

It is common to have NaNs (not a number) in the data, lets check for it.

[3]:
```
# ------------------------------------------
# === Your code here =======================
# ------------------------------------------

```

```
# It is common to have NaNs in the data, lets check for it. Hint: np.isnan()

# Fist check for NaNs in the data and then in the labels
print(np.isnan(Y).sum())
# Print the number of NaNs in the covariates
print(np.isnan(X).sum())
# ==========================================
```

```
0
0
```

2.0.3 1.3 Data preprocessing: normalization

[4]:
```
# ------------------------------------------
# === Your code here =======================
# ------------------------------------------

# Convert covariates to floats
X = X.astype(float)

# Convert labels to integers
Y = Y.astype(int)

# Remove mean of each covariate (column)
X = X - np.mean(X, axis=0)

# Divide each covariate (column) by its standard deviation
X = X / np.std(X, axis=0)

# Check that mean is 0 and standard deviation is 1 for all covariates, by␣
 ↪printing mean and std
print(np.mean(X, axis=0))
print(np.std(X, axis=0))
# ==========================================
```

```
[-3.19451533e-18 -6.32970181e-14  1.19926356e-13  4.56743018e-15
  4.10210037e-14  1.46130975e-13  5.85246484e-16 -1.69734859e-14
 -3.36915700e-13  1.28688437e-12 -2.69360995e-12 -1.10733213e-13
 -1.22392702e-13 -1.70649630e-13 -1.02461166e-14  2.50701280e-12
  1.47553162e-12  1.08446837e-12 -1.04981959e-13  6.83458762e-14
 -1.03373555e-13  5.98825773e-14 -1.02025960e-12 -1.68983055e-12
 -1.79101143e-12 -1.31828514e-13  4.42580403e-13  6.14635580e-13
  5.78048199e-14 -4.92623328e-13 -2.54513072e-12  1.86544900e-13
 -1.53444593e-13  1.68079591e-12  9.30041709e-13  1.50738177e-13
 -1.15688852e-12 -3.62610361e-13 -1.71390937e-12 -2.09264067e-13
  1.07161976e-12 -1.45236885e-12 -1.69724579e-14 -1.64918984e-16
 -5.13444996e-14 -1.02171349e-14 -1.74685907e-15  1.34264921e-13
  5.98801969e-14  1.48745574e-17 -4.25442340e-13  5.78079594e-14
```

```
 1.25638129e-15  1.69449684e-13  1.50725881e-13  2.14439542e-14
 3.65457183e-14  1.17260451e-13 -8.82752870e-13 -6.34816648e-13
-1.62109649e-12  2.63270303e-13 -7.57215123e-15 -2.89395002e-14
-3.90180996e-13 -1.53167085e-12 -9.57913621e-13  2.47411065e-13
 2.44200541e-13 -6.73050928e-15  1.07502596e-13  2.58222203e-13
-1.87714601e-13 -1.19882476e-12 -2.17154862e-12  5.48444735e-14
 5.46183481e-15  3.71315442e-14  1.47576646e-13 -1.62639245e-12
-1.23986972e-13 -1.71744315e-12  5.29956657e-13 -3.21442452e-14
-4.59767392e-14  3.56347870e-13 -1.48544246e-12 -1.26642728e-13
 1.52633871e-13  9.58048710e-14  4.34603426e-14 -4.07615740e-14]
[1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.
 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.]
```

Note: The mean is not exactly 0 for all covariates, probably due to some minor inaccuracies in the calculation.

2.0.4 1.4 Data split

Use the first 70% of the dataset for training, leave the other 30% for validation and test, call the variables: - `Xtrain` and `Ytrain` (70% of the dataset) - `Xtemp` and `Ytemp` (30% of the dataset)

We use a function from scikit learn (see the documentation for more details)

[5]:
```
from sklearn.model_selection import train_test_split

# ------------------------------------------
# === Your code here =======================
# ------------------------------------------

# split the original dataset into 70% Training and 30% Temp
Xtrain, Xtemp, Ytrain, Ytemp = train_test_split(X, Y, test_size=0.3,␣
 ↪random_state=42)

# Print the number of examples of each class, for the training data and the␣
 ↪remaining 30%
print(np.unique(Ytrain, return_counts=True))
print(np.unique(Ytemp, return_counts=True))
# ==========================================

print('Xtrain has size {}.'.format(Xtrain.shape))
print('Ytrain has size {}.'.format(Ytrain.shape))

print('Xtemp has size {}.'.format(Xtemp.shape))
print('Ytemp has size {}.'.format(Ytemp.shape))
```

```
(array([0, 1]), array([ 85248, 449647], dtype=int64))
(array([0, 1]), array([ 36373, 192869], dtype=int64))
```

```
Xtrain has size (534895, 92).
Ytrain has size (534895,).
Xtemp has size (229242, 92).
Ytemp has size (229242,).
```

Now split your non-training data (`Xtemp`, `Ytemp`) into 50% validation (`Xval`, `Yval`) and 50% testing (`Xtest`, `Ytest`), we use a function from scikit learn. In total this gives us 70% for training, 15% for validation, 15% for test.

[6]:
```
from sklearn.model_selection import train_test_split

# ------------------------------------------
# === Your code here =======================
# ------------------------------------------
# split the remaining 30% into 50% Validation and 50% Test
Xval, Xtest, Yval, Ytest = train_test_split(Xtemp, Ytemp, test_size=0.5,␣
 ↪random_state=42)

# ==========================================

print(f'The validation set has size {Xval.shape[0]}')
print(f'The test set has size {Xtest.shape[0]}')
```

```
The validation set has size 114621
The test set has size 114621
```

[7]:
```
X.shape[0] * 0.15
```

[7]:
```
114620.55
```

[8]:
```
# Get shapes for the training, validation and test sets
print(Xtrain.shape, Ytrain.shape)
print(Xval.shape, Yval.shape)
print(Xtest.shape, Ytest.shape)
```

```
(534895, 92) (534895,)
(114621, 92) (114621,)
(114621, 92) (114621,)
```

[9]:
```
# calculate test accuracy for a naive classifier
print(np.unique(Ytest, return_counts=True)[1][0] / np.shape(Ytest)[0])
print(np.unique(Ytest, return_counts=True)[1][1] / np.shape(Yval)[0])
```

```
0.1577546871864667
0.8422453128135333
```

Questions

1. Do all variables (`Xtrain`,`Ytrain`), (`Xval`,`Yval`), (`Xtest`,`Ytest`) have the shape that you expect?

2. Given the number of examples from each class, how high classification performance can a naive classifier obtain? The naive classifier will assume that all examples belong to one class. Note: you do not need to make a naive classifier, this is a theoretical question, just to understand how good performance we can obtain by guessing that all examples belong to one class.

Note, that if your classifier cannot perform better than a naive classifier or a random classifier, you are doing something wrong.

Answer

1. All variables have the expected shape with 92 covariates and the respective proportion of total data points.
2. The test accuracy for a naive classifier that assumes that everything belongs to class 1 would be 0.84.

[11]:
```
import os
import warnings

# Ignore FutureWarning from numpy
warnings.simplefilter(action='ignore', category=FutureWarning)

import tensorflow as tf

os.environ["CUDA_DEVICE_ORDER"]="PCI_BUS_ID"

# The GPU id to use, usually either "0" or "1";
os.environ["CUDA_VISIBLE_DEVICES"]="0"

# This sets the GPU to allocate memory only as needed
physical_devices = tf.config.experimental.list_physical_devices('GPU')
if len(physical_devices) != 0:
    tf.config.experimental.set_memory_growth(physical_devices[0], True)
else:
    print('No GPU available.')
```

```
No GPU available.
```

3 Part 2: DNN classification

In this next section you will define utilities for building the deep learning networks that will be used later and for visualizing the model training. You will also train several model experimenting with different model architecture configurations and methods for model regularization.

3.0.1 2.1 Build DNN model

Implement the `build_DNN` and `plot_results` functions in the `utilities.py` file. Note that for the changes in the `utilities.py` definitions to be visible by the notebook, you need to save the file.

Here are some relevant functions that you should use in `build_DNN`. For a complete list of functions and their definitions see the keras documentation:

- `model.add()`, adds a layer to the network;
- `Dense()`, a dense network layer. See the documentation what are the input options and outputs of the `Dense()` function.
- `model.compile()`, compiles the model. You can set the input metrics=['accuracy'] to print the classification accuracy during the training.
- cost and loss functions: check the documentation and chose a loss function for binary classification.

To get more information in model compile, training and evaluation see the relevant documentation.

After defining the`build_DNN` function use it to create the your first DNN classifier. Start with a simple network with 2 dense layers (with 20 nodes each), using sigmoid activation functions. The final dense layer should have a single node and a sigmoid activation function. We start with the SGD optimizer.

Make sure that the last layer always has a sigmoid activation function (why?).

[10]:
```
from utilities import build_DNN, plot_results, train_DNN
# ------------------------------------------
# === Your code here =======================
# ------------------------------------------
# import a suitable loss function from keras.losses and use as input to the␣
 ↪build_DNN function.

# Build a DNN model following the specifications above
model = build_DNN(input_shape=Xtrain.shape[1], n_hidden_layers=2,␣
 ↪n_hidden_units=20, loss="binary_crossentropy", act_fun="sigmoid")

# ==========================================
```

```
WARNING:tensorflow:From c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\tf_keras\src\losses.py:2976: The name
tf.losses.sparse_softmax_cross_entropy is deprecated. Please use
tf.compat.v1.losses.sparse_softmax_cross_entropy instead.

WARNING:tensorflow:From c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\tensorflow_probability\python\internal\backend\numpy\_utils.py:48: The
name tf.logging.TaskLevelStatusMessage is deprecated. Please use
tf.compat.v1.logging.TaskLevelStatusMessage instead.

WARNING:tensorflow:From c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\tensorflow_probability\python\internal\backend\numpy\_utils.py:48: The
name tf.control_flow_v2_enabled is deprecated. Please use
tf.compat.v1.control_flow_v2_enabled instead.

WARNING:tensorflow:From c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\tf_keras\src\backend.py:873: The name tf.get_default_graph is
```

```
deprecated. Please use tf.compat.v1.get_default_graph instead.
```

3.0.2 2.2 Train DNN model

Time to train the DNN! Start simple with 2 hidden layers with 20 nodes each.

Build set the different hyper-parameters, build the model and run the training. Use the following training and hyper-parameters: - `batch_size=20` - `epochs=20` - `learning_rate=0.1`

Make sure that you are using learning rate 0.1 !

3.0.3 2 hidden layers with 20 nodes each

[13]:
```
# Setup some training and hyper-parameters
batch_size = 10000
epochs = 20

# ------------------------------------------
# === Your code here =======================
# ------------------------------------------
# Specify the learning rate, the input shape and the loss function
learning_rate = 0.1
input_shape = Xtrain.shape[1]
loss = "binary_crossentropy"

model_config = {
    'learning_rate': learning_rate,
    'input_shape': input_shape,
    'loss': loss,
    'act_fun': 'sigmoid',
    'n_hidden_layers': 2,
    'n_hidden_units': 20
}
train_config = {
    'batch_size': batch_size,
    'epochs': epochs
}
# Train the model, provide training data and validation data
history1 = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval), train_config)
# ==========================================
```

```
Epoch 1/20
WARNING:tensorflow:From c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\tf_keras\src\utils\tf_utils.py:492: The name
tf.ragged.RaggedTensorValue is deprecated. Please use
tf.compat.v1.ragged.RaggedTensorValue instead.

54/54 [==============================] - 1s 9ms/step - loss: 0.4330 - accuracy:
```

```
0.8278 - val_loss: 0.3841 - val_accuracy: 0.8404
Epoch 2/20
51/54 [===========================>..] - ETA: 0s - loss: 0.3590 - accuracy:
0.8407

c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\ray\train\_internal\session.py:652: UserWarning: `report` is meant to
only be called inside a function that is executed by a Tuner or Trainer.
Returning `None`.
  warnings.warn(

54/54 [==============================] - 0s 4ms/step - loss: 0.3577 - accuracy:
0.8406 - val_loss: 0.3280 - val_accuracy: 0.8404
Epoch 3/20
54/54 [==============================] - 0s 4ms/step - loss: 0.3005 - accuracy:
0.8406 - val_loss: 0.2724 - val_accuracy: 0.8405
Epoch 4/20
54/54 [==============================] - 0s 4ms/step - loss: 0.2529 - accuracy:
0.8489 - val_loss: 0.2343 - val_accuracy: 0.8581
Epoch 5/20
54/54 [==============================] - 0s 4ms/step - loss: 0.2242 - accuracy:
0.8675 - val_loss: 0.2137 - val_accuracy: 0.8776
Epoch 6/20
54/54 [==============================] - 0s 4ms/step - loss: 0.2090 - accuracy:
0.8862 - val_loss: 0.2026 - val_accuracy: 0.8971
Epoch 7/20
54/54 [==============================] - 0s 4ms/step - loss: 0.2006 - accuracy:
0.8997 - val_loss: 0.1961 - val_accuracy: 0.9029
Epoch 8/20
54/54 [==============================] - 0s 4ms/step - loss: 0.1953 - accuracy:
0.9024 - val_loss: 0.1917 - val_accuracy: 0.9042
Epoch 9/20
54/54 [==============================] - 0s 4ms/step - loss: 0.1916 - accuracy:
0.9027 - val_loss: 0.1885 - val_accuracy: 0.9046
Epoch 10/20
54/54 [==============================] - 0s 4ms/step - loss: 0.1888 - accuracy:
0.9031 - val_loss: 0.1860 - val_accuracy: 0.9048
Epoch 11/20
54/54 [==============================] - 0s 4ms/step - loss: 0.1865 - accuracy:
0.9036 - val_loss: 0.1840 - val_accuracy: 0.9053
Epoch 12/20
54/54 [==============================] - 0s 3ms/step - loss: 0.1847 - accuracy:
0.9041 - val_loss: 0.1823 - val_accuracy: 0.9058
Epoch 13/20
54/54 [==============================] - 0s 4ms/step - loss: 0.1831 - accuracy:
0.9045 - val_loss: 0.1807 - val_accuracy: 0.9062
Epoch 14/20
54/54 [==============================] - 0s 4ms/step - loss: 0.1816 - accuracy:
0.9048 - val_loss: 0.1794 - val_accuracy: 0.9064
```

```
Epoch 15/20
54/54 [==============================] - 0s 4ms/step - loss: 0.1804 - accuracy:
0.9050 - val_loss: 0.1782 - val_accuracy: 0.9067
Epoch 16/20
54/54 [==============================] - 0s 4ms/step - loss: 0.1792 - accuracy:
0.9054 - val_loss: 0.1771 - val_accuracy: 0.9071
Epoch 17/20
54/54 [==============================] - 0s 4ms/step - loss: 0.1781 - accuracy:
0.9057 - val_loss: 0.1760 - val_accuracy: 0.9074
Epoch 18/20
54/54 [==============================] - 0s 4ms/step - loss: 0.1771 - accuracy:
0.9060 - val_loss: 0.1750 - val_accuracy: 0.9077
Epoch 19/20
54/54 [==============================] - 0s 3ms/step - loss: 0.1762 - accuracy:
0.9064 - val_loss: 0.1741 - val_accuracy: 0.9081
Epoch 20/20
54/54 [==============================] - 0s 3ms/step - loss: 0.1753 - accuracy:
0.9067 - val_loss: 0.1733 - val_accuracy: 0.9084
```

[14]:
```
# ------------------------------------------
# === Your code here =======================
# ------------------------------------------
# Evaluate the model on the test data
score = history1.model.evaluate(Xtest, Ytest)

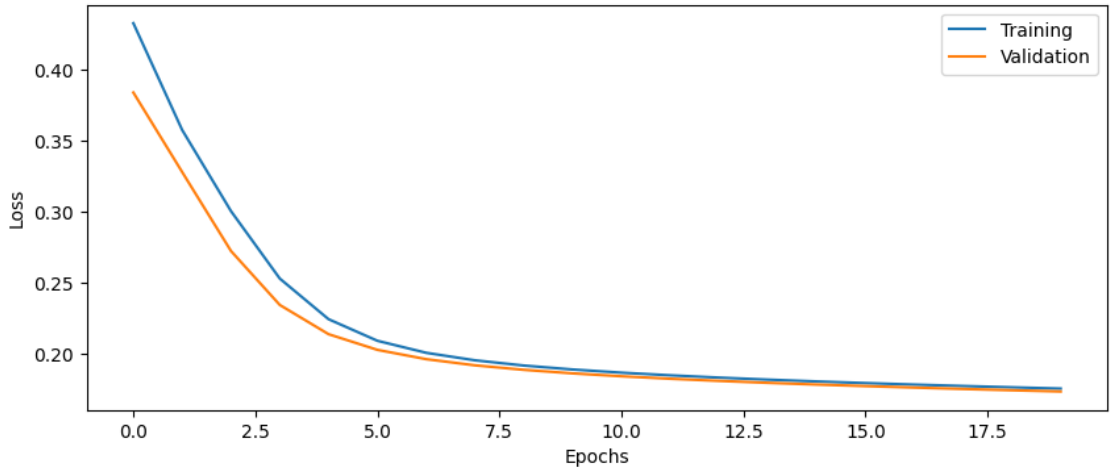
# ==========================================

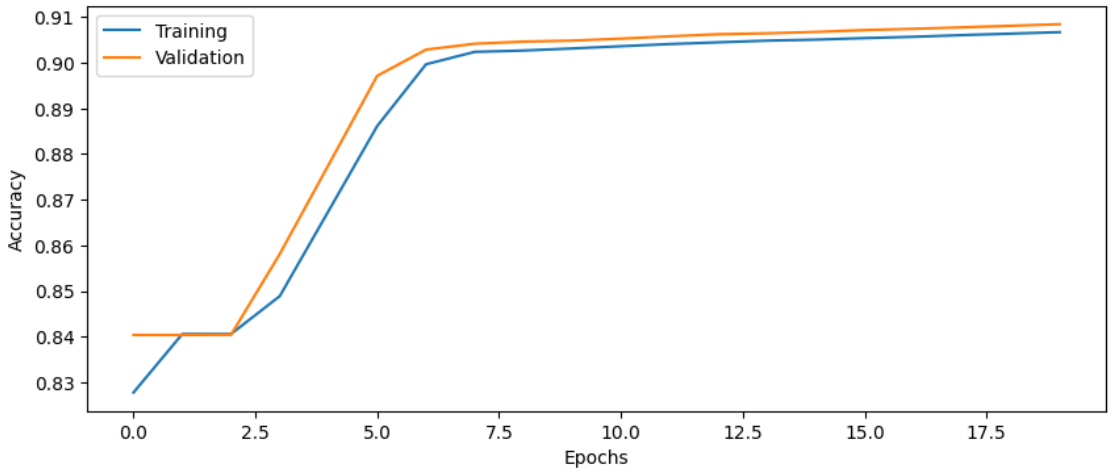
print('Test loss: %.4f' % score[0])
print('Test accuracy: %.4f' % score[1])
```

```
3582/3582 [==============================] - 3s 805us/step - loss: 0.1740 -
accuracy: 0.9066
Test loss: 0.1740
Test accuracy: 0.9066
```

[15]:
```
from utilities import plot_results

# Plot the history from the training run
plot_results(history1)
```





With the test accuracy of 0.91 it is better than the naive classifier that achieves 0.84.

Questions

3. What happens if you add several Dense layers without specifying the activation function?
4. How are the weights in each dense layer initialized as default? How are the bias weights initialized?

Answers

3. If we don't specify the activation funciton in the activation parameter for the keras.layers.Dense() function, no activation is applied to this layer.
4. By default the weights are initilized using glorot method to draw from a uniform distribution, which is also called xavier uniform method. For the bias weights the default values are zeros.

3.0.4 2.2 Adressing class imbalance

This dataset is rather unbalanced with the majority of the samples belonging to class=1. We need to define class weights so that the training pays more attention to the class with fewer samples. We use the `compute_class_weight` function from `scikit-learn`.

