

# Appendix 1

## Project 2

Data from Classification of the Wisconsin Breast Cancer Data set

The accuracy is computed using the Wisconsin Breast Cancer Data Set (WBCD) and a prediction made by our Feed Forward Neural Network (FFNN) or tensorflow (section 4). The data set is split so that 8/10 parts of the WBCD is used for training, and 2/10 parts is used for testing.

# 1 Section 1: variations in the number of nodes and hidden layers

A random seed has been set to 666. All the code in this section has been run with a learning rate of 0.01 and 1000 epochs.

## 1.1 Tables

Number of nodes in the hidden layer	Activation functions	Accuracy	Confusion matrix
10	Sigmoid, Sigmoid	0.851	Figure 1
10	ReLU, ReLU	0.395	Figure 2
10	Sigmoid, ReLU	0.605	Figure 3
10	ReLU, Sigmoid	0.807	Figure 4
5	Sigmoid, Sigmoid	0.807	Figure 5
5	ReLU, ReLU	0.385	Figure 6
5	Sigmoid, ReLU	0.904	Figure 7
5	ReLU, Sigmoid	0.868	Figure 8

Table 1: Accuracy score when our FFNN has a learning rate of 0.01, 1 hidden layer with differing numbers of nodes in the layer, and 1000 epochs

Number of nodes in each hidden layer	Activation functions	Accuracy	Confusion matrix
5, 10	Sigmoid, Sigmoid, ReLU	0.895	Figure 9
5, 10	Sigmoid, ReLU, Sigmoid	0.825	Figure 10
5, 10	Sigmoid, Sigmoid, Sigmoid	0.596	Figure 11
5, 10	ReLU, Sigmoid, Sigmoid	0.693	Figure 12

Table 2: Accuracy score when our FFNN has a learning rate of 0.01, 2 hidden layers with 5 and 10 nodes in each layer respectively, and 1000 epochs.

Num nodes in hidden layers	Activation functions	Accuracy	confusion matrix
100, 100, 100, 100	Sigmoid, Sigmoid, Sigmoid, Sigmoid, Sigmoid	0.595	Figure 13
100, 100, 100, 100	ReLU, ReLU, ReLU, ReLU, ReLU	0.404	Figure 14
100, 100, 100, 100	ReLU, ReLU, ReLU, ReLU, Sigmoid	0.649	Figure 15

Table 3: Accuracy score when our FFNN has a learning rate of 0.01, 4 hidden layers with 100 nodes each, and 1000 epochs

## 1.2 Confusion matrices

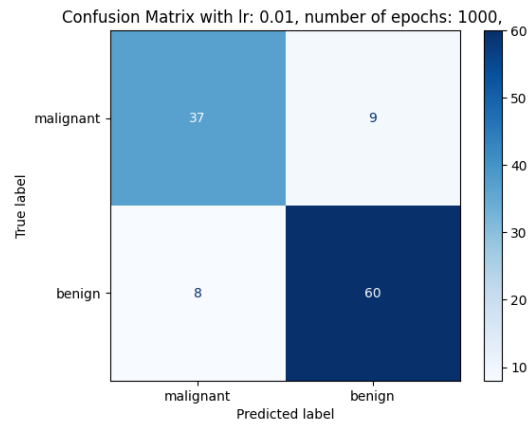


Figure 1: Confusion matrix with 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

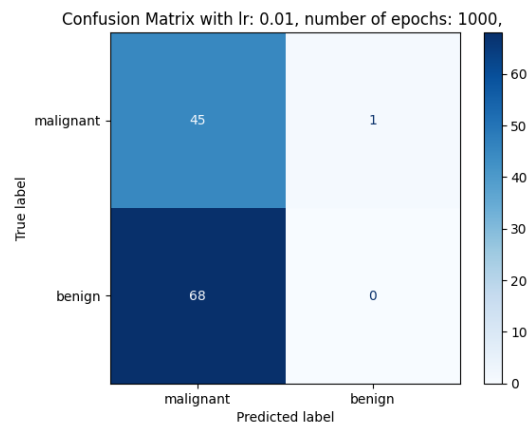


Figure 2: Confusion matrix with 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