You need to call the function something like this

```
class_weights = class_weight.compute_class_weight(class_weight = , classes = , y = )
```

otherwise it will through an error.

[17]:
```
history1.model.summary()
```

```
Model: "sequential_1"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_3 (Dense)             (None, 20)                1860

 dense_4 (Dense)             (None, 20)                420

 dense_5 (Dense)             (None, 1)                 21

=================================================================
Total params: 2301 (8.99 KB)
Trainable params: 2301 (8.99 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

[11]:
```
from sklearn.utils import class_weight

# ------------------------------------------
# === Your code here =======================
# ------------------------------------------
# Calculate class weights
value1, value2 = class_weight.compute_class_weight(class_weight='balanced',␣
 ↪classes=np.unique(Ytrain), y=Ytrain)

# Print the class weights
print(value1, value2)

# ==========================================

# Convert class weights into a dictionary that can be used as input to the␣
 ↪model.fit() function

class_weights = {0: value1,
                 1: value2}
```

3.1372876783033035 0.5947943609097803

3.0.5 Train a model using class weights. 2 hidden layers with 20 nodes each

[9]:
```
# Setup some training and hyper-parameters
batch_size = 1000
epochs = 20

# ------------------------------------------
# === Your code here =======================
# ------------------------------------------
# Specify the learning rate, the input shape and the loss function
learning_rate = 0.1
input_shape = Xtrain.shape[1]
loss = "binary_crossentropy"

model_config = {
    'learning_rate': learning_rate,
    'input_shape': input_shape,
    'loss': loss,
    'act_fun': 'sigmoid',
    'n_hidden_layers': 2,
    'n_hidden_units': 20
}
train_config = {
    'batch_size': batch_size,
    'epochs': epochs,
    'class_weight': class_weights
}
# Train the model, provide training data and validation data
history2 = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval), train_config)
# ==========================================
```

```
WARNING:tensorflow:From c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\tf_keras\src\backend.py:873: The name tf.get_default_graph is
deprecated. Please use tf.compat.v1.get_default_graph instead.

Epoch 1/20
WARNING:tensorflow:From c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\tf_keras\src\utils\tf_utils.py:492: The name
tf.ragged.RaggedTensorValue is deprecated. Please use
tf.compat.v1.ragged.RaggedTensorValue instead.

535/535 [==============================] - 1s 2ms/step - loss: 0.3123 -
accuracy: 0.8843 - val_loss: 0.2490 - val_accuracy: 0.8949
Epoch 2/20
127/535 [======>…] - ETA: 0s - loss: 0.2024 - accuracy:
0.8939
```

```
c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\ray\train\_internal\session.py:652: UserWarning: `report` is meant to
only be called inside a function that is executed by a Tuner or Trainer.
Returning `None`.
  warnings.warn(
535/535 [==============================] - 1s 1ms/step - loss: 0.1955 -
accuracy: 0.8968 - val_loss: 0.2307 - val_accuracy: 0.9012
Epoch 3/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1850 -
accuracy: 0.9026 - val_loss: 0.2231 - val_accuracy: 0.9082
Epoch 4/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1792 -
accuracy: 0.9086 - val_loss: 0.2215 - val_accuracy: 0.9114
Epoch 5/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1755 -
accuracy: 0.9104 - val_loss: 0.2155 - val_accuracy: 0.9125
Epoch 6/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1730 -
accuracy: 0.9109 - val_loss: 0.2138 - val_accuracy: 0.9130
Epoch 7/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1711 -
accuracy: 0.9127 - val_loss: 0.2133 - val_accuracy: 0.9157
Epoch 8/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1697 -
accuracy: 0.9142 - val_loss: 0.2071 - val_accuracy: 0.9166
Epoch 9/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1685 -
accuracy: 0.9147 - val_loss: 0.2065 - val_accuracy: 0.9170
Epoch 10/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1674 -
accuracy: 0.9150 - val_loss: 0.2061 - val_accuracy: 0.9172
Epoch 11/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1665 -
accuracy: 0.9153 - val_loss: 0.2062 - val_accuracy: 0.9173
Epoch 12/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1657 -
accuracy: 0.9154 - val_loss: 0.2055 - val_accuracy: 0.9176
Epoch 13/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1650 -
accuracy: 0.9156 - val_loss: 0.2050 - val_accuracy: 0.9175
Epoch 14/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1644 -
accuracy: 0.9156 - val_loss: 0.2035 - val_accuracy: 0.9177
Epoch 15/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1638 -
accuracy: 0.9158 - val_loss: 0.2058 - val_accuracy: 0.9177
Epoch 16/20
```

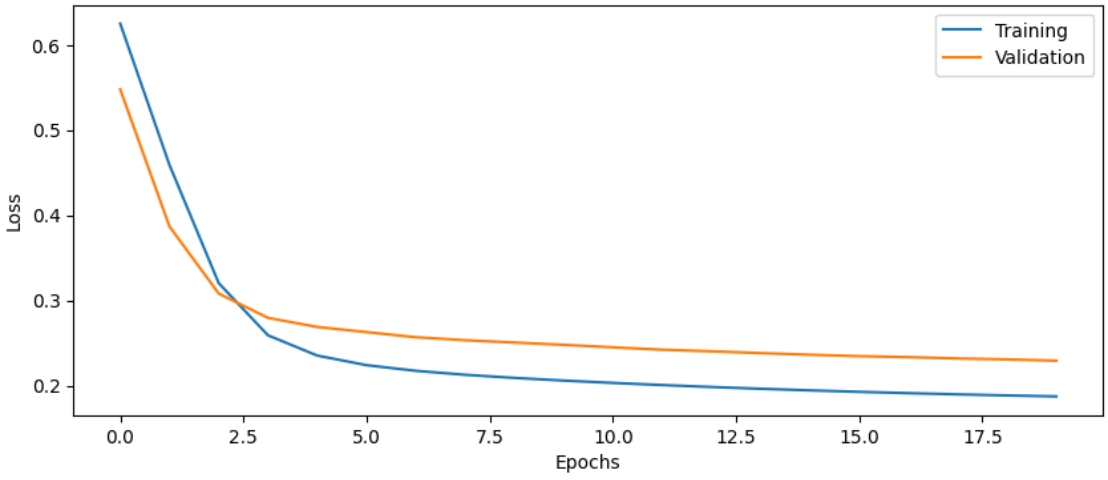
```
535/535 [==============================] - 1s 1ms/step - loss: 0.1633 -
accuracy: 0.9159 - val_loss: 0.2048 - val_accuracy: 0.9176
Epoch 17/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1628 -
accuracy: 0.9161 - val_loss: 0.2025 - val_accuracy: 0.9182
Epoch 18/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1623 -
accuracy: 0.9163 - val_loss: 0.1996 - val_accuracy: 0.9183
Epoch 19/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1619 -
accuracy: 0.9165 - val_loss: 0.2005 - val_accuracy: 0.9184
Epoch 20/20
535/535 [==============================] - 1s 1ms/step - loss: 0.1614 -
accuracy: 0.9167 - val_loss: 0.2030 - val_accuracy: 0.9184
```

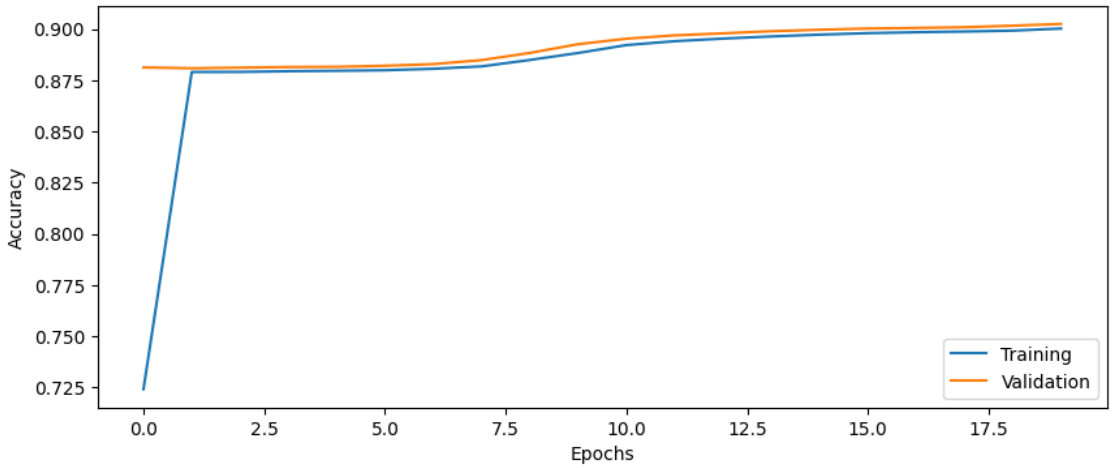
[ ]:
```
# ------------------------------------------
# === Your code here =======================
# ------------------------------------------
# Evaluate model on test data
score = history2.model.evaluate(Xtest, Ytest)

# ==========================================
print('Test loss: %.4f' % score[0])
print('Test accuracy: %.4f' % score[1])
```

```
3582/3582 [==============================] - 2s 686us/step - loss: 0.1490 -
accuracy: 0.9334
Test loss: 0.1490
Test accuracy: 0.9334
```

[ ]:
```
plot_results(history2)
```





This classifier has a better accuracy on the test data than the naive classifier. (0.93 compared to 0.84)

3.0.6 Additional questions

Questions

5. Why do we have to use a batch size? Why can't we simply use all data at once? This is more relevant for even larger datasets.
6. What is the processing time for one training epoch when the batch size is 100? What is the processing time for one epoch when the batch size is 1,000? What is the processing time for one epoch when the batch size is 10,000? Explain the results.
7. How many times are the weights in the DNN updated in each training epoch if the batch size is 100? How many times are the weights in the DNN updated in each training epoch if the batch size is 1,000? How many times are the weights in the DNN updated in each training epoch if the batch size is 10,000?
8. What limits how large the batch size can be?
9. Generally speaking, how is the learning rate related to the batch size? If the batch size is decreased, how should the learning rate be changed?
10. How many trainable parameters does the network with 4 dense layers with 50 nodes each have, compared to the initial network with 2 layers and 20 nodes per layer? Hint: use model.summary()

Answers

5. The memory is a limiting factor, therefore we have to use batches to load fewer data at the same time.
6. For batch size 100 one epoch takes 5249*1 ms=5249 ms . For batch size 1,000 one epoch takes 535*1 ms = 525ms. For batch size 10,000 one epoch takes 54*3 ms = 162ms. For smaller

batch sizes the CPU is not fully used, therefore much potential is wasted. Additionally, more weight updates have to be performed.

7. The weights are updated in every step, therefore we get the following numbers for the respective batch sizes. For 100 it is 5249 updates, for 1,000 535 and for 10,000 only 54.
8. The dedicated memory for the CPU or the GPU limits the batch size, as the data must fit in there.
9. For decreasing batch size the learning rate should also be decreased, because the weights are updated more frequently.
10. The initial model with 2 layers and 20 hidden units each has 2,301 trainable parameters. The model with 4 layers and 50 nodes each has 12,351.

[ ]:
```
# Setup some training and hyper-parameters
batch_size = 1000
epochs = 20

# ------------------------------------------
# === Your code here =======================
# ------------------------------------------
# Specify the learning rate, the input shape and the loss function
learning_rate = 0.1
input_shape = Xtrain.shape[1]
loss = "binary_crossentropy"

model_config = {
    'learning_rate': learning_rate,
    'input_shape': input_shape,
    'loss': loss,
    'act_fun': 'sigmoid',
    'n_hidden_layers': 4,
    'n_hidden_units': 50
}
train_config = {
    'batch_size': batch_size,
    'epochs': epochs,
    'class_weight': class_weights
}
# Train the model, provide training data and validation data
history3 = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval), train_config)
# ==========================================
```

```
Epoch 1/20
535/535 [==============================] - 2s 3ms/step - loss: 0.6780 -
accuracy: 0.6767 - val_loss: 0.6230 - val_accuracy: 0.8838
Epoch 2/20
535/535 [==============================] - 1s 2ms/step - loss: 0.3086 -
accuracy: 0.8847 - val_loss: 0.2484 - val_accuracy: 0.8940
```

```
Epoch 3/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1962 -
accuracy: 0.8961 - val_loss: 0.2329 - val_accuracy: 0.9001
Epoch 4/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1851 -
accuracy: 0.9025 - val_loss: 0.2264 - val_accuracy: 0.9085
Epoch 5/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1793 -
accuracy: 0.9090 - val_loss: 0.2183 - val_accuracy: 0.9125
Epoch 6/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1758 -
accuracy: 0.9107 - val_loss: 0.2184 - val_accuracy: 0.9128
Epoch 7/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1735 -
accuracy: 0.9117 - val_loss: 0.2228 - val_accuracy: 0.9131
Epoch 8/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1717 -
accuracy: 0.9131 - val_loss: 0.2135 - val_accuracy: 0.9157
Epoch 9/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1703 -
accuracy: 0.9135 - val_loss: 0.2100 - val_accuracy: 0.9159
Epoch 10/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1690 -
accuracy: 0.9141 - val_loss: 0.2068 - val_accuracy: 0.9166
Epoch 11/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1679 -
accuracy: 0.9145 - val_loss: 0.2085 - val_accuracy: 0.9168
Epoch 12/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1669 -
accuracy: 0.9148 - val_loss: 0.2092 - val_accuracy: 0.9169
Epoch 13/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1659 -
accuracy: 0.9150 - val_loss: 0.2058 - val_accuracy: 0.9173
Epoch 14/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1651 -
accuracy: 0.9152 - val_loss: 0.2027 - val_accuracy: 0.9175
Epoch 15/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1642 -
accuracy: 0.9154 - val_loss: 0.2071 - val_accuracy: 0.9176
Epoch 16/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1634 -
accuracy: 0.9157 - val_loss: 0.1975 - val_accuracy: 0.9181
Epoch 17/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1627 -
accuracy: 0.9159 - val_loss: 0.1975 - val_accuracy: 0.9182
Epoch 18/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1619 -
accuracy: 0.9161 - val_loss: 0.2013 - val_accuracy: 0.9183
```

```
Epoch 19/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1612 -
accuracy: 0.9164 - val_loss: 0.2051 - val_accuracy: 0.9183
Epoch 20/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1605 -
accuracy: 0.9167 - val_loss: 0.2023 - val_accuracy: 0.9187
```

[ ]:
```
history3.model.summary()
```

```
Model: "sequential_28"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_79 (Dense)            (None, 50)                4650

 dense_80 (Dense)            (None, 50)                2550

 dense_81 (Dense)            (None, 50)                2550

 dense_82 (Dense)            (None, 50)                2550

 dense_83 (Dense)            (None, 1)                 51

=================================================================
Total params: 12351 (48.25 KB)
Trainable params: 12351 (48.25 KB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

3.0.7 2.3 Model regularization

In the following sections you will explore methods for model normalization, namely `BatchNormalization` and `Dropout`, and also look at the impact of ofter activation functions and optimization algorithms. #### **2.3.1 Batch normalization**

Now add batch normalization after each hidden dense layer in `build_DNN`.

See the documentation for information about how to call the function.

Questions

11. Why is batch normalization important when training deep networks?

Answers

11. Batch normalization stabilizes and speeds up the training of the network. It addresses the probvlem called internal covariante shift. By normalizing the output of every layer it can be avoided that the activation function puts out values in their saturated area.

3.0.8 2 hidden layers, 20 nodes each, class weights and batch normalization

[22]:
```
# Setup some training and hyper-parameters
batch_size = 1000
epochs = 20

# ------------------------------------------
# === Your code here =======================
# ------------------------------------------

# Build and train model
model_config = {
    'learning_rate': learning_rate,
    'input_shape': input_shape,
    'loss': loss,
    'act_fun': 'sigmoid',
    'n_hidden_layers': 2,
    'n_hidden_units': 20,
    'use_bn': True
}
train_config = {
    'batch_size': batch_size,
    'epochs': epochs,
    'class_weight': class_weights
}

history6 = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval), train_config)

# Evaluate model on test data
score = history6.model.evaluate(Xtest, Ytest)

# ==========================================

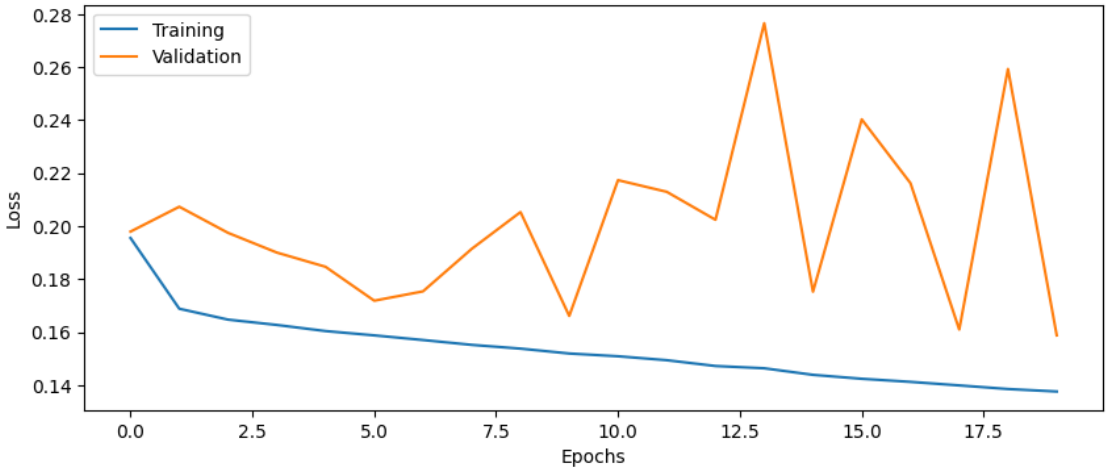
print('Test loss: %.4f' % score[0])
print('Test accuracy: %.4f' % score[1])

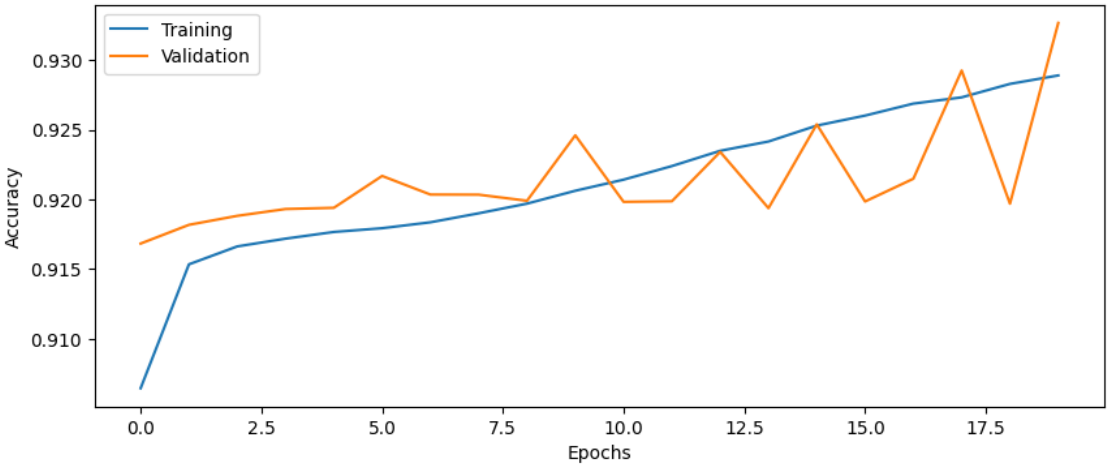
# Plot the history from the training run
plot_results(history6)
```

```
Epoch 1/20
535/535 [==============================] - 3s 3ms/step - loss: 0.1955 -
accuracy: 0.9065 - val_loss: 0.1979 - val_accuracy: 0.9168
Epoch 2/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1688 -
accuracy: 0.9153 - val_loss: 0.2073 - val_accuracy: 0.9182
Epoch 3/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1647 -
accuracy: 0.9166 - val_loss: 0.1974 - val_accuracy: 0.9188
```

```
Epoch 4/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1627 -
accuracy: 0.9172 - val_loss: 0.1900 - val_accuracy: 0.9193
Epoch 5/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1604 -
accuracy: 0.9177 - val_loss: 0.1846 - val_accuracy: 0.9194
Epoch 6/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1587 -
accuracy: 0.9179 - val_loss: 0.1718 - val_accuracy: 0.9217
Epoch 7/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1570 -
accuracy: 0.9184 - val_loss: 0.1754 - val_accuracy: 0.9204
Epoch 8/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1552 -
accuracy: 0.9190 - val_loss: 0.1914 - val_accuracy: 0.9203
Epoch 9/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1537 -
accuracy: 0.9197 - val_loss: 0.2053 - val_accuracy: 0.9199
Epoch 10/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1519 -
accuracy: 0.9206 - val_loss: 0.1661 - val_accuracy: 0.9246
Epoch 11/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1509 -
accuracy: 0.9214 - val_loss: 0.2173 - val_accuracy: 0.9198
Epoch 12/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1494 -
accuracy: 0.9224 - val_loss: 0.2129 - val_accuracy: 0.9199
Epoch 13/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1472 -
accuracy: 0.9235 - val_loss: 0.2024 - val_accuracy: 0.9234
Epoch 14/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1463 -
accuracy: 0.9242 - val_loss: 0.2765 - val_accuracy: 0.9194
Epoch 15/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1438 -
accuracy: 0.9253 - val_loss: 0.1752 - val_accuracy: 0.9254
Epoch 16/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1424 -
accuracy: 0.9260 - val_loss: 0.2403 - val_accuracy: 0.9199
Epoch 17/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1412 -
accuracy: 0.9269 - val_loss: 0.2162 - val_accuracy: 0.9215
Epoch 18/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1399 -
accuracy: 0.9273 - val_loss: 0.1609 - val_accuracy: 0.9293
Epoch 19/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1385 -
accuracy: 0.9283 - val_loss: 0.2593 - val_accuracy: 0.9197
```

```
Epoch 20/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1376 -
accuracy: 0.9289 - val_loss: 0.1588 - val_accuracy: 0.9327
3582/3582 [==============================] - 3s 855us/step - loss: 0.1608 -
accuracy: 0.9318
Test loss: 0.1608
Test accuracy: 0.9318
```





The resulting model reaches a higher test accuracy than the naive classifier (0.93 vs. 0.84).