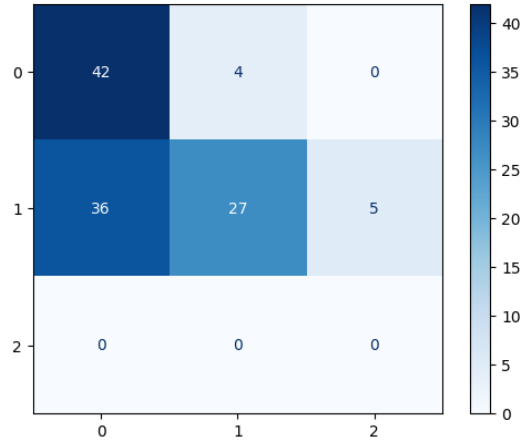


Figure 3: Confusion matrix with 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]. True malignant = 42, false malignant = 36, false benign = 4, true benign = 27, other = 5

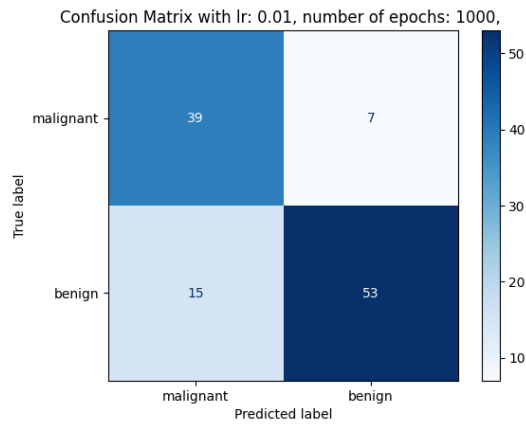


Figure 4: Confusion matrix with 1 hidden layer with 10 neurons and the activation functions [ReLU, sigmoid]

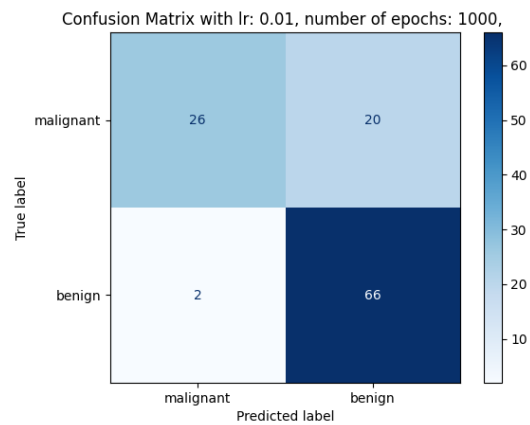


Figure 5: Confusion matrix with 1 hidden layer with 5 neurons and the activation functions [Sigmoid, sigmoid]

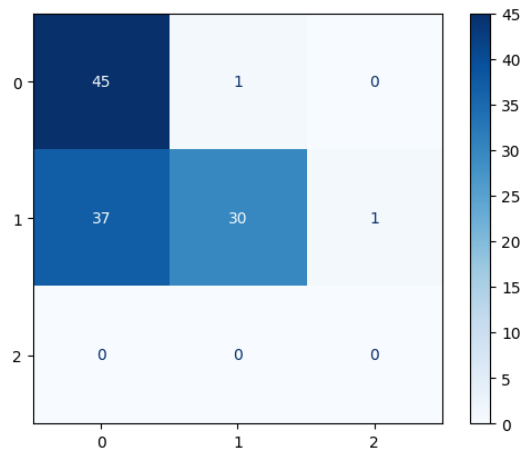


Figure 6: Confusion matrix with 1 hidden layer with 5 neurons and the activation functions [ReLU, ReLU]

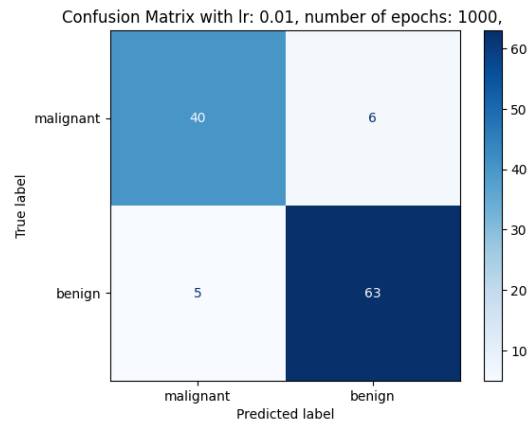


Figure 7: Confusion matrix with 1 hidden layer with 5 neurons and the activation functions [sigmoid, ReLU]

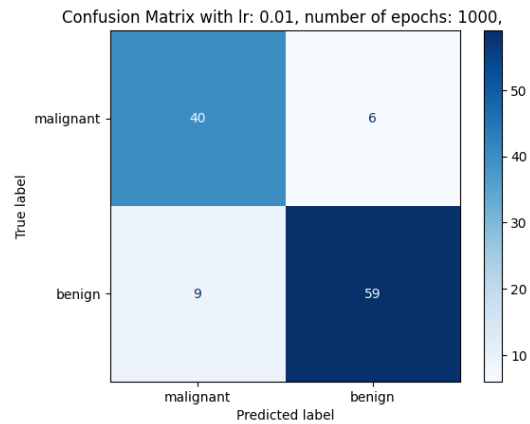


Figure 8: Confusion matrix with 1 hidden layer with 5 neurons and the activation functions [ReLU, sigmoid]

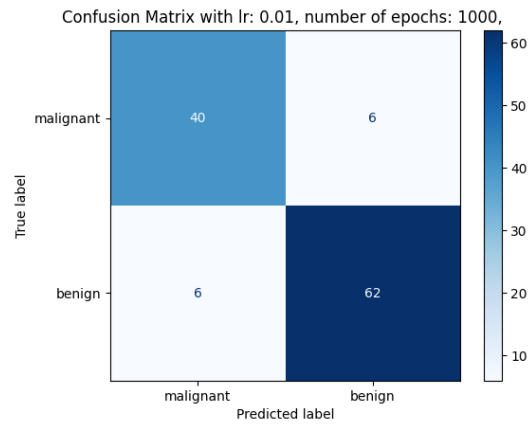


Figure 9: Confusion matrix with 2 hidden layers with 5 and 10 neurons and the activation functions [sigmoid, sigmoid, ReLU]

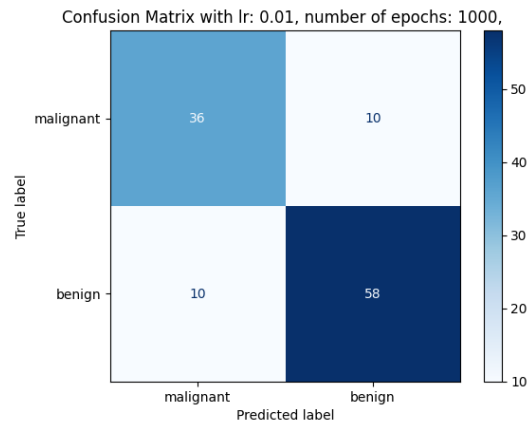


Figure 10: Confusion matrix with 2 hidden layers with 5 and 10 neurons and the activation functions [sigmoid, ReLU, sigmoid]

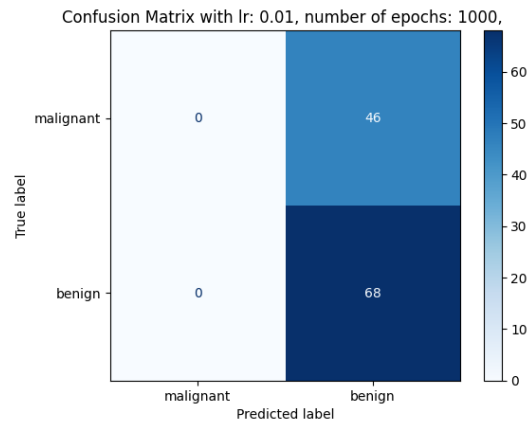


Figure 11: Confusion matrix with 2 hidden layers with 5 and 10 neurons and the activation functions [sigmoid, sigmoid, sigmoid]