2.3.2 Activation function Try changing the activation function in each layer from sigmoid to ReLU.

Note: the last layer should still have a sigmoid activation function.

3.0.9 2 hidden layers, 20 nodes each, class weights, ReLU and no batch normalization

[28]:
```
# Setup some training and hyper-parameters
batch_size = 1000
epochs = 20

# ------------------------------------------
# === Your code here =======================
# ------------------------------------------

# Build and train model
model_config = {
    'learning_rate': learning_rate,
    'input_shape': input_shape,
    'loss': loss,
    'act_fun': 'relu',
    'n_hidden_layers': 2,
    'n_hidden_units': 20,
    'use_bn': False,
    'print_args': True
}
train_config = {
    'batch_size': batch_size,
    'epochs': epochs,
    'class_weight': class_weights
}

history7 = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval), train_config)

# Evaluate model on test data
score = history7.model.evaluate(Xtest, Ytest)

# ==========================================

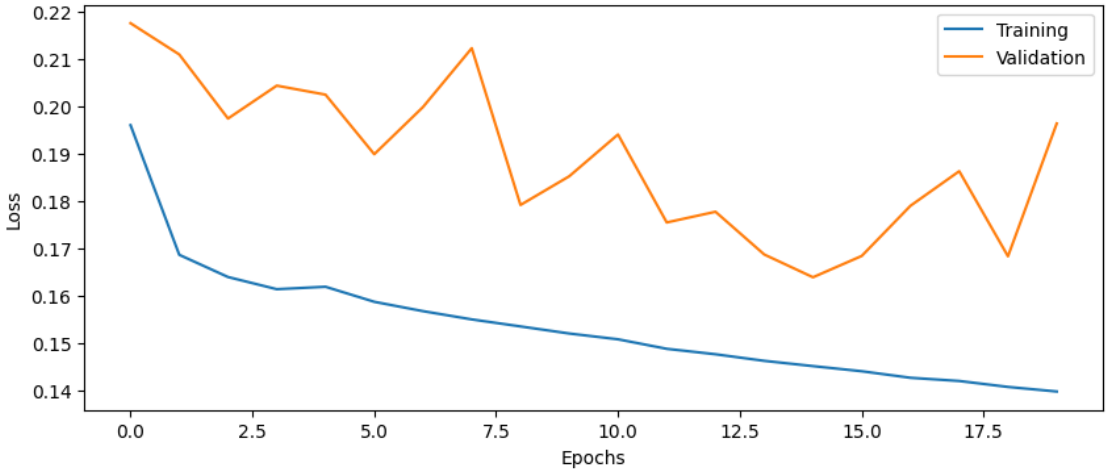
print('Test loss: %.4f' % score[0])
print('Test accuracy: %.4f' % score[1])

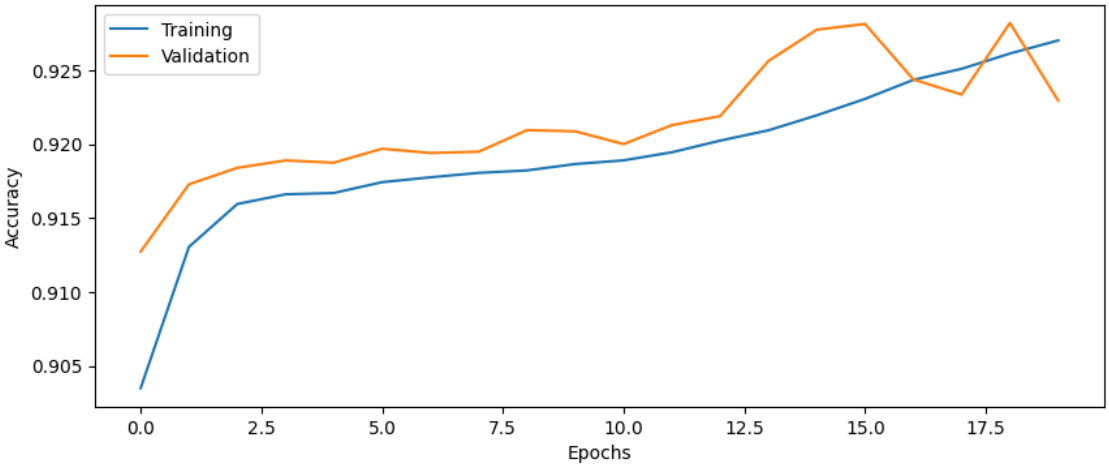
# Plot the history from the training run
plot_results(history7)
```

```
activation function:  relu
optimizer:  sgd
use_bn:  False
use_dropout:  False
Epoch 1/20
535/535 [==============================] - 2s 3ms/step - loss: 0.1960 -
accuracy: 0.9035 - val_loss: 0.2175 - val_accuracy: 0.9127
Epoch 2/20
```

```
535/535 [==============================] - 1s 2ms/step - loss: 0.1686 -
accuracy: 0.9131 - val_loss: 0.2109 - val_accuracy: 0.9173
Epoch 3/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1639 -
accuracy: 0.9159 - val_loss: 0.1974 - val_accuracy: 0.9184
Epoch 4/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1614 -
accuracy: 0.9166 - val_loss: 0.2043 - val_accuracy: 0.9189
Epoch 5/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1619 -
accuracy: 0.9167 - val_loss: 0.2024 - val_accuracy: 0.9187
Epoch 6/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1587 -
accuracy: 0.9174 - val_loss: 0.1898 - val_accuracy: 0.9197
Epoch 7/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1567 -
accuracy: 0.9178 - val_loss: 0.1998 - val_accuracy: 0.9194
Epoch 8/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1550 -
accuracy: 0.9181 - val_loss: 0.2122 - val_accuracy: 0.9195
Epoch 9/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1535 -
accuracy: 0.9182 - val_loss: 0.1791 - val_accuracy: 0.9209
Epoch 10/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1520 -
accuracy: 0.9187 - val_loss: 0.1852 - val_accuracy: 0.9209
Epoch 11/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1508 -
accuracy: 0.9189 - val_loss: 0.1940 - val_accuracy: 0.9200
Epoch 12/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1488 -
accuracy: 0.9195 - val_loss: 0.1754 - val_accuracy: 0.9213
Epoch 13/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1476 -
accuracy: 0.9202 - val_loss: 0.1777 - val_accuracy: 0.9219
Epoch 14/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1462 -
accuracy: 0.9209 - val_loss: 0.1687 - val_accuracy: 0.9256
Epoch 15/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1451 -
accuracy: 0.9220 - val_loss: 0.1639 - val_accuracy: 0.9277
Epoch 16/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1440 -
accuracy: 0.9231 - val_loss: 0.1684 - val_accuracy: 0.9281
Epoch 17/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1427 -
accuracy: 0.9243 - val_loss: 0.1790 - val_accuracy: 0.9244
Epoch 18/20
```

```
535/535 [==============================] - 1s 2ms/step - loss: 0.1420 -
accuracy: 0.9251 - val_loss: 0.1863 - val_accuracy: 0.9234
Epoch 19/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1407 -
accuracy: 0.9261 - val_loss: 0.1683 - val_accuracy: 0.9282
Epoch 20/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1398 -
accuracy: 0.9270 - val_loss: 0.1963 - val_accuracy: 0.9229
3582/3582 [==============================] - 3s 833us/step - loss: 0.2000 -
accuracy: 0.9217
Test loss: 0.2000
Test accuracy: 0.9217
```





With 0.92 this classifier has a worse test accuracy than previous ones but is still better than the naive clssifier.

2.3.3 Optimizer Try changing the optimizer from SGD to Adam (with learning rate 0.1 as before). Remember to import the Adam optimizer from keras.optimizers.

3.0.10 2 hidden layers, 20 nodes each, class weights, Adam optimizer, no batch normalization, sigmoid activations

[29]:
```
# ------------------------------------------
# === Your code here =======================
# ------------------------------------------

# Build and train model
model_config = {
    'learning_rate': learning_rate,
    'input_shape': input_shape,
    'loss': loss,
    'act_fun': 'sigmoid',
    'n_hidden_layers': 2,
    'n_hidden_units': 20,
    'optimizer': 'adam',
    'print_args': True
}

train_config = {
    'batch_size': batch_size,
    'epochs': epochs,
    'class_weight': class_weights
}

history8 = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval), train_config)

# Evaluate model on test data
score = history8.model.evaluate(Xtest, Ytest)

# ==========================================

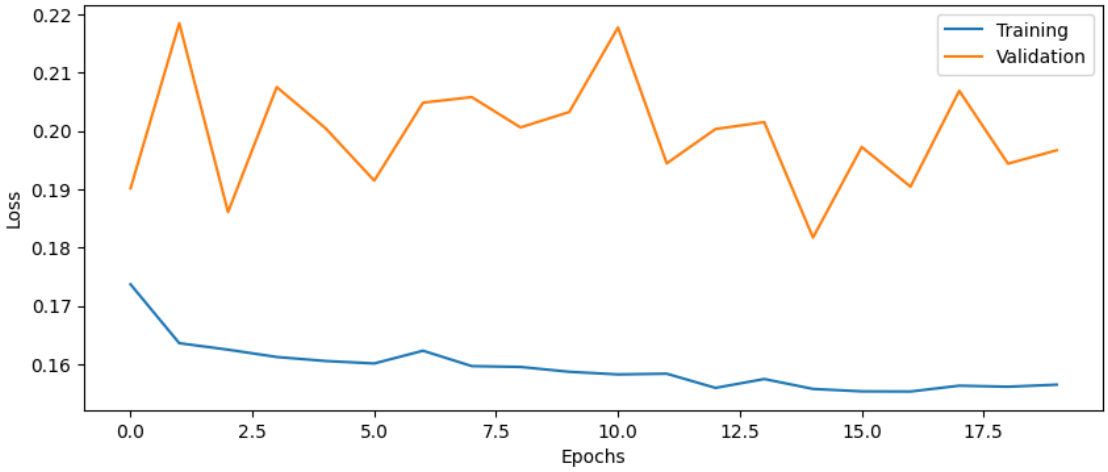
print('Test loss: %.4f' % score[0])
print('Test accuracy: %.4f' % score[1])

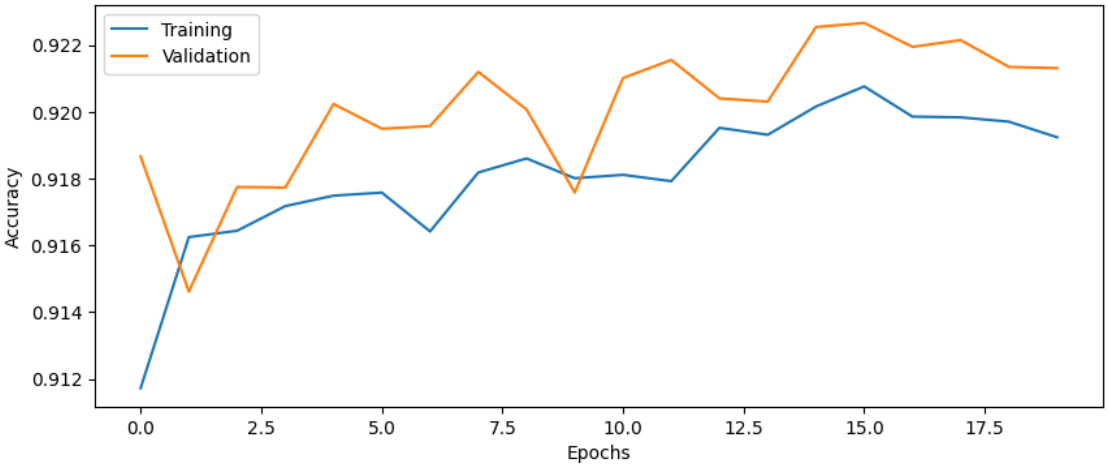
# Plot the history from the training run
plot_results(history8)
```

```
activation function:  sigmoid
optimizer:  adam
use_bn:  False
use_dropout:  False
Epoch 1/20
535/535 [==============================] - 2s 3ms/step - loss: 0.1737 -
accuracy: 0.9117 - val_loss: 0.1901 - val_accuracy: 0.9187
```

```
Epoch 2/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1636 -
accuracy: 0.9162 - val_loss: 0.2185 - val_accuracy: 0.9146
Epoch 3/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1625 -
accuracy: 0.9164 - val_loss: 0.1861 - val_accuracy: 0.9177
Epoch 4/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1612 -
accuracy: 0.9172 - val_loss: 0.2075 - val_accuracy: 0.9177
Epoch 5/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1605 -
accuracy: 0.9175 - val_loss: 0.2005 - val_accuracy: 0.9202
Epoch 6/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1601 -
accuracy: 0.9176 - val_loss: 0.1915 - val_accuracy: 0.9195
Epoch 7/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1623 -
accuracy: 0.9164 - val_loss: 0.2049 - val_accuracy: 0.9196
Epoch 8/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1596 -
accuracy: 0.9182 - val_loss: 0.2058 - val_accuracy: 0.9212
Epoch 9/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1595 -
accuracy: 0.9186 - val_loss: 0.2006 - val_accuracy: 0.9201
Epoch 10/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1587 -
accuracy: 0.9180 - val_loss: 0.2032 - val_accuracy: 0.9176
Epoch 11/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1582 -
accuracy: 0.9181 - val_loss: 0.2178 - val_accuracy: 0.9210
Epoch 12/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1583 -
accuracy: 0.9179 - val_loss: 0.1944 - val_accuracy: 0.9216
Epoch 13/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1559 -
accuracy: 0.9195 - val_loss: 0.2003 - val_accuracy: 0.9204
Epoch 14/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1574 -
accuracy: 0.9193 - val_loss: 0.2015 - val_accuracy: 0.9203
Epoch 15/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1557 -
accuracy: 0.9202 - val_loss: 0.1817 - val_accuracy: 0.9225
Epoch 16/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1553 -
accuracy: 0.9208 - val_loss: 0.1972 - val_accuracy: 0.9227
Epoch 17/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1553 -
accuracy: 0.9199 - val_loss: 0.1904 - val_accuracy: 0.9219
```

```
Epoch 18/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1563 -
accuracy: 0.9198 - val_loss: 0.2069 - val_accuracy: 0.9221
Epoch 19/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1561 -
accuracy: 0.9197 - val_loss: 0.1944 - val_accuracy: 0.9213
Epoch 20/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1565 -
accuracy: 0.9192 - val_loss: 0.1967 - val_accuracy: 0.9213
3582/3582 [==============================] - 3s 819us/step - loss: 0.1998 -
accuracy: 0.9200
Test loss: 0.1998
Test accuracy: 0.9200
```





As for the previous classifiers, the one using adam as optimizer outperforms the naive classifier.

2.3.4 Dropout regularization Dropout is a type of regularization that can improve accuracy for validation and test data. It randomly removes connections to force the neural network to not rely too much on a small number of weights.

Add a Dropout layer after each Dense layer (but not after the final dense layer) in `build_DNN`, with a dropout probability of 50%. Look at the documentation for more information on how to call set this layer.

Questions

12. How does the validation accuracy change when adding dropout?
13. How does the test accuracy change when adding dropout?

Answers

12. The validation accuracy is lower compared to using batch normalization but a bit higher than using no regularization. The improvment during the training is more stable than for batch normalization though.