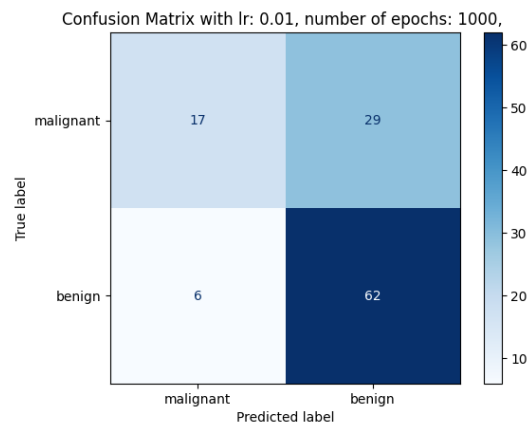


Figure 12: Confusion matrix with 2 hidden layers with 5 and 10 neurons and the activation functions [ReLU, sigmoid, sigmoid]



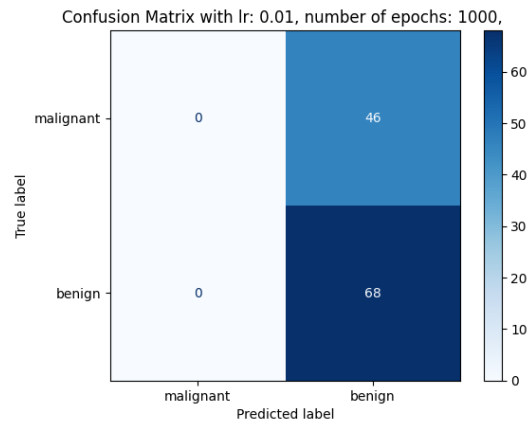


Figure 13: Confusion matrix with 4 hidden layers with 100 neurons in each layer and the activation functions [sigmoid, sigmoid, sigmoid, sigmoid, sigmoid]

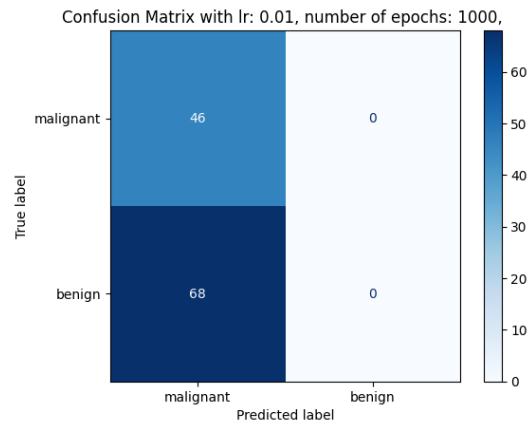


Figure 14: Confusion matrix with 4 hidden layers with 100 neurons in each layer and the activation functions [ReLU, ReLU, ReLU, ReLU, ReLU]

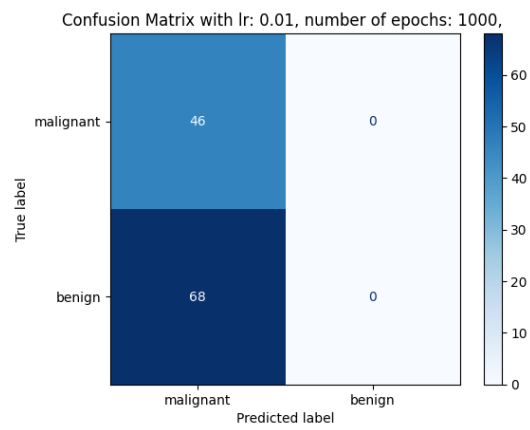


Figure 15: Confusion matrix with 4 hidden layers with 100 neurons in each layer and the activation functions [ReLU, ReLU, ReLU, ReLU, sigmoid]

## 2 Section 2: Variations in the learning rate

### 2.1 Tables

Learning rate	Activation functions	Accuracy	Confusion matrix
0.001	Sigmoid, Sigmoid	0.465	Figure 16
0.001	ReLU, ReLU	0.386	Figure 17
0.001	Sigmoid, ReLU	0.404	Figure 18
0.001	ReLU, Sigmoid	0.526	Figure 19
0.1	Sigmoid, Sigmoid	0.947	Figure 20
0.1	ReLU, ReLU	0.395	Figure 21
0.1	Sigmoid, ReLU	0.974	Figure 22
0.1	ReLU, Sigmoid	0.930	Figure 23
0.2	Sigmoid, Sigmoid	0.956	Figure 24
0.2	ReLU, ReLU	0.404	Figure 25
0.2	Sigmoid, ReLU	0.965	Figure 26
0.2	ReLU, Sigmoid	0.939	Figure 27

Table 4: FFNN with 1 hidden layer with 10 nodes and number of epochs=1000.

Learning rate	Activation functions	Accuracy	Confusion matrix
0.1	Sigmoid, Sigmoid	0.965	Figure 28
0.1	ReLU, ReLU	0.404	Figure 29
0.1	Sigmoid, ReLU	0.956	Figure 30
0.1	ReLU, Sigmoid	0.965	Figure 31
0.2	Sigmoid, Sigmoid	0.965	Figure 32
0.2	ReLU, ReLU	0.404	Figure 33
0.2	Sigmoid, ReLU	0.965	Figure 34
0.2	ReLU, Sigmoid	0.965	Figure 35

Table 5: FFNN with 1 hidden layer with 5 nodes and epochs=1000.

### 2.2 Confusion matrices

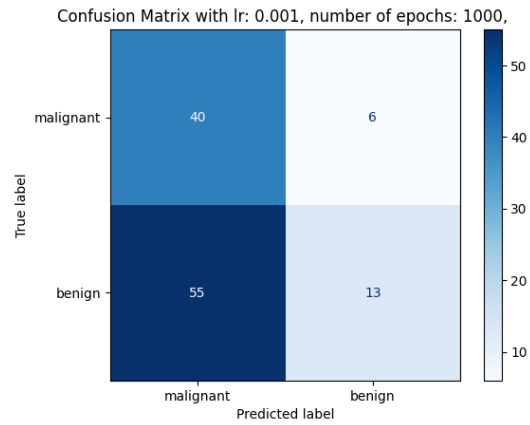


Figure 16: Confusion matrix with a learning rate of 0.001, 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

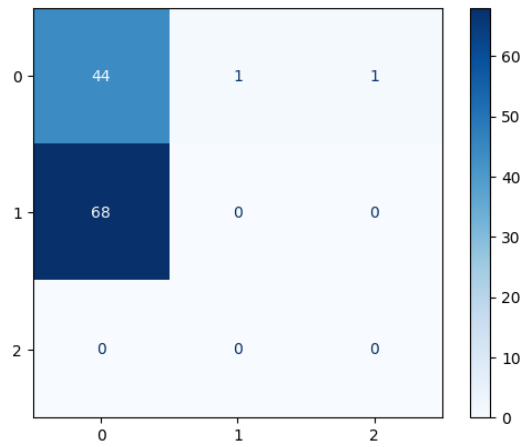


Figure 17: Confusion matrix with a learning rate of 0.001, 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

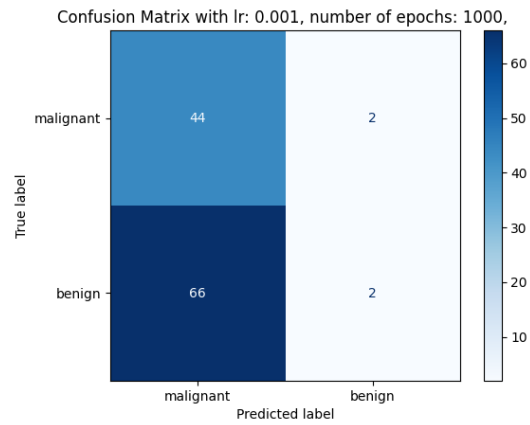


Figure 18: Confusion matrix with a learning rate of 0.001, 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]