13. For the used hyperparameters the test accuracy is lower than for previous runs.

3.0.11 2 hidden layers with 20 nodes each, class weights, dropout, SGD optimizer, no batch normalization and sigmoid activations

[26]:
```
epochs = 50


# ------------------------------------------
# === Your code here =======================
# ------------------------------------------

# Build and train model
model_config = {
    'learning_rate': learning_rate,
    'input_shape': input_shape,
    'loss': loss,
    'act_fun': 'sigmoid',
    'n_hidden_layers': 2,
    'n_hidden_units': 20,
    'use_dropout': True
}

train_config = {
    'batch_size': batch_size,
    'epochs': epochs,
    'class_weight': class_weights
}

history9 = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval), train_config)
```

```
# Evaluate model on test data
score = history9.model.evaluate(Xtest, Ytest)

# ========================================

print('Test loss: %.4f' % score[0])
print('Test accuracy: %.4f' % score[1])

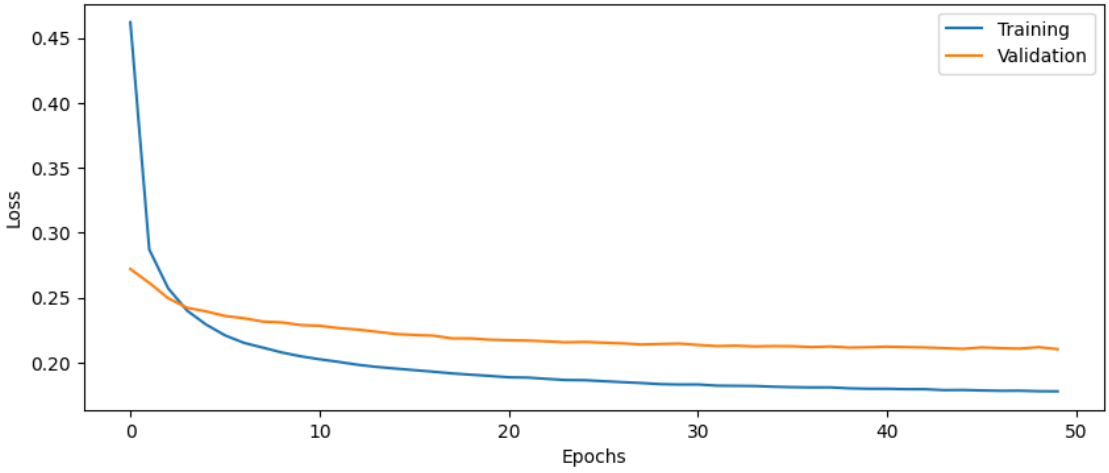
# Plot the history from the training run
plot_results(history9)
```

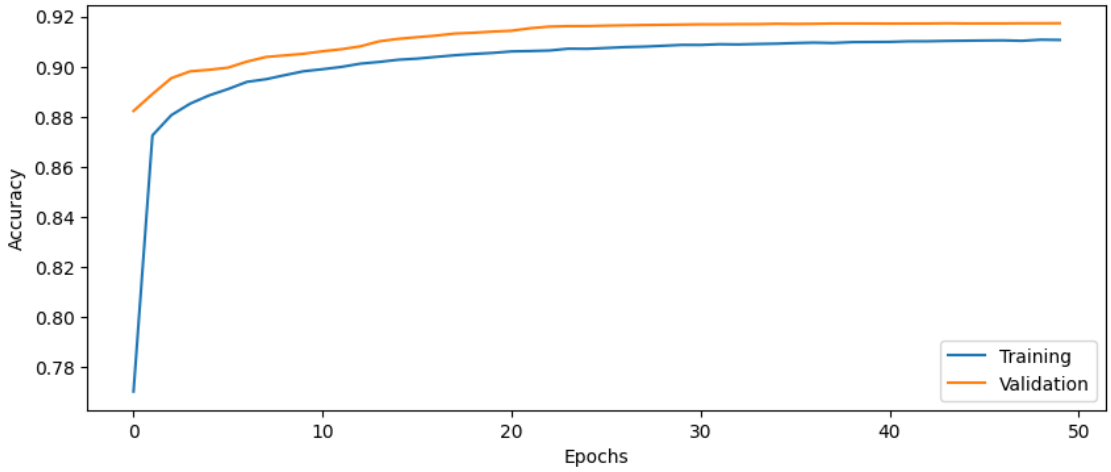
```
Epoch 1/50
535/535 [==============================] - 2s 2ms/step - loss: 0.4622 -
accuracy: 0.7703 - val_loss: 0.2720 - val_accuracy: 0.8823
Epoch 2/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2870 -
accuracy: 0.8726 - val_loss: 0.2613 - val_accuracy: 0.8891
Epoch 3/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2571 -
accuracy: 0.8807 - val_loss: 0.2495 - val_accuracy: 0.8954
Epoch 4/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2399 -
accuracy: 0.8853 - val_loss: 0.2421 - val_accuracy: 0.8981
Epoch 5/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2292 -
accuracy: 0.8885 - val_loss: 0.2393 - val_accuracy: 0.8988
Epoch 6/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2209 -
accuracy: 0.8911 - val_loss: 0.2358 - val_accuracy: 0.8996
Epoch 7/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2151 -
accuracy: 0.8939 - val_loss: 0.2341 - val_accuracy: 0.9020
Epoch 8/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2114 -
accuracy: 0.8950 - val_loss: 0.2315 - val_accuracy: 0.9039
Epoch 9/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2077 -
accuracy: 0.8966 - val_loss: 0.2308 - val_accuracy: 0.9045
Epoch 10/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2047 -
accuracy: 0.8982 - val_loss: 0.2288 - val_accuracy: 0.9052
Epoch 11/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2024 -
accuracy: 0.8990 - val_loss: 0.2282 - val_accuracy: 0.9062
Epoch 12/50
535/535 [==============================] - 1s 2ms/step - loss: 0.2004 -
accuracy: 0.8999 - val_loss: 0.2265 - val_accuracy: 0.9070
```

```
Epoch 13/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1982 -
accuracy: 0.9012 - val_loss: 0.2253 - val_accuracy: 0.9081
Epoch 14/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1966 -
accuracy: 0.9019 - val_loss: 0.2237 - val_accuracy: 0.9101
Epoch 15/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1953 -
accuracy: 0.9028 - val_loss: 0.2219 - val_accuracy: 0.9111
Epoch 16/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1940 -
accuracy: 0.9032 - val_loss: 0.2211 - val_accuracy: 0.9118
Epoch 17/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1929 -
accuracy: 0.9039 - val_loss: 0.2207 - val_accuracy: 0.9124
Epoch 18/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1915 -
accuracy: 0.9046 - val_loss: 0.2185 - val_accuracy: 0.9132
Epoch 19/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1905 -
accuracy: 0.9051 - val_loss: 0.2185 - val_accuracy: 0.9135
Epoch 20/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1896 -
accuracy: 0.9055 - val_loss: 0.2175 - val_accuracy: 0.9140
Epoch 21/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1885 -
accuracy: 0.9061 - val_loss: 0.2171 - val_accuracy: 0.9144
Epoch 22/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1883 -
accuracy: 0.9062 - val_loss: 0.2168 - val_accuracy: 0.9154
Epoch 23/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1873 -
accuracy: 0.9065 - val_loss: 0.2162 - val_accuracy: 0.9160
Epoch 24/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1864 -
accuracy: 0.9072 - val_loss: 0.2155 - val_accuracy: 0.9162
Epoch 25/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1863 -
accuracy: 0.9071 - val_loss: 0.2158 - val_accuracy: 0.9162
Epoch 26/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1855 -
accuracy: 0.9075 - val_loss: 0.2152 - val_accuracy: 0.9164
Epoch 27/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1848 -
accuracy: 0.9078 - val_loss: 0.2147 - val_accuracy: 0.9165
Epoch 28/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1841 -
accuracy: 0.9080 - val_loss: 0.2138 - val_accuracy: 0.9166
```

```
Epoch 29/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1833 -
accuracy: 0.9083 - val_loss: 0.2142 - val_accuracy: 0.9167
Epoch 30/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1830 -
accuracy: 0.9087 - val_loss: 0.2145 - val_accuracy: 0.9168
Epoch 31/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1830 -
accuracy: 0.9087 - val_loss: 0.2135 - val_accuracy: 0.9169
Epoch 32/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1821 -
accuracy: 0.9090 - val_loss: 0.2126 - val_accuracy: 0.9169
Epoch 33/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1819 -
accuracy: 0.9089 - val_loss: 0.2129 - val_accuracy: 0.9170
Epoch 34/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1818 -
accuracy: 0.9091 - val_loss: 0.2123 - val_accuracy: 0.9170
Epoch 35/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1813 -
accuracy: 0.9092 - val_loss: 0.2126 - val_accuracy: 0.9171
Epoch 36/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1809 -
accuracy: 0.9094 - val_loss: 0.2124 - val_accuracy: 0.9171
Epoch 37/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1807 -
accuracy: 0.9096 - val_loss: 0.2118 - val_accuracy: 0.9171
Epoch 38/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1808 -
accuracy: 0.9095 - val_loss: 0.2123 - val_accuracy: 0.9172
Epoch 39/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1800 -
accuracy: 0.9098 - val_loss: 0.2114 - val_accuracy: 0.9172
Epoch 40/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1797 -
accuracy: 0.9099 - val_loss: 0.2117 - val_accuracy: 0.9172
Epoch 41/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1797 -
accuracy: 0.9099 - val_loss: 0.2121 - val_accuracy: 0.9172
Epoch 42/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1794 -
accuracy: 0.9101 - val_loss: 0.2118 - val_accuracy: 0.9172
Epoch 43/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1794 -
accuracy: 0.9102 - val_loss: 0.2115 - val_accuracy: 0.9172
Epoch 44/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1786 -
accuracy: 0.9103 - val_loss: 0.2110 - val_accuracy: 0.9173
```

```
Epoch 45/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1788 -
accuracy: 0.9104 - val_loss: 0.2105 - val_accuracy: 0.9173
Epoch 46/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1784 -
accuracy: 0.9105 - val_loss: 0.2115 - val_accuracy: 0.9173
Epoch 47/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1781 -
accuracy: 0.9105 - val_loss: 0.2110 - val_accuracy: 0.9173
Epoch 48/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1782 -
accuracy: 0.9103 - val_loss: 0.2107 - val_accuracy: 0.9173
Epoch 49/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1778 -
accuracy: 0.9108 - val_loss: 0.2117 - val_accuracy: 0.9173
Epoch 50/50
535/535 [==============================] - 1s 2ms/step - loss: 0.1777 -
accuracy: 0.9107 - val_loss: 0.2102 - val_accuracy: 0.9174
3582/3582 [==============================] - 3s 841us/step - loss: 0.2136 -
accuracy: 0.9157
Test loss: 0.2136
Test accuracy: 0.9157
```





4 Part 3: Hyper parameter tuning

4.0.1 3.1 Manual hyper parameter tuning

Spend some time (20 to 30 minutes) tuning the network architecture (number of layers, number of nodes per layer, activation function) and other hyper parameters (optimizer, learning rate, batch size, number of epochs, degree of regularization). For example, try a much deeper network. How much does the training time increase for a network with 10 layers?

Question

14. How high classification accuracy can you achieve for the test data? What is your best configuration?

Answers

15. Within 30 minutes the highest test accuracy that we achieved was 0.9338 using the small NN from the beginning adding class weights and batch normalization. With the configurations that we tried, deeper netoworks did not perform better. For a network with 10 layers and 100 hidden units each the training increased from 2 ms per step to 9ms.

The result is better than the naive classifier with test accuracy 0.84.

[28]:
```
# ------------------------------------------
# === Your code here =======================
# ------------------------------------------
batch_size = 1000
epochs = 20
learning_rate = 0.1
input_shape = Xtrain.shape[1]
loss = "binary_crossentropy"
```

```
# Build and train model
model_config = {
    'learning_rate': learning_rate,
    'input_shape': input_shape,
    'loss': loss,
    'act_fun': 'sigmoid',
    'n_hidden_layers': 2,
    'n_hidden_units': 20,
    'optimizer': 'sgd',
    'use_bn': True,
    'use_dropout': False,
}
train_config = {
    'batch_size': batch_size,
    'epochs': epochs,
    'class_weight': class_weights
}

best_history = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval),␣
 ↪train_config)
# Evaluate model on test data
best_score = best_history.model.evaluate(Xtest, Ytest)

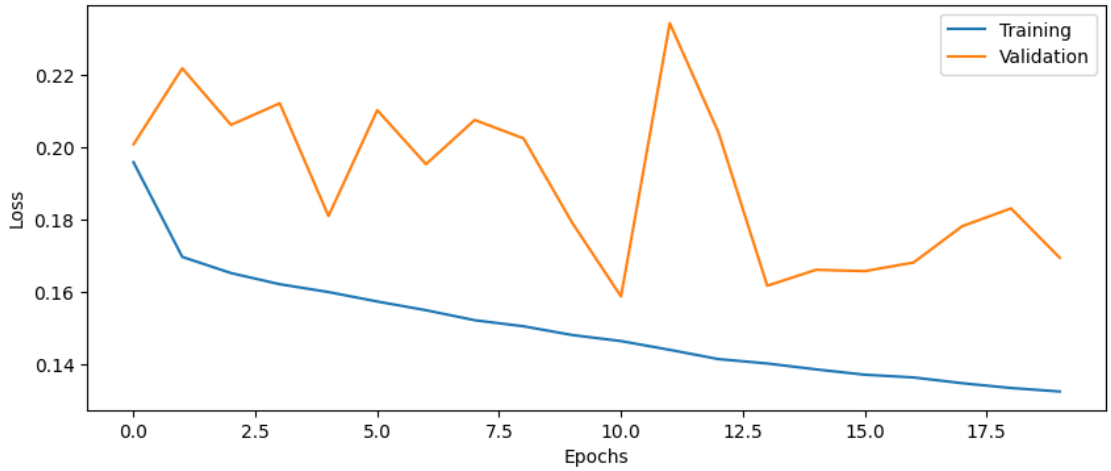
# ============================================

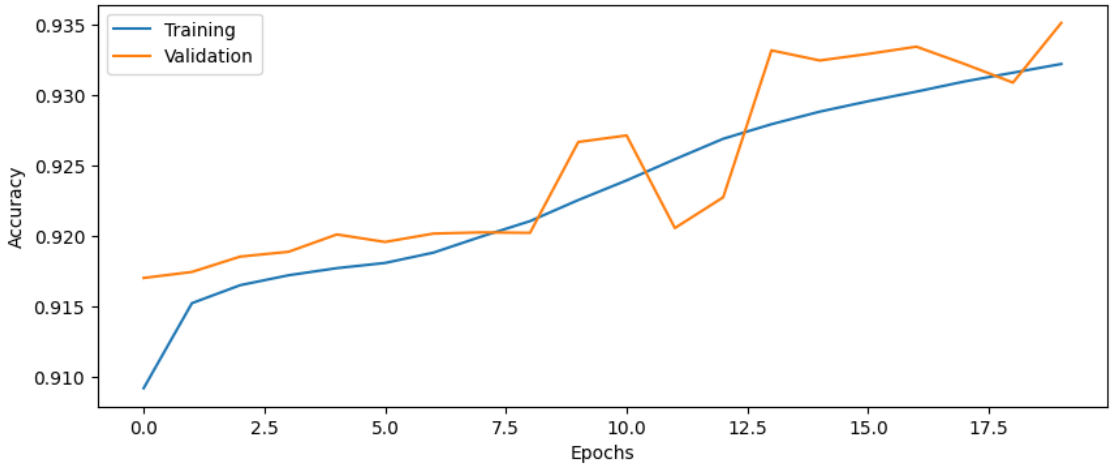
print('Test loss: %.4f' % best_score[0])
print('Test accuracy: %.4f' % best_score[1])

# Plot the history from the training run
plot_results(best_history)
```

```
Epoch 1/20
535/535 [==============================] - 2s 2ms/step - loss: 0.1958 -
accuracy: 0.9092 - val_loss: 0.2007 - val_accuracy: 0.9170
Epoch 2/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1696 -
accuracy: 0.9152 - val_loss: 0.2217 - val_accuracy: 0.9175
Epoch 3/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1652 -
accuracy: 0.9165 - val_loss: 0.2061 - val_accuracy: 0.9185
Epoch 4/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1621 -
accuracy: 0.9172 - val_loss: 0.2121 - val_accuracy: 0.9189
Epoch 5/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1599 -
accuracy: 0.9177 - val_loss: 0.1809 - val_accuracy: 0.9201
Epoch 6/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1573 -
```

```
accuracy: 0.9181 - val_loss: 0.2102 - val_accuracy: 0.9196
Epoch 7/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1549 -
accuracy: 0.9188 - val_loss: 0.1952 - val_accuracy: 0.9202
Epoch 8/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1522 -
accuracy: 0.9200 - val_loss: 0.2075 - val_accuracy: 0.9203
Epoch 9/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1505 -
accuracy: 0.9211 - val_loss: 0.2024 - val_accuracy: 0.9202
Epoch 10/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1481 -
accuracy: 0.9226 - val_loss: 0.1791 - val_accuracy: 0.9267
Epoch 11/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1464 -
accuracy: 0.9240 - val_loss: 0.1587 - val_accuracy: 0.9271
Epoch 12/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1440 -
accuracy: 0.9255 - val_loss: 0.2342 - val_accuracy: 0.9206
Epoch 13/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1414 -
accuracy: 0.9269 - val_loss: 0.2040 - val_accuracy: 0.9228
Epoch 14/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1402 -
accuracy: 0.9279 - val_loss: 0.1617 - val_accuracy: 0.9332
Epoch 15/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1386 -
accuracy: 0.9288 - val_loss: 0.1661 - val_accuracy: 0.9325
Epoch 16/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1371 -
accuracy: 0.9296 - val_loss: 0.1657 - val_accuracy: 0.9329
Epoch 17/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1364 -
accuracy: 0.9303 - val_loss: 0.1681 - val_accuracy: 0.9334
Epoch 18/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1348 -
accuracy: 0.9310 - val_loss: 0.1781 - val_accuracy: 0.9322
Epoch 19/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1334 -
accuracy: 0.9316 - val_loss: 0.1830 - val_accuracy: 0.9309
Epoch 20/20
535/535 [==============================] - 1s 2ms/step - loss: 0.1325 -
accuracy: 0.9322 - val_loss: 0.1694 - val_accuracy: 0.9351
3582/3582 [==============================] - 2s 681us/step - loss: 0.1728 -
accuracy: 0.9338
Test loss: 0.1728
Test accuracy: 0.9338
```





4.0.2 3.2 Automatic hyper parameter search

The number of hyper parameters that can be tried manually is limited and the process of trying out the different combinations and keeping track of them is time consuming and tedious. Today, there are several libraries available for automatic hyper parameter tuning (see an extensive list here). The library that we will use in this lab is `Ray Tune` which can be integrated with many of the deep learning APIs available today (for the full description of the library capabilities see the documentation).

To use the `Ray Tune` functionality we need a function that defines the model training. This will then be used in a wrapper function that defines the hyper parameter search space, the resources available for running the search and the search algorithm.

Start by implementing the `train_DNN` function in the `utilities.py` file (more detailed instructions are available in `utilities.py`). In the cell below, you can set up the search space and a `tune` ray

object that takes the `train_DNN`. The tuner will set `train_DNN`, will select a set of hyper parameters and train several models for us (more information here).

`Ray Tune` library provides several types of hyper parameter search algorithms, including random and grid search, and Bayesian optimization. In this lab we will be using the `Bayesian Optimization` searching algorithm (additional information about this method can be found here).

Question

15. Run the automatic hyper parameter search with range of possible hyper parameter values as in your manual search. Does the automatic search set of parameters match those that you have found?
16. What are the benefits and drawbacks of automatic hyper parameter search?

Answers

15. The result from our manual search showed that regularization with batch norm seems to improve the results while dropout does not hava a positive effect, therefore we set the fixed parameters accordingly. Contrary to our manual search, the best configuration found by the tuner uses a deeper and broader net with the maximum values that we defined for depth and hidden units. Also sigmoid seemed to work better for us as activation function, the automatic search found relu to be prefered in its best configuration.

16. The benefits incldue, that the hyperparameter search can be automated and be performed on a large search space, that could not be covered by hand. If the computational power is available it can also be parallalized on different GPUs. The drawbacks are e.g. the high computational cost or the dependency on the search algorithm. Grid search might not have the chance to find an optimum for example.

[63]:
```
# import train_DNN
from utilities import train_DNN_tune

# imports for hyperparameter tuning
from ray import tune, train
from ray.tune.schedulers import AsyncHyperBandScheduler
from ray.tune.search.bayesopt import BayesOptSearch

#import os
#from tensorboardX import SummaryWriter

#logdir = os.path.abspath("C:/ray_results/logs")  # Use an absolute, short path
#writer = SummaryWriter(logdir=logdir)

# ------------------------------------------
# === Your code here =======================
# ------------------------------------------

# Define the hyper parameter, both those that should be searched and those that␣
 ↪are fixed.
```

```
#  Hyperparameters to search are: act_fun, optimizer, use_bn, n_hidden_layers␣
 ↪and n_hidden_units.
# The remaining parameters can be set to fixed values (This is to reduce the␣
 ↪search space and time).
# Add the batch size and epochs so that the train_DNN can access them.
hyperparameter_space =  {
            "act_fun": tune.choice(["s", "r"]),
            "optimizer": tune.choice(["sgd", "adam"]),
            "use_bn": tune.choice([True, False]),
            "n_hidden_layers": tune.choice([2, 4, 6, 10]),
            "n_hidden_units": tune.choice([20, 50, 100]),

            # here define the fixed parameters
            "loss": "binary_crossentropy",
            "learning_rate": 0.1,
            "use_bn": True,
            "use_dropout": False,
            "use_custom_dropout": False,
            "use_variational_layer": False,
            "input_shape": Xtrain.shape[1],
        }

# specify batch and number of epochs
training_config = {
            "epochs": 20,
            "batch_size": 1000,
            "class_weight": class_weights
        }

# specify the number of samples to take from the hyper parameter space and run.␣
 ↪The larger the number, the longer the search time.
# Start small (e.g. 2) to test your implementation, then increase.
num_samples = 50

# ------------------------------------------


# Specification of the search algorithm
bayesopt = BayesOptSearch(metric="mean_accuracy", mode="max")

# Definition of the Scheduler. This allows for several models to be trained/
 ↪stopped/re-started simultaneously
sched = AsyncHyperBandScheduler(
        time_attr="training_iteration", max_t=100, grace_period=20
    )

# Setting up the tuner.
```

```
tuner = tune.Tuner(
        tune.with_resources(train_DNN_tune, resources={"cpu": 12, "gpu":0}), #␣
 ↪definition of which training function to use and the available resources.␣
 ↪Consider adding "gpu":0 to resources if available.
        tune_config=tune.TuneConfig(
            search_alg=bayesopt,
            scheduler=sched,
            trial_dirname_creator="1"
        ),
        run_config=train.RunConfig(
            name="DNN_hp_tuning",
            stop={"mean_accuracy": 1},
        ),
    )

# Run the hyper parameter search.
data = (Xtrain, Ytrain, Xval, Yval)
analysis0 = tune.run(
        tune.with_parameters(train_DNN_tune, data=data,␣
 ↪training_config=training_config),
        verbose=1,
        config=hyperparameter_space,
        num_samples=num_samples,
        storage_path='C:\\ray'
        )
```

```
<IPython.core.display.HTML object>
```

```
2025-02-28 16:48:43,376 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00000_0_act_fun=r,n_hidden_layers=4,n_h
idden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,378 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00000_0_act_fun=r,n_hidden_layers=4,n_h
idden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,384 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00001_1_act_fun=s,n_hidden_layers=10,n_
```

```
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,386 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00001_1_act_fun=s,n_hidden_layers=10,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,386 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00002_2_act_fun=s,n_hidden_layers=4,n_h
idden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,392 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00002_2_act_fun=s,n_hidden_layers=4,n_h
idden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,395 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00003_3_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,395 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00003_3_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,398 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00004_4_act_fun=r,n_hidden_layers=6,n_h
idden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,398 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
```

```
43\driver_artifacts\train_DNN_tune_7cdd3_00004_4_act_fun=r,n_hidden_layers=6,n_h
idden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,398 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00005_5_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,398 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00005_5_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,409 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00006_6_act_fun=r,n_hidden_layers=4,n_h
idden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,411 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00006_6_act_fun=r,n_hidden_layers=4,n_h
idden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,415 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00007_7_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,417 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00007_7_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,420 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
```

```
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00008_8_act_fun=r,n_hidden_layers=2,n_h
idden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,421 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00008_8_act_fun=r,n_hidden_layers=2,n_h
idden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,424 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00009_9_act_fun=s,n_hidden_layers=10,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,426 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00009_9_act_fun=s,n_hidden_layers=10,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,428 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00010_10_act_fun=r,n_hidden_layers=6,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,432 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00010_10_act_fun=r,n_hidden_layers=6,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,434 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00011_11_act_fun=r,n_hidden_layers=10,n
_hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,434 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
```

```
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00011_11_act_fun=r,n_hidden_layers=10,n
_hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,438 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00012_12_act_fun=s,n_hidden_layers=4,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,441 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00012_12_act_fun=s,n_hidden_layers=4,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,444 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00013_13_act_fun=s,n_hidden_layers=10,n
_hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,445 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00013_13_act_fun=s,n_hidden_layers=10,n
_hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,450 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00014_14_act_fun=r,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,451 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00014_14_act_fun=r,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,453 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
```

```
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00015_15_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,455 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00015_15_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,460 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00016_16_act_fun=s,n_hidden_layers=2,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,462 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00016_16_act_fun=s,n_hidden_layers=2,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,464 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00017_17_act_fun=r,n_hidden_layers=6,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,467 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00017_17_act_fun=r,n_hidden_layers=6,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,469 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00018_18_act_fun=s,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,472 WARNING trial.py:647 -- The path to the trial log
```

```
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00018_18_act_fun=s,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,474 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00019_19_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,476 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00019_19_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,479 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00020_20_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,481 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00020_20_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,484 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00021_21_act_fun=r,n_hidden_layers=4,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,486 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00021_21_act_fun=r,n_hidden_layers=4,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
```

```
2025-02-28 16:48:43,489 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00022_22_act_fun=s,n_hidden_layers=4,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,492 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00022_22_act_fun=s,n_hidden_layers=4,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,495 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00023_23_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,497 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00023_23_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,497 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00024_24_act_fun=r,n_hidden_layers=10,n
_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,497 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00024_24_act_fun=r,n_hidden_layers=10,n
_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,497 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00025_25_act_fun=s,n_hidden_layers=2,n_
```

```
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,506 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00025_25_act_fun=s,n_hidden_layers=2,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,509 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00026_26_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,512 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00026_26_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,515 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00027_27_act_fun=r,n_hidden_layers=10,n
_hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,515 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00027_27_act_fun=r,n_hidden_layers=10,n
_hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,518 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00028_28_act_fun=s,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,518 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
```

```
43\driver_artifacts\train_DNN_tune_7cdd3_00028_28_act_fun=s,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,518 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00029_29_act_fun=r,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,526 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00029_29_act_fun=r,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,530 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00030_30_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,531 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00030_30_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,535 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00031_31_act_fun=r,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,537 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00031_31_act_fun=r,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,540 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
```

```
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00032_32_act_fun=r,n_hidden_layers=6,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,542 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00032_32_act_fun=r,n_hidden_layers=6,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,545 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00033_33_act_fun=r,n_hidden_layers=4,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,547 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00033_33_act_fun=r,n_hidden_layers=4,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,550 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00034_34_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,552 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00034_34_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,556 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00035_35_act_fun=r,n_hidden_layers=2,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,559 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
```

02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00035_35_act_fun=r,n_hidden_layers=2,n_hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,563 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00036_36_act_fun=r,n_hidden_layers=6,n_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,567 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00036_36_act_fun=r,n_hidden_layers=6,n_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,571 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00037_37_act_fun=r,n_hidden_layers=4,n_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,573 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00037_37_act_fun=r,n_hidden_layers=4,n_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,577 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00038_38_act_fun=r,n_hidden_layers=4,n_hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,580 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00038_38_act_fun=r,n_hidden_layers=4,n_hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,584 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator`

```
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00039_39_act_fun=s,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,584 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00039_39_act_fun=s,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,590 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00040_40_act_fun=s,n_hidden_layers=2,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,594 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00040_40_act_fun=s,n_hidden_layers=2,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,597 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00041_41_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,601 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00041_41_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,601 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00042_42_act_fun=s,n_hidden_layers=10,n
_hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,606 WARNING trial.py:647 -- The path to the trial log
```

```
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00042_42_act_fun=s,n_hidden_layers=10,n
_hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,608 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00043_43_act_fun=s,n_hidden_layers=6,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,610 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00043_43_act_fun=s,n_hidden_layers=6,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,613 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00044_44_act_fun=r,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,615 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00044_44_act_fun=r,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,615 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00045_45_act_fun=s,n_hidden_layers=6,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,620 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00045_45_act_fun=s,n_hidden_layers=6,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
```

```
2025-02-28 16:48:43,624 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00046_46_act_fun=s,n_hidden_layers=2,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,626 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00046_46_act_fun=s,n_hidden_layers=2,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,629 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00047_47_act_fun=r,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,629 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00047_47_act_fun=r,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,634 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00048_48_act_fun=s,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,636 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00048_48_act_fun=s,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:43,636 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00049_49_act_fun=r,n_hidden_layers=2,n_
```

```
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:43,636 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00049_49_act_fun=r,n_hidden_layers=2,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:48:57,863 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00000_0_act_fun=r,n_hidden_layers=4,n_h
idden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:48:57,870 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00000_0_act_fun=r,n_hidden_layers=4,n_h
idden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:49:01,669 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00000_0_act_fun=r,n_hidden_layers=4,n_h
idden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:49:46,612 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00001_1_act_fun=s,n_hidden_layers=10,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:49:46,612 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00001_1_act_fun=s,n_hidden_layers=10,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:49:51,581 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
```

```
43\driver_artifacts\train_DNN_tune_7cdd3_00001_1_act_fun=s,n_hidden_layers=10,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:50:50,786 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00002_2_act_fun=s,n_hidden_layers=4,n_h
idden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:50:50,788 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00002_2_act_fun=s,n_hidden_layers=4,n_h
idden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:50:54,879 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00002_2_act_fun=s,n_hidden_layers=4,n_h
idden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:51:40,567 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00003_3_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:51:40,567 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00003_3_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:51:49,133 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00003_3_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:53:16,134 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
```

```
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00004_4_act_fun=r,n_hidden_layers=6,n_h
idden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:53:16,134 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00004_4_act_fun=r,n_hidden_layers=6,n_h
idden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:53:22,511 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00004_4_act_fun=r,n_hidden_layers=6,n_h
idden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:54:50,668 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00005_5_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:54:50,670 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00005_5_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:54:59,678 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00005_5_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:56:32,912 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00006_6_act_fun=r,n_hidden_layers=4,n_h
idden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:56:32,914 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
```

```
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00006_6_act_fun=r,n_hidden_layers=4,n_h
idden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:56:38,341 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00006_6_act_fun=r,n_hidden_layers=4,n_h
idden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:57:52,538 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00007_7_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:57:52,541 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00007_7_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:58:00,421 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00007_7_act_fun=s,n_hidden_layers=10,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 16:59:32,003 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00008_8_act_fun=r,n_hidden_layers=2,n_h
idden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:59:32,004 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00008_8_act_fun=r,n_hidden_layers=2,n_h
idden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 16:59:34,934 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
```

```
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00008_8_act_fun=r,n_hidden_layers=2,n_h
idden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:00:08,011 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00009_9_act_fun=s,n_hidden_layers=10,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:00:08,016 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00009_9_act_fun=s,n_hidden_layers=10,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:00:18,646 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00009_9_act_fun=s,n_hidden_layers=10,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:02:37,502 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00010_10_act_fun=r,n_hidden_layers=6,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:02:37,505 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00010_10_act_fun=r,n_hidden_layers=6,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:02:45,106 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00010_10_act_fun=r,n_hidden_layers=6,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:04:11,583 WARNING trial.py:647 -- The path to the trial log
```

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directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00011_11_act_fun=r,n_hidden_layers=10,n
_hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:04:11,583 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00011_11_act_fun=r,n_hidden_layers=10,n
_hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:04:18,489 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00011_11_act_fun=r,n_hidden_layers=10,n
_hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:05:47,034 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00012_12_act_fun=s,n_hidden_layers=4,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:05:47,037 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00012_12_act_fun=s,n_hidden_layers=4,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:05:50,911 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00012_12_act_fun=s,n_hidden_layers=4,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:06:34,820 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00013_13_act_fun=s,n_hidden_layers=10,n
_hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
```

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2025-02-28 17:06:34,822 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00013_13_act_fun=s,n_hidden_layers=10,n
_hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:06:42,529 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00013_13_act_fun=s,n_hidden_layers=10,n
_hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:08:17,201 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00014_14_act_fun=r,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:08:17,203 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00014_14_act_fun=r,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:08:26,867 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00014_14_act_fun=r,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:10:45,518 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00015_15_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:10:45,521 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00015_15_act_fun=s,n_hidden_layers=6,n_
```

```
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:10:50,143 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00015_15_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:11:42,594 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00016_16_act_fun=s,n_hidden_layers=2,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:11:42,596 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00016_16_act_fun=s,n_hidden_layers=2,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:11:45,876 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00016_16_act_fun=s,n_hidden_layers=2,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:12:25,436 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00017_17_act_fun=r,n_hidden_layers=6,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:12:25,438 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00017_17_act_fun=r,n_hidden_layers=6,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:12:31,670 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
```

```
43\driver_artifacts\train_DNN_tune_7cdd3_00017_17_act_fun=r,n_hidden_layers=6,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:13:39,618 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00018_18_act_fun=s,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:13:39,620 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00018_18_act_fun=s,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:13:49,687 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00018_18_act_fun=s,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:16:11,745 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00019_19_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:16:11,749 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00019_19_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:16:16,053 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00019_19_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:17:09,122 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
```

```
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00020_20_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:17:09,124 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00020_20_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:17:14,173 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00020_20_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:18:05,166 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00021_21_act_fun=r,n_hidden_layers=4,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:18:05,169 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00021_21_act_fun=r,n_hidden_layers=4,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:18:09,881 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00021_21_act_fun=r,n_hidden_layers=4,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:19:05,864 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00022_22_act_fun=s,n_hidden_layers=4,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:19:05,866 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
```

02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00022_22_act_fun=s,n_hidden_layers=4,n_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:19:11,017 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00022_22_act_fun=s,n_hidden_layers=4,n_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:20:26,921 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00023_23_act_fun=s,n_hidden_layers=6,n_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:20:26,923 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00023_23_act_fun=s,n_hidden_layers=6,n_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:20:32,220 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00023_23_act_fun=s,n_hidden_layers=6,n_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:21:24,264 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00024_24_act_fun=r,n_hidden_layers=10,n_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:21:24,268 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00024_24_act_fun=r,n_hidden_layers=10,n_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:21:31,591 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator`

```
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00024_24_act_fun=r,n_hidden_layers=10,n
_hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:22:35,274 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00025_25_act_fun=s,n_hidden_layers=2,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:22:35,274 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00025_25_act_fun=s,n_hidden_layers=2,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:22:38,297 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00025_25_act_fun=s,n_hidden_layers=2,n_
hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:23:23,366 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00026_26_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:23:23,370 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00026_26_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:23:27,151 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00026_26_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:24:17,385 WARNING trial.py:647 -- The path to the trial log
```

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directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00027_27_act_fun=r,n_hidden_layers=10,n
_hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:24:17,390 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00027_27_act_fun=r,n_hidden_layers=10,n
_hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:24:23,747 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00027_27_act_fun=r,n_hidden_layers=10,n
_hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:25:31,427 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00028_28_act_fun=s,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:25:31,429 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00028_28_act_fun=s,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:25:41,393 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00028_28_act_fun=s,n_hidden_layers=10,n
_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:28:02,061 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00029_29_act_fun=r,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
```

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2025-02-28 17:28:02,061 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00029_29_act_fun=r,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:28:07,942 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00029_29_act_fun=r,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:29:21,879 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00030_30_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:29:21,879 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00030_30_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:29:27,065 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00030_30_act_fun=s,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:30:17,747 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00031_31_act_fun=r,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:30:17,747 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00031_31_act_fun=r,n_hidden_layers=4,n_
```

```
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:30:23,131 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00031_31_act_fun=r,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:31:36,724 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00032_32_act_fun=r,n_hidden_layers=6,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:31:36,726 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00032_32_act_fun=r,n_hidden_layers=6,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:31:42,010 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00032_32_act_fun=r,n_hidden_layers=6,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:33:06,345 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00033_33_act_fun=r,n_hidden_layers=4,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:33:06,345 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00033_33_act_fun=r,n_hidden_layers=4,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:33:08,971 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
```

```
43\driver_artifacts\train_DNN_tune_7cdd3_00033_33_act_fun=r,n_hidden_layers=4,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:33:44,003 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00034_34_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:33:44,007 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00034_34_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:33:47,909 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00034_34_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:34:29,344 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00035_35_act_fun=r,n_hidden_layers=2,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:34:29,344 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00035_35_act_fun=r,n_hidden_layers=2,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:34:31,850 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00035_35_act_fun=r,n_hidden_layers=2,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:35:07,270 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
```

```
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00036_36_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:35:07,271 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00036_36_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:35:11,325 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00036_36_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:35:51,478 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00037_37_act_fun=r,n_hidden_layers=4,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:35:51,480 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00037_37_act_fun=r,n_hidden_layers=4,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:35:54,934 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00037_37_act_fun=r,n_hidden_layers=4,n_
hidden_units=20,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:36:30,239 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00038_38_act_fun=r,n_hidden_layers=4,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:36:30,240 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
```

02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00038_38_act_fun=r,n_hidden_layers=4,n_hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:36:33,620 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00038_38_act_fun=r,n_hidden_layers=4,n_hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:37:16,695 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00039_39_act_fun=s,n_hidden_layers=2,n_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:37:16,696 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00039_39_act_fun=s,n_hidden_layers=2,n_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:37:19,433 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00039_39_act_fun=s,n_hidden_layers=2,n_hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:38:01,226 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00040_40_act_fun=s,n_hidden_layers=2,n_hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:38:01,228 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator` to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-02-28_16-48-43\driver_artifacts\train_DNN_tune_7cdd3_00040_40_act_fun=s,n_hidden_layers=2,n_hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:38:04,434 WARNING trial.py:647 -- The path to the trial log directory is too long (max length: 260. Consider using `trial_dirname_creator`

```
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00040_40_act_fun=s,n_hidden_layers=2,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:38:46,512 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00041_41_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:38:46,513 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00041_41_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:38:49,745 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00041_41_act_fun=r,n_hidden_layers=6,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:39:29,262 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00042_42_act_fun=s,n_hidden_layers=10,n
_hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:39:29,264 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00042_42_act_fun=s,n_hidden_layers=10,n
_hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:39:36,368 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00042_42_act_fun=s,n_hidden_layers=10,n
_hidden_units=50,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:40:56,135 WARNING trial.py:647 -- The path to the trial log
```

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directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00043_43_act_fun=s,n_hidden_layers=6,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:40:56,136 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00043_43_act_fun=s,n_hidden_layers=6,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:41:01,453 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00043_43_act_fun=s,n_hidden_layers=6,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:42:20,927 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00044_44_act_fun=r,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:42:20,928 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00044_44_act_fun=r,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:42:23,841 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00044_44_act_fun=r,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:43:05,298 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00045_45_act_fun=s,n_hidden_layers=6,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
```

```
2025-02-28 17:43:05,299 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00045_45_act_fun=s,n_hidden_layers=6,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:43:11,404 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00045_45_act_fun=s,n_hidden_layers=6,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:44:32,009 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00046_46_act_fun=s,n_hidden_layers=2,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:44:32,010 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00046_46_act_fun=s,n_hidden_layers=2,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:44:34,789 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00046_46_act_fun=s,n_hidden_layers=2,n_
hidden_units=50,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:45:08,653 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00047_47_act_fun=r,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:45:08,655 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00047_47_act_fun=r,n_hidden_layers=2,n_
```

```
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:45:11,392 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00047_47_act_fun=r,n_hidden_layers=2,n_
hidden_units=100,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:45:53,192 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00048_48_act_fun=s,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:45:53,193 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00048_48_act_fun=s,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:45:58,085 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00048_48_act_fun=s,n_hidden_layers=4,n_
hidden_units=100,optimizer=adam_2025-02-28_16-48-43
2025-02-28 17:46:59,857 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00049_49_act_fun=r,n_hidden_layers=2,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:46:59,859 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
43\driver_artifacts\train_DNN_tune_7cdd3_00049_49_act_fun=r,n_hidden_layers=2,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:47:01,876 WARNING trial.py:647 -- The path to the trial log
directory is too long (max length: 260. Consider using `trial_dirname_creator`
to shorten the path. Path: C:\Users\jakob\AppData\Local\Temp\ray\session_2025-
02-28_13-05-29_309809_25788\artifacts\2025-02-28_16-48-43\train_DNN_tune_2025-
02-28_16-48-
```

```
43\driver_artifacts\train_DNN_tune_7cdd3_00049_49_act_fun=r,n_hidden_layers=2,n_
hidden_units=20,optimizer=sgd_2025-02-28_16-48-43
2025-02-28 17:47:16,859 INFO tune.py:1009 -- Wrote the latest version of all
result files and experiment state to 'C:/ray/train_DNN_tune_2025-02-28_16-48-43'
in 0.0576s.
2025-02-28 17:47:16,883 INFO tune.py:1041 -- Total run time: 3513.61 seconds
(3513.52 seconds for the tuning loop).
```

[ ]:
```python
# Show the best hyper parameter configuration that was found
best_configuration = analysis0.get_best_config(metric="_metric",mode='max')
for k, v in best_configuration.items():
    print(f"{k}: {v}")

# Print its accuracy
analysis0_df = analysis0.dataframe()
print(f'\nBest configuration accuracy: {analysis0_df.
 ↪iloc[analysis0_df["_metric"].idxmax()]["_metric"]}')
```

```
act_fun: r
optimizer: sgd
use_bn: True
n_hidden_layers: 10
n_hidden_units: 100
loss: binary_crossentropy
learning_rate: 0.1
use_dropout: False
use_custom_dropout: False
use_variational_layer: False
input_shape: 92

Best configuration accuracy: 0.9413021802902222
```

[ ]:
```
```

[ ]:
```
```

[11]:
```python
config = {
    "act_fun": "r",
    "optimizer": "sgd",
    "use_bn": True,
    "n_hidden_layers": 10,
    "n_hidden_units": 100,
    "loss": "binary_crossentropy",
    "learning_rate": 0.1,
    "use_dropout": False,
    "use_custom_dropout": False,
    "use_variational_layer": False,
    "input_shape": Xtrain.shape[1]
```

```
}

train_config = {
    "epochs": 20,
    "batch_size": 1000,
    "class_weight": class_weights
}


best_model = train_DNN(config, (Xtrain, Ytrain, Xval, Yval), train_config)
```

```
Epoch 1/20
WARNING:tensorflow:From c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\tf_keras\src\utils\tf_utils.py:492: The name
tf.ragged.RaggedTensorValue is deprecated. Please use
tf.compat.v1.ragged.RaggedTensorValue instead.