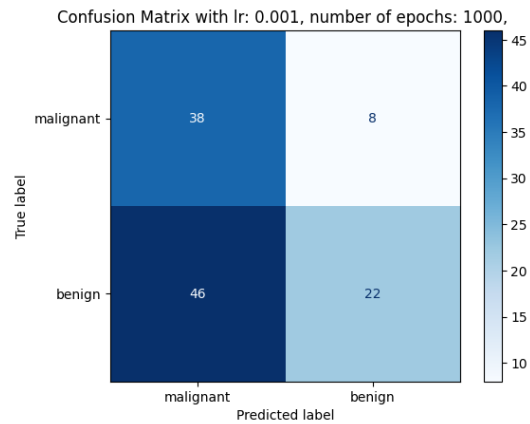


Figure 19: Confusion matrix with a learning rate of 0.001, 1 hidden layer with 10 neurons and the activation functions [ReLU, sigmoid]

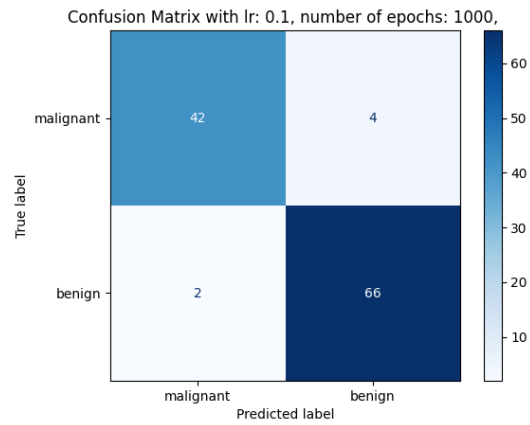


Figure 20: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

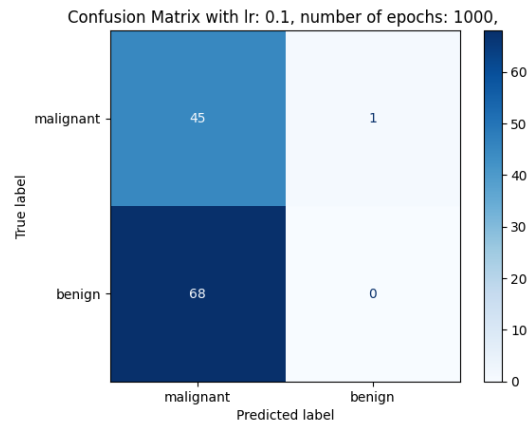


Figure 21: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

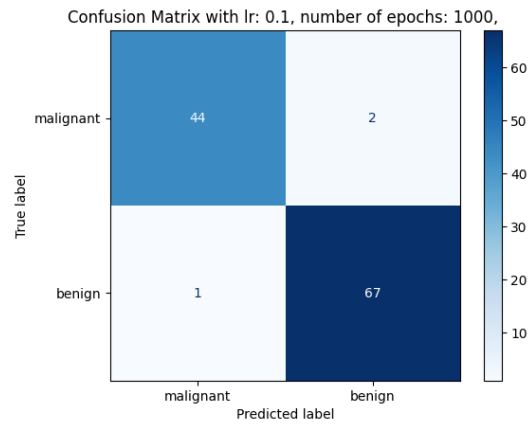


Figure 22: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]

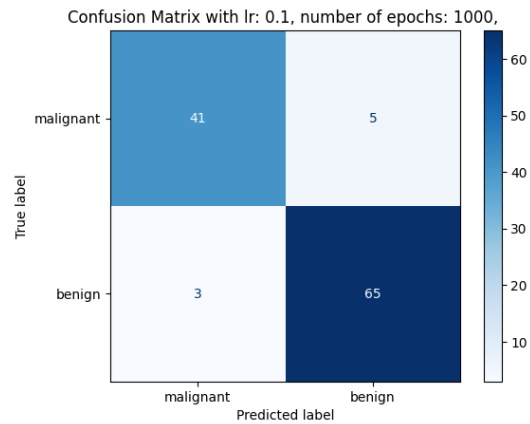


Figure 23: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 10 neurons and the activation functions [ReLU, sigmoid]