535/535 [==============================] - 7s 10ms/step - loss: 0.1920 -
accuracy: 0.9104 - val_loss: 0.1845 - val_accuracy: 0.9206
Epoch 2/20
 21/535 [>…] - ETA: 4s - loss: 0.1625 - accuracy:
0.9181

c:\Users\jakob\Documents\venvs\732A82\Lib\site-
packages\ray\train\_internal\session.py:652: UserWarning: `report` is meant to
only be called inside a function that is executed by a Tuner or Trainer.
Returning `None`.
  warnings.warn(

535/535 [==============================] - 5s 9ms/step - loss: 0.1590 -
accuracy: 0.9195 - val_loss: 0.1739 - val_accuracy: 0.9278
Epoch 3/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1465 -
accuracy: 0.9249 - val_loss: 0.2033 - val_accuracy: 0.9228
Epoch 4/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1370 -
accuracy: 0.9296 - val_loss: 0.2126 - val_accuracy: 0.9256
Epoch 5/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1332 -
accuracy: 0.9315 - val_loss: 0.1587 - val_accuracy: 0.9339
Epoch 6/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1286 -
accuracy: 0.9335 - val_loss: 0.1691 - val_accuracy: 0.9349
Epoch 7/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1263 -
accuracy: 0.9352 - val_loss: 0.1493 - val_accuracy: 0.9396
Epoch 8/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1238 -
accuracy: 0.9365 - val_loss: 0.1680 - val_accuracy: 0.9362
```

```
Epoch 9/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1226 -
accuracy: 0.9370 - val_loss: 0.1347 - val_accuracy: 0.9408
Epoch 10/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1208 -
accuracy: 0.9381 - val_loss: 0.1647 - val_accuracy: 0.9363
Epoch 11/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1191 -
accuracy: 0.9389 - val_loss: 0.1577 - val_accuracy: 0.9366
Epoch 12/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1196 -
accuracy: 0.9388 - val_loss: 0.1793 - val_accuracy: 0.9325
Epoch 13/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1160 -
accuracy: 0.9407 - val_loss: 0.1681 - val_accuracy: 0.9380
Epoch 14/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1148 -
accuracy: 0.9413 - val_loss: 0.1317 - val_accuracy: 0.9418
Epoch 15/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1142 -
accuracy: 0.9419 - val_loss: 0.1676 - val_accuracy: 0.9227
Epoch 16/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1135 -
accuracy: 0.9421 - val_loss: 0.1886 - val_accuracy: 0.9389
Epoch 17/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1117 -
accuracy: 0.9434 - val_loss: 0.1641 - val_accuracy: 0.9297
Epoch 18/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1111 -
accuracy: 0.9435 - val_loss: 0.1491 - val_accuracy: 0.9309
Epoch 19/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1100 -
accuracy: 0.9441 - val_loss: 0.3487 - val_accuracy: 0.9257
Epoch 20/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1093 -
accuracy: 0.9443 - val_loss: 0.1531 - val_accuracy: 0.9409
```

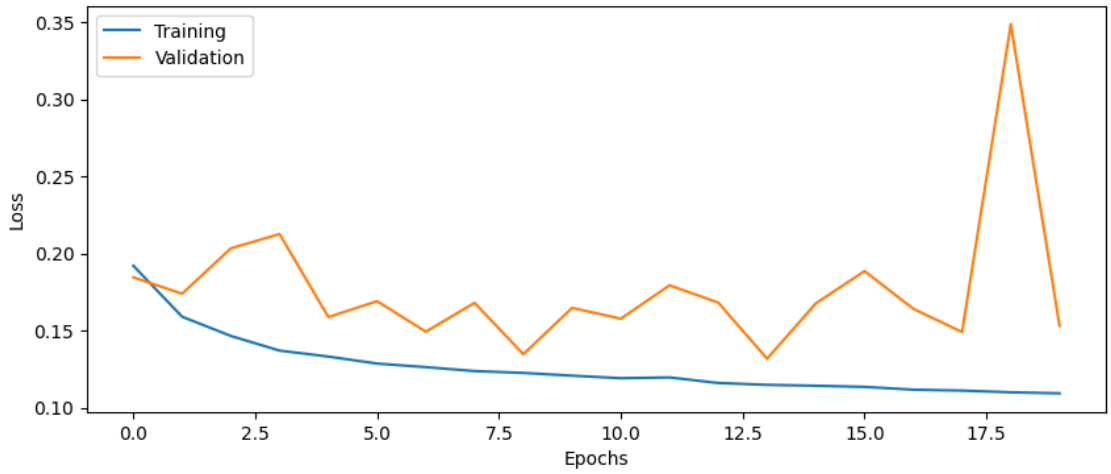
[12]:
```
score = best_model.model.evaluate(Xtest, Ytest)

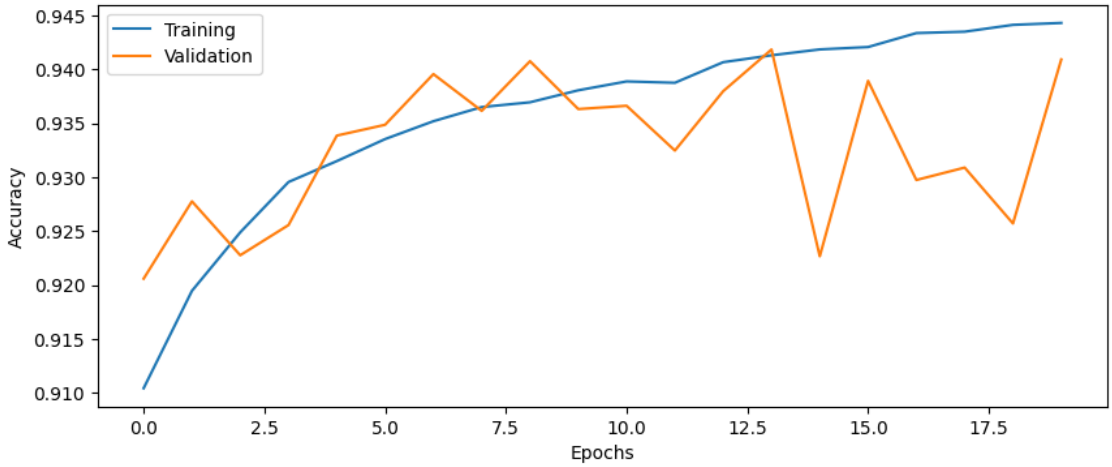
print('Test loss: %.4f' % score[0])
print('Test accuracy: %.4f' % score[1])

# Plot the history from the training run
plot_results(best_model)
```

```
3582/3582 [==============================] - 3s 970us/step - loss: 0.1575 -
accuracy: 0.9396
Test loss: 0.1575
```

```
Test accuracy: 0.9396
```





The best configuration found by the tuner is slightly better than our previous models if we look at the test accuracy. Therefore it is also better than the naive classifier.

5 Part 4: Uncertainty quantification

In the next sections you will explore three methods for model uncertainty estimation: - Monte Carlo dropout where we take advantage of the dropout layer during inference time. - Cross validation where we train several models on different splits of data. - Bayesian neural networks (BNN) where we modify our model definition to allow the model to learn distributions over weights and the output.

!Note: through the next sections, use your best model configuration that you found through hyper parameter tuning (either manual or automatic).

5.0.1 4.1 Dropout uncertainty

Dropout can also be used during testing, to obtain an estimate of the model uncertainty. Since dropout will randomly remove connections, the network will produce different results every time the same (test) data is put into the network. This technique is called Monte Carlo dropout. For more information, see this paper

To achieve this, we need to redefine the Keras Dropout. This was already done for you and it is available in `utilities.py` under `myDropout`. Adapt the `build_DNN` function to two boolean arguments, use_dropout and use_custom_dropout; add a standard Dropout layer if use_dropout is true, add a `myDropout` layer if use_custom_dropout is true.

Run the same test data through the trained network 100 times, with dropout turned on.

[13]:
```
from utilities import train_DNN
# ----------------------------------------
# === Your code here =====================
# ----------------------------------------

# Your best training parameters
batch_size = 1000
epochs = 20
input_shape = Xtrain.shape[1]
loss = "binary_crossentropy"
learning_rate = 0.1

# Build and train model
model_config = {
    "act_fun": "r",
    "optimizer": "sgd",
    "use_bn": True,
    "n_hidden_layers": 10,
    "n_hidden_units": 100,
    "loss": "binary_crossentropy",
    "learning_rate": 0.1,
    "use_dropout": True,
    "use_custom_dropout": True,
    "use_variational_layer": False,
    "input_shape": Xtrain.shape[1]
}

train_config = {
    "epochs": 20,
    "batch_size": 1000,
    "class_weight": class_weights
}
# Train the model, provide training data and validation data
history10 = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval), train_config)
```

```
Epoch 1/20
```

```
535/535 [==============================] - 10s 15ms/step - loss: 0.6419 -
accuracy: 0.7837 - val_loss: 0.5029 - val_accuracy: 0.8404
Epoch 2/20
535/535 [==============================] - 8s 15ms/step - loss: 0.5731 -
accuracy: 0.8632 - val_loss: 0.4754 - val_accuracy: 0.8404
Epoch 3/20
535/535 [==============================] - 8s 14ms/step - loss: 0.5167 -
accuracy: 0.8749 - val_loss: 0.4448 - val_accuracy: 0.8404
Epoch 4/20
535/535 [==============================] - 8s 14ms/step - loss: 0.4167 -
accuracy: 0.8823 - val_loss: 0.4237 - val_accuracy: 0.8480
Epoch 5/20
535/535 [==============================] - 8s 15ms/step - loss: 0.3537 -
accuracy: 0.8914 - val_loss: 0.3334 - val_accuracy: 0.8728
Epoch 6/20
535/535 [==============================] - 8s 14ms/step - loss: 0.3132 -
accuracy: 0.8950 - val_loss: 0.2459 - val_accuracy: 0.8976
Epoch 7/20
535/535 [==============================] - 8s 15ms/step - loss: 0.2841 -
accuracy: 0.8971 - val_loss: 0.2143 - val_accuracy: 0.9087
Epoch 8/20
535/535 [==============================] - 8s 15ms/step - loss: 0.2648 -
accuracy: 0.9001 - val_loss: 0.2025 - val_accuracy: 0.9117
Epoch 9/20
535/535 [==============================] - 8s 14ms/step - loss: 0.2530 -
accuracy: 0.9025 - val_loss: 0.1981 - val_accuracy: 0.9131
Epoch 10/20
535/535 [==============================] - 8s 15ms/step - loss: 0.2438 -
accuracy: 0.9030 - val_loss: 0.1884 - val_accuracy: 0.9144
Epoch 11/20
535/535 [==============================] - 8s 15ms/step - loss: 0.2388 -
accuracy: 0.9032 - val_loss: 0.1875 - val_accuracy: 0.9150
Epoch 12/20
535/535 [==============================] - 8s 15ms/step - loss: 0.2338 -
accuracy: 0.9046 - val_loss: 0.1854 - val_accuracy: 0.9150
Epoch 13/20
535/535 [==============================] - 8s 15ms/step - loss: 0.2333 -
accuracy: 0.9044 - val_loss: 0.1817 - val_accuracy: 0.9135
Epoch 14/20
535/535 [==============================] - 8s 15ms/step - loss: 0.2337 -
accuracy: 0.9032 - val_loss: 0.1830 - val_accuracy: 0.9152
Epoch 15/20
535/535 [==============================] - 8s 15ms/step - loss: 0.2306 -
accuracy: 0.9054 - val_loss: 0.1875 - val_accuracy: 0.9153
Epoch 16/20
535/535 [==============================] - 8s 14ms/step - loss: 0.2285 -
accuracy: 0.9064 - val_loss: 0.1794 - val_accuracy: 0.9156
Epoch 17/20
```

```
535/535 [==============================] - 8s 15ms/step - loss: 0.2296 -
accuracy: 0.9053 - val_loss: 0.1830 - val_accuracy: 0.9153
Epoch 18/20
535/535 [==============================] - 8s 15ms/step - loss: 0.2270 -
accuracy: 0.9065 - val_loss: 0.1825 - val_accuracy: 0.9153
Epoch 19/20
535/535 [==============================] - 8s 15ms/step - loss: 0.2297 -
accuracy: 0.9043 - val_loss: 0.1872 - val_accuracy: 0.9151
Epoch 20/20
535/535 [==============================] - 8s 14ms/step - loss: 0.2276 -
accuracy: 0.9058 - val_loss: 0.1856 - val_accuracy: 0.9157
```

[14]:
```
# Run this cell a few times to evalute the model on test data,
# if you get slightly different test accuracy every time, Dropout during␣
 ↪testing is working

# Evaluate model on test data
score = history10.model.evaluate(Xtest, Ytest, verbose=0)

print('Test accuracy: %.4f' % score[1])
```

```
Test accuracy: 0.9139
```

[15]:
```
# ================================================
# === Your code here ============================
# ================================================
# Run the testing 100 times, and save the accuracies in an array
accs = [history10.model.evaluate(Xtest, Ytest, verbose=0)[1] for _ in␣
 ↪range(100)]

# Calculate and print mean and std of accuracies
print(np.mean(accs), np.std(accs))

# ================================================
```

```
0.9139684695005417 0.0001267350697988975
```

5.0.2 4.2: Cross validation uncertainty

Cross validation (CV) is often used to evaluate a model, by training and testing using different subsets of the data it is possible to get the uncertainty as the standard deviation over folds. We here use a help function from scikit-learn to setup the CV. Use 10 folds with shuffling, random state 1234.

Note: We here assume that you have found the best hyper parameters, so here the data are only split into training and testing, no validation.

[16]:
```
from sklearn.model_selection import StratifiedKFold
```

```
random_state = 1234
# ------------------------------------------
# === Your code here =======================
# ------------------------------------------

# Define 10-fold cross validation
n_splits = 10
skf = StratifiedKFold(n_splits=n_splits, random_state=random_state,␣
 ↪shuffle=True)
folds = skf.split(X, Y)
# Define where to save the test accuracies
test_accuracies = []

# Loop over cross validation folds
for train_i, test_i in folds:
    X_train, X_test = X[train_i], X[test_i]
    Y_train, Y_test = Y[train_i], Y[test_i]

    # Calculate class weights for current split (remember to call the function␣
 ↪using the input variable names e.g. class_weight='balanced', etc.)
    value1, value2 = class_weight.compute_class_weight(class_weight='balanced',␣
 ↪classes=np.unique(Ytrain), y=Ytrain)
    class_weights = {0: value1, 1: value2}

    # Rebuild the DNN model, to not continue training on the previously trained␣
 ↪model

    # Your best training parameters
    batch_size = 1000
    epochs = 20
    input_shape = Xtrain.shape[1]
    loss = "binary_crossentropy"
    learning_rate = 0.1

    # Build and train model
    model_config = {
        "act_fun": "r",
        "optimizer": "sgd",
        "use_bn": True,
        "n_hidden_layers": 10,
        "n_hidden_units": 100,
        "loss": "binary_crossentropy",
        "learning_rate": 0.1,
        "use_dropout": False,
        "use_custom_dropout": False,
        "use_variational_layer": False,
        "input_shape": Xtrain.shape[1]
```

```
    }

    train_config = {
        "epochs": 20,
        "batch_size": 1000,
        "class_weight": class_weights
    }


    # Fit the model with training set and class weights for this fold
    history = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval),␣
 ↪train_config)

    # Evaluate the model using the test set for this fold
    score = history.model.evaluate(Xtest, Ytest, verbose=0)

    # Save the test accuracy in an array
    test_accuracies.append(score[1])

# Calculate and print mean and std of accuracies
print(np.mean(test_accuracies), np.std(test_accuracies))

# ============================================
```

```
Epoch 1/20
535/535 [==============================] - 8s 12ms/step - loss: 0.1924 -
accuracy: 0.9107 - val_loss: 0.1980 - val_accuracy: 0.9187
Epoch 2/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1597 -
accuracy: 0.9183 - val_loss: 0.2064 - val_accuracy: 0.9194
Epoch 3/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1488 -
accuracy: 0.9238 - val_loss: 0.1763 - val_accuracy: 0.9259
Epoch 4/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1399 -
accuracy: 0.9283 - val_loss: 0.1715 - val_accuracy: 0.9301
Epoch 5/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1349 -
accuracy: 0.9302 - val_loss: 0.1800 - val_accuracy: 0.9312
Epoch 6/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1327 -
accuracy: 0.9312 - val_loss: 0.1875 - val_accuracy: 0.9257
Epoch 7/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1280 -
accuracy: 0.9340 - val_loss: 0.1692 - val_accuracy: 0.9351
Epoch 8/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1264 -
accuracy: 0.9344 - val_loss: 0.1753 - val_accuracy: 0.9347
```

```
Epoch 9/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1236 -
accuracy: 0.9360 - val_loss: 0.1584 - val_accuracy: 0.9373
Epoch 10/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1219 -
accuracy: 0.9371 - val_loss: 0.1681 - val_accuracy: 0.9365
Epoch 11/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1208 -
accuracy: 0.9374 - val_loss: 0.2009 - val_accuracy: 0.9295
Epoch 12/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1195 -
accuracy: 0.9384 - val_loss: 0.2837 - val_accuracy: 0.9264
Epoch 13/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1193 -
accuracy: 0.9382 - val_loss: 0.1541 - val_accuracy: 0.9363
Epoch 14/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1172 -
accuracy: 0.9397 - val_loss: 0.1394 - val_accuracy: 0.9418
Epoch 15/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1155 -
accuracy: 0.9404 - val_loss: 0.1744 - val_accuracy: 0.9370
Epoch 16/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1158 -
accuracy: 0.9405 - val_loss: 0.1591 - val_accuracy: 0.9372
Epoch 17/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1142 -
accuracy: 0.9413 - val_loss: 0.1906 - val_accuracy: 0.9330
Epoch 18/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1130 -
accuracy: 0.9417 - val_loss: 0.1738 - val_accuracy: 0.9324
Epoch 19/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1121 -
accuracy: 0.9424 - val_loss: 0.1608 - val_accuracy: 0.9336
Epoch 20/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1105 -
accuracy: 0.9433 - val_loss: 0.1740 - val_accuracy: 0.9391
Epoch 1/20
535/535 [==============================] - 8s 11ms/step - loss: 0.1914 -
accuracy: 0.9106 - val_loss: 0.2020 - val_accuracy: 0.9196
Epoch 2/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1590 -
accuracy: 0.9186 - val_loss: 0.1761 - val_accuracy: 0.9273
Epoch 3/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1461 -
accuracy: 0.9254 - val_loss: 0.1610 - val_accuracy: 0.9336
Epoch 4/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1401 -
accuracy: 0.9278 - val_loss: 0.1535 - val_accuracy: 0.9326
```

```
Epoch 5/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1342 -
accuracy: 0.9304 - val_loss: 0.1629 - val_accuracy: 0.9328
Epoch 6/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1332 -
accuracy: 0.9306 - val_loss: 0.1767 - val_accuracy: 0.9302
Epoch 7/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1274 -
accuracy: 0.9344 - val_loss: 0.1642 - val_accuracy: 0.9366
Epoch 8/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1252 -
accuracy: 0.9354 - val_loss: 0.1456 - val_accuracy: 0.9388
Epoch 9/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1230 -
accuracy: 0.9366 - val_loss: 0.1562 - val_accuracy: 0.9365
Epoch 10/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1222 -
accuracy: 0.9370 - val_loss: 0.1608 - val_accuracy: 0.9346
Epoch 11/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1240 -
accuracy: 0.9358 - val_loss: 0.1560 - val_accuracy: 0.9371
Epoch 12/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1214 -
accuracy: 0.9376 - val_loss: 0.1610 - val_accuracy: 0.9380
Epoch 13/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1192 -
accuracy: 0.9388 - val_loss: 0.1666 - val_accuracy: 0.9362
Epoch 14/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1181 -
accuracy: 0.9396 - val_loss: 0.1244 - val_accuracy: 0.9463
Epoch 15/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1220 -
accuracy: 0.9375 - val_loss: 0.1435 - val_accuracy: 0.9415
Epoch 16/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1154 -
accuracy: 0.9409 - val_loss: 0.1499 - val_accuracy: 0.9388
Epoch 17/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1152 -
accuracy: 0.9408 - val_loss: 0.1341 - val_accuracy: 0.9434
Epoch 18/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1141 -
accuracy: 0.9414 - val_loss: 0.1510 - val_accuracy: 0.9345
Epoch 19/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1130 -
accuracy: 0.9422 - val_loss: 0.1656 - val_accuracy: 0.9374
Epoch 20/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1123 -
accuracy: 0.9425 - val_loss: 0.1498 - val_accuracy: 0.9401
```

```
Epoch 1/20
535/535 [==============================] - 8s 12ms/step - loss: 0.1937 -
accuracy: 0.9102 - val_loss: 0.1770 - val_accuracy: 0.9192
Epoch 2/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1599 -
accuracy: 0.9188 - val_loss: 0.1799 - val_accuracy: 0.9249
Epoch 3/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1467 -
accuracy: 0.9254 - val_loss: 0.1533 - val_accuracy: 0.9338
Epoch 4/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1384 -
accuracy: 0.9293 - val_loss: 0.1536 - val_accuracy: 0.9336
Epoch 5/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1357 -
accuracy: 0.9299 - val_loss: 0.2174 - val_accuracy: 0.9246
Epoch 6/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1307 -
accuracy: 0.9319 - val_loss: 0.1844 - val_accuracy: 0.9364
Epoch 7/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1285 -
accuracy: 0.9333 - val_loss: 0.1856 - val_accuracy: 0.9372
Epoch 8/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1265 -
accuracy: 0.9346 - val_loss: 0.1453 - val_accuracy: 0.9374
Epoch 9/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1243 -
accuracy: 0.9359 - val_loss: 0.1776 - val_accuracy: 0.9350
Epoch 10/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1251 -
accuracy: 0.9351 - val_loss: 0.1413 - val_accuracy: 0.9399
Epoch 11/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1229 -
accuracy: 0.9365 - val_loss: 0.1849 - val_accuracy: 0.9346
Epoch 12/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1201 -
accuracy: 0.9385 - val_loss: 0.1776 - val_accuracy: 0.9380
Epoch 13/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1192 -
accuracy: 0.9390 - val_loss: 0.1595 - val_accuracy: 0.9377
Epoch 14/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1173 -
accuracy: 0.9401 - val_loss: 0.1323 - val_accuracy: 0.9430
Epoch 15/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1159 -
accuracy: 0.9408 - val_loss: 0.1741 - val_accuracy: 0.9369
Epoch 16/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1158 -
accuracy: 0.9409 - val_loss: 0.1491 - val_accuracy: 0.9390
```

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Epoch 17/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1147 -
accuracy: 0.9414 - val_loss: 0.1283 - val_accuracy: 0.9461
Epoch 18/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1150 -
accuracy: 0.9411 - val_loss: 0.1921 - val_accuracy: 0.9371
Epoch 19/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1128 -
accuracy: 0.9423 - val_loss: 0.1699 - val_accuracy: 0.9372
Epoch 20/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1121 -
accuracy: 0.9426 - val_loss: 0.1309 - val_accuracy: 0.9462
Epoch 1/20
535/535 [==============================] - 8s 12ms/step - loss: 0.1920 -
accuracy: 0.9102 - val_loss: 0.2136 - val_accuracy: 0.9171
Epoch 2/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1592 -
accuracy: 0.9180 - val_loss: 0.1819 - val_accuracy: 0.9272
Epoch 3/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1454 -
accuracy: 0.9259 - val_loss: 0.2000 - val_accuracy: 0.9305
Epoch 4/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1385 -
accuracy: 0.9289 - val_loss: 0.1604 - val_accuracy: 0.9307
Epoch 5/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1338 -
accuracy: 0.9309 - val_loss: 0.1733 - val_accuracy: 0.9311
Epoch 6/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1304 -
accuracy: 0.9320 - val_loss: 0.1873 - val_accuracy: 0.9339
Epoch 7/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1277 -
accuracy: 0.9337 - val_loss: 0.1776 - val_accuracy: 0.9355
Epoch 8/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1257 -
accuracy: 0.9349 - val_loss: 0.1635 - val_accuracy: 0.9368
Epoch 9/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1246 -
accuracy: 0.9353 - val_loss: 0.1844 - val_accuracy: 0.9286
Epoch 10/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1237 -
accuracy: 0.9359 - val_loss: 0.1683 - val_accuracy: 0.9338
Epoch 11/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1221 -
accuracy: 0.9367 - val_loss: 0.1397 - val_accuracy: 0.9384
Epoch 12/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1204 -
accuracy: 0.9376 - val_loss: 0.2184 - val_accuracy: 0.9258
```

```
Epoch 13/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1189 -
accuracy: 0.9386 - val_loss: 0.1579 - val_accuracy: 0.9379
Epoch 14/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1186 -
accuracy: 0.9386 - val_loss: 0.1824 - val_accuracy: 0.9374
Epoch 15/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1188 -
accuracy: 0.9384 - val_loss: 0.1827 - val_accuracy: 0.9358
Epoch 16/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1182 -
accuracy: 0.9387 - val_loss: 0.1589 - val_accuracy: 0.9369
Epoch 17/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1158 -
accuracy: 0.9402 - val_loss: 0.3134 - val_accuracy: 0.9284
Epoch 18/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1149 -
accuracy: 0.9409 - val_loss: 0.1526 - val_accuracy: 0.9390
Epoch 19/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1145 -
accuracy: 0.9409 - val_loss: 0.1668 - val_accuracy: 0.9329
Epoch 20/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1133 -
accuracy: 0.9419 - val_loss: 0.2594 - val_accuracy: 0.9241
Epoch 1/20
535/535 [==============================] - 8s 11ms/step - loss: 0.1921 -
accuracy: 0.9107 - val_loss: 0.1940 - val_accuracy: 0.9220
Epoch 2/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1533 -
accuracy: 0.9228 - val_loss: 0.1808 - val_accuracy: 0.9306
Epoch 3/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1411 -
accuracy: 0.9285 - val_loss: 0.1630 - val_accuracy: 0.9322
Epoch 4/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1343 -
accuracy: 0.9310 - val_loss: 0.1862 - val_accuracy: 0.9327
Epoch 5/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1297 -
accuracy: 0.9331 - val_loss: 0.1622 - val_accuracy: 0.9296
Epoch 6/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1266 -
accuracy: 0.9347 - val_loss: 0.1551 - val_accuracy: 0.9356
Epoch 7/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1240 -
accuracy: 0.9360 - val_loss: 0.1515 - val_accuracy: 0.9382
Epoch 8/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1225 -
accuracy: 0.9370 - val_loss: 0.1807 - val_accuracy: 0.9368
```

```
Epoch 9/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1210 -
accuracy: 0.9379 - val_loss: 0.1847 - val_accuracy: 0.9360
Epoch 10/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1191 -
accuracy: 0.9389 - val_loss: 0.1635 - val_accuracy: 0.9379
Epoch 11/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1195 -
accuracy: 0.9385 - val_loss: 0.2089 - val_accuracy: 0.9223
Epoch 12/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1182 -
accuracy: 0.9392 - val_loss: 0.1333 - val_accuracy: 0.9433
Epoch 13/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1171 -
accuracy: 0.9399 - val_loss: 0.1449 - val_accuracy: 0.9398
Epoch 14/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1142 -
accuracy: 0.9413 - val_loss: 0.1426 - val_accuracy: 0.9436
Epoch 15/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1143 -
accuracy: 0.9412 - val_loss: 0.1771 - val_accuracy: 0.9371
Epoch 16/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1127 -
accuracy: 0.9423 - val_loss: 0.1607 - val_accuracy: 0.9399
Epoch 17/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1132 -
accuracy: 0.9420 - val_loss: 0.1423 - val_accuracy: 0.9423
Epoch 18/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1116 -
accuracy: 0.9433 - val_loss: 0.2292 - val_accuracy: 0.9318
Epoch 19/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1112 -
accuracy: 0.9432 - val_loss: 0.1337 - val_accuracy: 0.9432
Epoch 20/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1107 -
accuracy: 0.9434 - val_loss: 0.1776 - val_accuracy: 0.9382
Epoch 1/20
535/535 [==============================] - 8s 12ms/step - loss: 0.1936 -
accuracy: 0.9108 - val_loss: 0.2021 - val_accuracy: 0.9191
Epoch 2/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1597 -
accuracy: 0.9187 - val_loss: 0.1957 - val_accuracy: 0.9212
Epoch 3/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1493 -
accuracy: 0.9240 - val_loss: 0.1855 - val_accuracy: 0.9249
Epoch 4/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1400 -
accuracy: 0.9280 - val_loss: 0.1814 - val_accuracy: 0.9298
```

```
Epoch 5/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1349 -
accuracy: 0.9301 - val_loss: 0.1607 - val_accuracy: 0.9342
Epoch 6/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1311 -
accuracy: 0.9323 - val_loss: 0.2932 - val_accuracy: 0.9229
Epoch 7/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1284 -
accuracy: 0.9337 - val_loss: 0.1742 - val_accuracy: 0.9350
Epoch 8/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1248 -
accuracy: 0.9356 - val_loss: 0.1524 - val_accuracy: 0.9372
Epoch 9/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1242 -
accuracy: 0.9361 - val_loss: 0.1747 - val_accuracy: 0.9323
Epoch 10/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1238 -
accuracy: 0.9367 - val_loss: 0.1574 - val_accuracy: 0.9323
Epoch 11/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1212 -
accuracy: 0.9379 - val_loss: 0.1457 - val_accuracy: 0.9400
Epoch 12/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1193 -
accuracy: 0.9390 - val_loss: 0.1611 - val_accuracy: 0.9390
Epoch 13/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1183 -
accuracy: 0.9394 - val_loss: 0.1551 - val_accuracy: 0.9397
Epoch 14/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1174 -
accuracy: 0.9400 - val_loss: 0.2378 - val_accuracy: 0.9280
Epoch 15/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1160 -
accuracy: 0.9408 - val_loss: 0.2728 - val_accuracy: 0.9272
Epoch 16/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1153 -
accuracy: 0.9411 - val_loss: 0.1737 - val_accuracy: 0.9287
Epoch 17/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1144 -
accuracy: 0.9415 - val_loss: 0.4039 - val_accuracy: 0.9234
Epoch 18/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1158 -
accuracy: 0.9407 - val_loss: 0.1392 - val_accuracy: 0.9419
Epoch 19/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1136 -
accuracy: 0.9416 - val_loss: 0.1560 - val_accuracy: 0.9378
Epoch 20/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1130 -
accuracy: 0.9418 - val_loss: 0.2354 - val_accuracy: 0.9312
```

```
Epoch 1/20
535/535 [==============================] - 9s 12ms/step - loss: 0.1908 -
accuracy: 0.9104 - val_loss: 0.1954 - val_accuracy: 0.9185
Epoch 2/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1596 -
accuracy: 0.9182 - val_loss: 0.1758 - val_accuracy: 0.9251
Epoch 3/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1490 -
accuracy: 0.9234 - val_loss: 0.2193 - val_accuracy: 0.9207
Epoch 4/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1399 -
accuracy: 0.9278 - val_loss: 0.1748 - val_accuracy: 0.9292
Epoch 5/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1339 -
accuracy: 0.9305 - val_loss: 0.1886 - val_accuracy: 0.9299
Epoch 6/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1305 -
accuracy: 0.9318 - val_loss: 0.1544 - val_accuracy: 0.9360
Epoch 7/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1269 -
accuracy: 0.9338 - val_loss: 0.2143 - val_accuracy: 0.9289
Epoch 8/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1258 -
accuracy: 0.9345 - val_loss: 0.2013 - val_accuracy: 0.9251
Epoch 9/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1230 -
accuracy: 0.9363 - val_loss: 0.1441 - val_accuracy: 0.9381
Epoch 10/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1223 -
accuracy: 0.9367 - val_loss: 0.1598 - val_accuracy: 0.9389
Epoch 11/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1203 -
accuracy: 0.9376 - val_loss: 0.1633 - val_accuracy: 0.9373
Epoch 12/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1195 -
accuracy: 0.9381 - val_loss: 0.1567 - val_accuracy: 0.9387
Epoch 13/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1185 -
accuracy: 0.9386 - val_loss: 0.1573 - val_accuracy: 0.9330
Epoch 14/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1168 -
accuracy: 0.9399 - val_loss: 0.2343 - val_accuracy: 0.9286
Epoch 15/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1167 -
accuracy: 0.9398 - val_loss: 0.2726 - val_accuracy: 0.9258
Epoch 16/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1151 -
accuracy: 0.9404 - val_loss: 0.1630 - val_accuracy: 0.9351
```

```
Epoch 17/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1142 -
accuracy: 0.9412 - val_loss: 0.1649 - val_accuracy: 0.9372
Epoch 18/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1140 -
accuracy: 0.9413 - val_loss: 0.1611 - val_accuracy: 0.9377
Epoch 19/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1151 -
accuracy: 0.9404 - val_loss: 0.1596 - val_accuracy: 0.9376
Epoch 20/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1139 -
accuracy: 0.9411 - val_loss: 0.1436 - val_accuracy: 0.9406
Epoch 1/20
535/535 [==============================] - 8s 12ms/step - loss: 0.1922 -
accuracy: 0.9103 - val_loss: 0.2059 - val_accuracy: 0.9185
Epoch 2/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1608 -
accuracy: 0.9180 - val_loss: 0.1959 - val_accuracy: 0.9200
Epoch 3/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1504 -
accuracy: 0.9232 - val_loss: 0.1660 - val_accuracy: 0.9312
Epoch 4/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1398 -
accuracy: 0.9283 - val_loss: 0.1617 - val_accuracy: 0.9323
Epoch 5/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1343 -
accuracy: 0.9307 - val_loss: 0.2126 - val_accuracy: 0.9259
Epoch 6/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1300 -
accuracy: 0.9327 - val_loss: 0.2239 - val_accuracy: 0.9282
Epoch 7/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1271 -
accuracy: 0.9345 - val_loss: 0.1392 - val_accuracy: 0.9405
Epoch 8/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1242 -
accuracy: 0.9360 - val_loss: 0.1748 - val_accuracy: 0.9373
Epoch 9/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1221 -
accuracy: 0.9371 - val_loss: 0.1536 - val_accuracy: 0.9344
Epoch 10/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1202 -
accuracy: 0.9382 - val_loss: 0.1784 - val_accuracy: 0.9347
Epoch 11/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1210 -
accuracy: 0.9376 - val_loss: 0.4339 - val_accuracy: 0.9227
Epoch 12/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1193 -
accuracy: 0.9387 - val_loss: 0.2038 - val_accuracy: 0.9293
```

```
Epoch 13/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1173 -
accuracy: 0.9399 - val_loss: 0.1285 - val_accuracy: 0.9388
Epoch 14/20
535/535 [==============================] - 6s 12ms/step - loss: 0.1168 -
accuracy: 0.9401 - val_loss: 0.1382 - val_accuracy: 0.9424
Epoch 15/20
535/535 [==============================] - 7s 13ms/step - loss: 0.1151 -
accuracy: 0.9409 - val_loss: 0.1468 - val_accuracy: 0.9361
Epoch 16/20
535/535 [==============================] - 7s 12ms/step - loss: 0.1143 -
accuracy: 0.9414 - val_loss: 0.1364 - val_accuracy: 0.9409
Epoch 17/20
535/535 [==============================] - 6s 11ms/step - loss: 0.1119 -
accuracy: 0.9428 - val_loss: 0.1428 - val_accuracy: 0.9422
Epoch 18/20
535/535 [==============================] - 6s 10ms/step - loss: 0.1118 -
accuracy: 0.9430 - val_loss: 0.1712 - val_accuracy: 0.9331
Epoch 19/20
535/535 [==============================] - 6s 10ms/step - loss: 0.1107 -
accuracy: 0.9434 - val_loss: 0.1289 - val_accuracy: 0.9471
Epoch 20/20
535/535 [==============================] - 6s 10ms/step - loss: 0.1106 -
accuracy: 0.9435 - val_loss: 0.1532 - val_accuracy: 0.9364
Epoch 1/20
535/535 [==============================] - 7s 10ms/step - loss: 0.1931 -
accuracy: 0.9107 - val_loss: 0.2086 - val_accuracy: 0.9181
Epoch 2/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1611 -
accuracy: 0.9177 - val_loss: 0.2042 - val_accuracy: 0.9192
Epoch 3/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1509 -
accuracy: 0.9225 - val_loss: 0.2051 - val_accuracy: 0.9266
Epoch 4/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1414 -
accuracy: 0.9275 - val_loss: 0.1492 - val_accuracy: 0.9335
Epoch 5/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1364 -
accuracy: 0.9297 - val_loss: 0.1559 - val_accuracy: 0.9342
Epoch 6/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1317 -
accuracy: 0.9317 - val_loss: 0.1504 - val_accuracy: 0.9263
Epoch 7/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1299 -
accuracy: 0.9324 - val_loss: 0.1979 - val_accuracy: 0.9309
Epoch 8/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1276 -
accuracy: 0.9340 - val_loss: 0.1596 - val_accuracy: 0.9363
```

```
Epoch 9/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1243 -
accuracy: 0.9360 - val_loss: 0.1682 - val_accuracy: 0.9363
Epoch 10/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1232 -
accuracy: 0.9364 - val_loss: 0.1470 - val_accuracy: 0.9379
Epoch 11/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1216 -
accuracy: 0.9373 - val_loss: 0.1485 - val_accuracy: 0.9413
Epoch 12/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1203 -
accuracy: 0.9382 - val_loss: 0.1452 - val_accuracy: 0.9432
Epoch 13/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1193 -
accuracy: 0.9388 - val_loss: 0.1594 - val_accuracy: 0.9376
Epoch 14/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1169 -
accuracy: 0.9401 - val_loss: 0.1342 - val_accuracy: 0.9418
Epoch 15/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1160 -
accuracy: 0.9405 - val_loss: 0.1800 - val_accuracy: 0.9359
Epoch 16/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1144 -
accuracy: 0.9413 - val_loss: 0.1577 - val_accuracy: 0.9382
Epoch 17/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1140 -
accuracy: 0.9417 - val_loss: 0.1572 - val_accuracy: 0.9402
Epoch 18/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1127 -
accuracy: 0.9425 - val_loss: 0.1801 - val_accuracy: 0.9353
Epoch 19/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1124 -
accuracy: 0.9427 - val_loss: 0.2014 - val_accuracy: 0.9350
Epoch 20/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1120 -
accuracy: 0.9429 - val_loss: 0.1533 - val_accuracy: 0.9377
Epoch 1/20
535/535 [==============================] - 7s 10ms/step - loss: 0.1939 -
accuracy: 0.9089 - val_loss: 0.2115 - val_accuracy: 0.9176
Epoch 2/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1578 -
accuracy: 0.9196 - val_loss: 0.2033 - val_accuracy: 0.9217
Epoch 3/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1467 -
accuracy: 0.9256 - val_loss: 0.1826 - val_accuracy: 0.9298
Epoch 4/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1384 -
accuracy: 0.9291 - val_loss: 0.1636 - val_accuracy: 0.9333
```

```
Epoch 5/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1336 -
accuracy: 0.9310 - val_loss: 0.1603 - val_accuracy: 0.9333
Epoch 6/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1301 -
accuracy: 0.9326 - val_loss: 0.1405 - val_accuracy: 0.9374
Epoch 7/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1269 -
accuracy: 0.9346 - val_loss: 0.1471 - val_accuracy: 0.9375
Epoch 8/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1254 -
accuracy: 0.9352 - val_loss: 0.1525 - val_accuracy: 0.9406
Epoch 9/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1232 -
accuracy: 0.9365 - val_loss: 0.1369 - val_accuracy: 0.9418
Epoch 10/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1230 -
accuracy: 0.9359 - val_loss: 0.1482 - val_accuracy: 0.9289
Epoch 11/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1221 -
accuracy: 0.9361 - val_loss: 0.1434 - val_accuracy: 0.9399
Epoch 12/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1213 -
accuracy: 0.9369 - val_loss: 0.1436 - val_accuracy: 0.9398
Epoch 13/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1204 -
accuracy: 0.9380 - val_loss: 0.1632 - val_accuracy: 0.9373
Epoch 14/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1205 -
accuracy: 0.9380 - val_loss: 0.1285 - val_accuracy: 0.9421
Epoch 15/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1175 -
accuracy: 0.9396 - val_loss: 0.1418 - val_accuracy: 0.9424
Epoch 16/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1170 -
accuracy: 0.9400 - val_loss: 0.1922 - val_accuracy: 0.9281
Epoch 17/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1153 -
accuracy: 0.9409 - val_loss: 0.1391 - val_accuracy: 0.9450
Epoch 18/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1146 -
accuracy: 0.9412 - val_loss: 0.1469 - val_accuracy: 0.9354
Epoch 19/20
535/535 [==============================] - 5s 10ms/step - loss: 0.1140 -
accuracy: 0.9416 - val_loss: 0.3275 - val_accuracy: 0.9284
Epoch 20/20
535/535 [==============================] - 5s 9ms/step - loss: 0.1145 -
accuracy: 0.9413 - val_loss: 0.1648 - val_accuracy: 0.9354
```

`0.93557288646698 0.005251319842851667`

5.0.3 4.3 Bayesian neural networks (BNN)

Instead of mimicking Bayesian inference through MC dropout (see more details in this paper), what if we could build a model that can inherently give us a way to probe both model uncertainty (i.e. epistemic uncertainty caused by few training samples) and data uncertainty (i.e. aleatoric uncertainty)?

One way to achieve this is to train models to learn distributions over weights in the layers and over the output. This can be achieved by using TenssorFlow probability (see the documentation for an in-depth description of all the functionalities). In this example we will only scratch the surface of the capabilities that a probabilistic deep learning approach has to offer, by addressing only model uncertainty.

To start with, think about a BNN as an extension of your classical DNN, where during training instead of learning a weights for each 'connection' in the network, we ask the model to lean a distribution. After model training, during inference time, we sample from the learned distributions to obtain the weights used in the model in the forward pass. The modifications that we have to implement in our `build_DNN` function are the following: - Substitute the hidden `Dense` layers with `DenseVariational` layers (this can be found under tensorflow-probability.layers). Do not forget to specify the `kl_weight` as 1/ number of iterations per epoch (reference). - Define the prior weights distribution (`make_prior_fn` input in the `DenseVariational`): this is the distribution that we expect the weights to have prior having seen the data. In this example we will not train the prior distribution. - Define the posterior weights distribution (`make_posterior_fn` input in the `DenseVariational`): this is the distribution that we expect the model to learn during training. Since we do not know at priory which is the posterior distribution, we let it be very general (i.e. multivariate Gaussian distribution) which parameters are learned by the model.

You will find the `BNN_prior` and `BNN_posterior` defined for you in the `utilities.py` file. Update the `build_DNN` to accept a new boolean input `use_variational_layer` that when true substitutes the hidden `Dense` layers with the `DenseVariational` layers.

!NOTE As you will see, training the BNN model is more computationally demanding and is more prone to over-fitting. Reduce the learning rate and increase the number of epochs to address this issue.

Questions

17. (MC dropout) What is the mean and the standard deviation of the test accuracy after evaluating the model on 100 times?
18. (CV) What is the mean and the standard deviation of the test accuracy?
19. (CV) What is the main advantage of dropout compared to CV for estimating test uncertainty? The difference may not be so large in this notebook, but imagine that you have a network that takes 24 hours to train.
20. (BNN) Build the BNN model and look at the number of parameters. Is there a difference between the previous DNN and the BNN? Why is that?
21. (BNN) Without training the model, evaluate the model a twice on the validation set: do you obtain the same validation accuracy? Why

22. Think of at least one advantage and one disadvantage for each of the three uncertainty estimation methods.

Answer

17. For the MC dropout we get a mean test accuracy of 0.9140 with very small standard deviation of 0.0001.
18. With cross validation we get a mean test accuracy of 0.9356 with a bit higher but still small standard deviation of 0.0053.
19. The dropout method for measuring uncertainty has the big advantage that it is performed on the trained model by using the dropout layers during the evaluation. This can save a lot of time, because the model does not have to be retrained every time.

20. With 1821441 trainable parameters, the BNN has significantly more than the previous DNN with the same amount of hidden layers and units with 2301 trainable parameters. The variational layer adds more parameters due to the posterior distribution that must be trained. But this jump still seems to big.

21. We don't get the same validation accuracy twice, as BNNs use different sets of weights drawn from the learned distribution for each run.
22.
    - MC dropout: a benefit is the computational efficency: it is performed on the trained model and it doesn't add more trainable parameter scompared to BNNs. A drawback is that it only approximates bayesian inference and might therefore not capture all sources of uncertainty.
    - CV: As it uses different sub datasets it is a robust method to estimate data uncertainty. But it has a high computational cost.
    - BNN: An advantage is that it is not just approximates the bayesian inference and hence is more accurate. A disadvantage is that it is computationally expensive.

Note:
For our best configuration with a deep net our device crashes after a few steps, that take extremly long. As we were not able to find the problem that caused the failure, we used the small net that reached a good test accuracy earlier in this notebook.

[16]:
```
# ------------------------------------------
# === Your code here =======================
# ------------------------------------------

# Build and train model
model_config = {
    "act_fun": "s",
    "optimizer": "sgd",
    "use_bn": False,
    "n_hidden_layers": 2,
    "n_hidden_units": 20,
    "loss": "binary_crossentropy",
    "learning_rate": 0.001,
    "use_dropout": False,
```

```
    "use_custom_dropout": False,
    'use_variational_layer': True,
    'kl_weight': 1/(Xtrain.shape[0]/batch_size),
    "input_shape": Xtrain.shape[1]
}

train_config = {
    "epochs": 50,
    "batch_size": 1000,
    "class_weight": class_weights
}


# Fit the model with training set and class weights for this fold
history11 = train_DNN( model_config, (Xtrain, Ytrain, Xval, Yval), train_config)

# Evaluate the model using the test set for this fold
score = history11.model.evaluate(Xtest, Ytest, verbose=0)
# ========================================
```

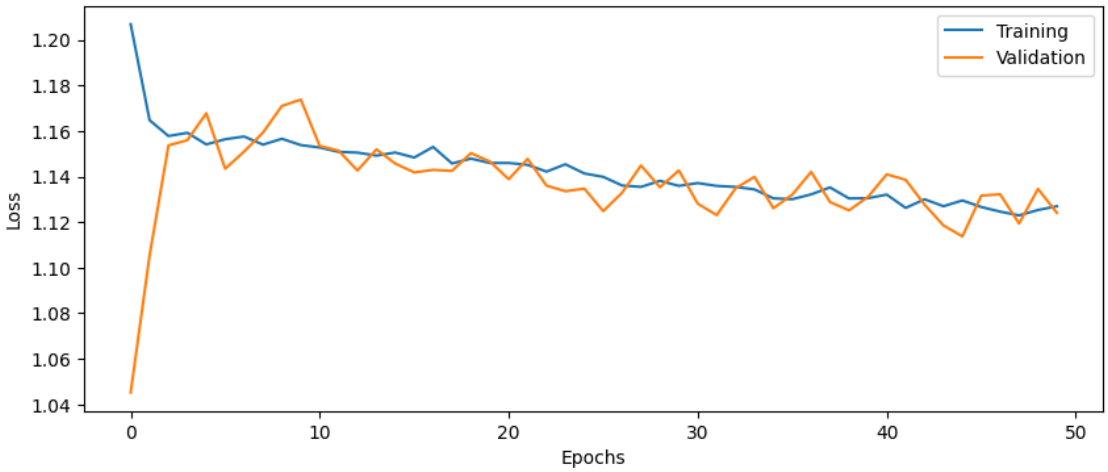
```
Epoch 1/50
535/535 [==============================] - 22s 39ms/step - loss: 1.2069 -
accuracy: 0.7893 - val_loss: 1.0452 - val_accuracy: 0.7699
Epoch 2/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1647 -
accuracy: 0.7017 - val_loss: 1.1054 - val_accuracy: 0.6464
Epoch 3/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1578 -
accuracy: 0.5990 - val_loss: 1.1537 - val_accuracy: 0.5352
Epoch 4/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1592 -
accuracy: 0.5483 - val_loss: 1.1560 - val_accuracy: 0.4741
Epoch 5/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1541 -
accuracy: 0.5268 - val_loss: 1.1678 - val_accuracy: 0.4847
Epoch 6/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1564 -
accuracy: 0.5008 - val_loss: 1.1434 - val_accuracy: 0.5339
Epoch 7/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1576 -
accuracy: 0.4927 - val_loss: 1.1509 - val_accuracy: 0.4883
Epoch 8/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1540 -
accuracy: 0.5056 - val_loss: 1.1593 - val_accuracy: 0.4697
Epoch 9/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1566 -
accuracy: 0.5062 - val_loss: 1.1710 - val_accuracy: 0.4706
Epoch 10/50
```

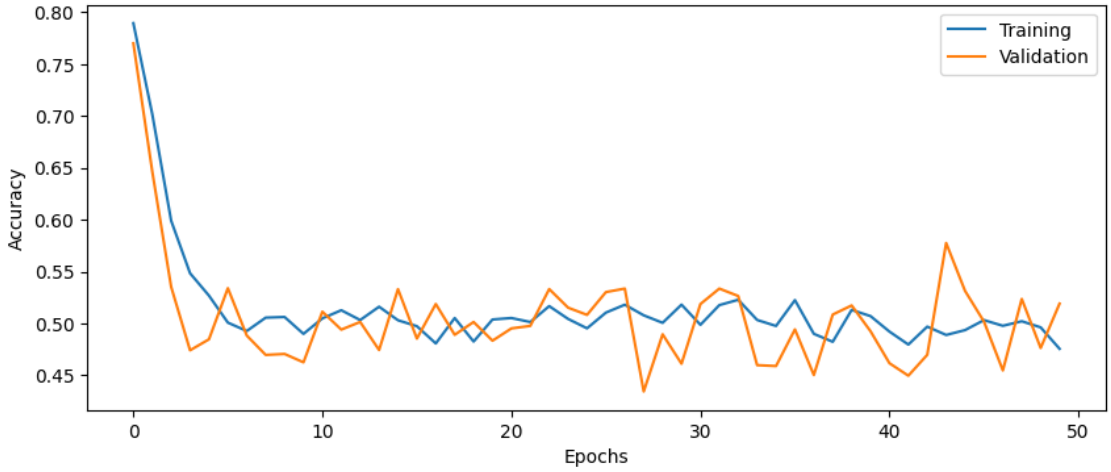
```
535/535 [==============================] - 20s 38ms/step - loss: 1.1538 -
accuracy: 0.4899 - val_loss: 1.1738 - val_accuracy: 0.4625
Epoch 11/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1527 -
accuracy: 0.5049 - val_loss: 1.1534 - val_accuracy: 0.5113
Epoch 12/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1508 -
accuracy: 0.5127 - val_loss: 1.1513 - val_accuracy: 0.4940
Epoch 13/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1505 -
accuracy: 0.5032 - val_loss: 1.1427 - val_accuracy: 0.5014
Epoch 14/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1492 -
accuracy: 0.5161 - val_loss: 1.1519 - val_accuracy: 0.4744
Epoch 15/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1505 -
accuracy: 0.5031 - val_loss: 1.1457 - val_accuracy: 0.5330
Epoch 16/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1483 -
accuracy: 0.4973 - val_loss: 1.1418 - val_accuracy: 0.4854
Epoch 17/50
535/535 [==============================] - 21s 38ms/step - loss: 1.1530 -
accuracy: 0.4807 - val_loss: 1.1429 - val_accuracy: 0.5187
Epoch 18/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1457 -
accuracy: 0.5052 - val_loss: 1.1425 - val_accuracy: 0.4890
Epoch 19/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1479 -
accuracy: 0.4825 - val_loss: 1.1503 - val_accuracy: 0.5014
Epoch 20/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1460 -
accuracy: 0.5038 - val_loss: 1.1466 - val_accuracy: 0.4833
Epoch 21/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1460 -
accuracy: 0.5052 - val_loss: 1.1388 - val_accuracy: 0.4952
Epoch 22/50
535/535 [==============================] - 21s 38ms/step - loss: 1.1451 -
accuracy: 0.5013 - val_loss: 1.1478 - val_accuracy: 0.4976
Epoch 23/50
535/535 [==============================] - 21s 39ms/step - loss: 1.1422 -
accuracy: 0.5167 - val_loss: 1.1360 - val_accuracy: 0.5331
Epoch 24/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1454 -
accuracy: 0.5043 - val_loss: 1.1336 - val_accuracy: 0.5152
Epoch 25/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1413 -
accuracy: 0.4953 - val_loss: 1.1347 - val_accuracy: 0.5082
Epoch 26/50
```

```
535/535 [==============================] - 20s 38ms/step - loss: 1.1399 -
accuracy: 0.5104 - val_loss: 1.1248 - val_accuracy: 0.5302
Epoch 27/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1361 -
accuracy: 0.5181 - val_loss: 1.1329 - val_accuracy: 0.5336
Epoch 28/50
535/535 [==============================] - 20s 38ms/step - loss: 1.1355 -
accuracy: 0.5078 - val_loss: 1.1449 - val_accuracy: 0.4344
Epoch 29/50
535/535 [==============================] - 19s 36ms/step - loss: 1.1381 -
accuracy: 0.5006 - val_loss: 1.1353 - val_accuracy: 0.4895
Epoch 30/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1359 -
accuracy: 0.5181 - val_loss: 1.1427 - val_accuracy: 0.4612
Epoch 31/50
535/535 [==============================] - 19s 35ms/step - loss: 1.1371 -
accuracy: 0.4987 - val_loss: 1.1281 - val_accuracy: 0.5187
Epoch 32/50
535/535 [==============================] - 18s 35ms/step - loss: 1.1359 -
accuracy: 0.5176 - val_loss: 1.1231 - val_accuracy: 0.5336
Epoch 33/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1354 -
accuracy: 0.5228 - val_loss: 1.1348 - val_accuracy: 0.5264
Epoch 34/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1344 -
accuracy: 0.5033 - val_loss: 1.1399 - val_accuracy: 0.4598
Epoch 35/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1304 -
accuracy: 0.4976 - val_loss: 1.1261 - val_accuracy: 0.4589
Epoch 36/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1301 -
accuracy: 0.5225 - val_loss: 1.1320 - val_accuracy: 0.4942
Epoch 37/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1322 -
accuracy: 0.4900 - val_loss: 1.1420 - val_accuracy: 0.4503
Epoch 38/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1352 -
accuracy: 0.4823 - val_loss: 1.1288 - val_accuracy: 0.5085
Epoch 39/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1304 -
accuracy: 0.5130 - val_loss: 1.1252 - val_accuracy: 0.5173
Epoch 40/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1305 -
accuracy: 0.5070 - val_loss: 1.1310 - val_accuracy: 0.4925
Epoch 41/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1321 -
accuracy: 0.4921 - val_loss: 1.1410 - val_accuracy: 0.4617
Epoch 42/50
```

```
535/535 [==============================] - 18s 34ms/step - loss: 1.1262 -
accuracy: 0.4796 - val_loss: 1.1385 - val_accuracy: 0.4496
Epoch 43/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1300 -
accuracy: 0.4969 - val_loss: 1.1277 - val_accuracy: 0.4698
Epoch 44/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1270 -
accuracy: 0.4889 - val_loss: 1.1186 - val_accuracy: 0.5775
Epoch 45/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1295 -
accuracy: 0.4936 - val_loss: 1.1137 - val_accuracy: 0.5313
Epoch 46/50
535/535 [==============================] - 18s 33ms/step - loss: 1.1266 -
accuracy: 0.5032 - val_loss: 1.1316 - val_accuracy: 0.5018
Epoch 47/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1246 -
accuracy: 0.4977 - val_loss: 1.1322 - val_accuracy: 0.4547
Epoch 48/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1230 -
accuracy: 0.5021 - val_loss: 1.1194 - val_accuracy: 0.5236
Epoch 49/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1253 -
accuracy: 0.4962 - val_loss: 1.1346 - val_accuracy: 0.4763
Epoch 50/50
535/535 [==============================] - 18s 34ms/step - loss: 1.1269 -
accuracy: 0.4755 - val_loss: 1.1241 - val_accuracy: 0.5191
```

[17]:
```
plot_results(history11)
```





[31]:
```
history11.model.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_variational_8 (Dense  (None, 20)                1732590
 Variational)

 dense_variational_9 (Dense  (None, 20)                88830
 Variational)

 dense_7 (Dense)             (None, 1)                 21

=================================================================
Total params: 1821441 (6.95 MB)
Trainable params: 1821441 (6.95 MB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

As we have done for the MC dropout uncertainty estimation, run the evaluation on the test set 100 times and show the mean and standard deviation.

[18]:
```
# ============================================
# === Your code here =========================
# ============================================
# Run the testing 100 times, and save the accuracies in an array

n_runs = 100

# Define where to save the test accuracies
```

```
test_accuracies = []
for _ in range(n_runs):
    # predict the test set

    # Save predictions
    test_accuracies.append(history11.model.evaluate(Xtest, Ytest, verbose=0)[1])

# Calculate and print mean and std of accuracies
print(np.mean(test_accuracies), np.std(test_accuracies))
# ============================================
```

```
0.49067919433116913 0.005161408028977437
```

Check if we get the same test accuracy twice:

[34]:
```
print(history11.model.evaluate(Xval, Yval, verbose=0)[1], history11.model.
↪evaluate(Xval, Yval, verbose=0)[1])
```

```
0.4900934398174286 0.4887236952781677
```

6 Part 5: DNN for regression

A similar DNN can be used for regression, instead of classification.

Questions

23. How would you change the DNN used in this lab in order to use it for regression instead?

Answer

23. For regression the loss function must be changed to e.g. Mean Sqaured Error. Additionally, the output layer does not require an activation function anymore.

6.1 Report

Send in this jupyter notebook, with answers to all questions.