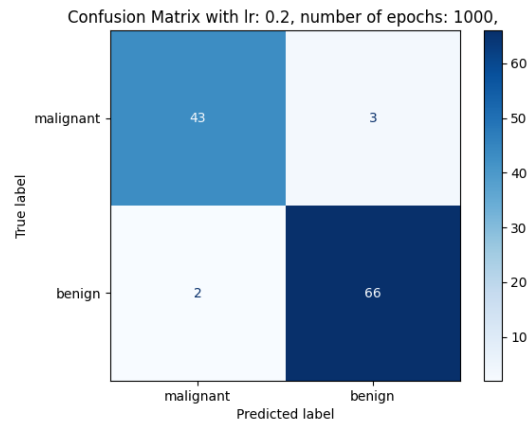


Figure 24: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

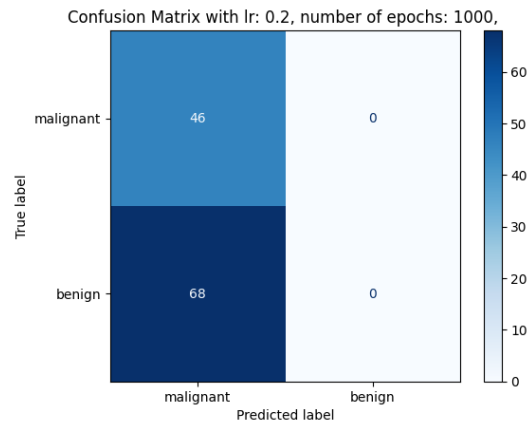


Figure 25: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]



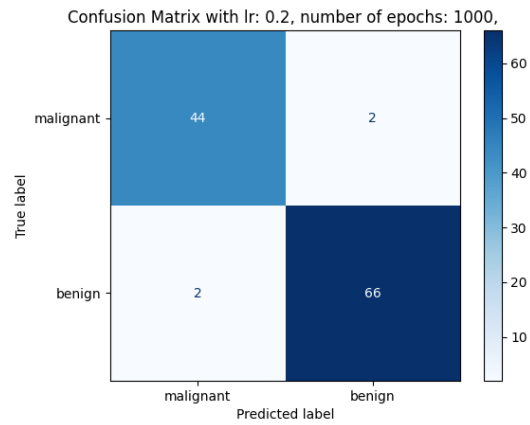


Figure 26: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]

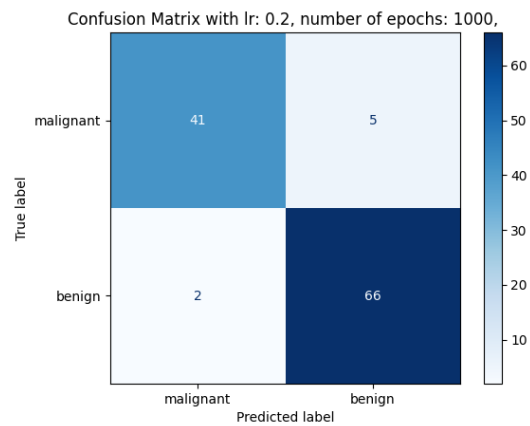


Figure 27: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 10 neurons and the activation functions [ReLU, sigmoid]

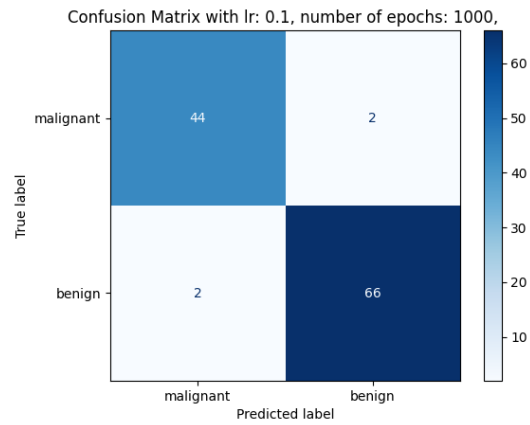


Figure 28: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 5 neurons and the activation functions [sigmoid, sigmoid]

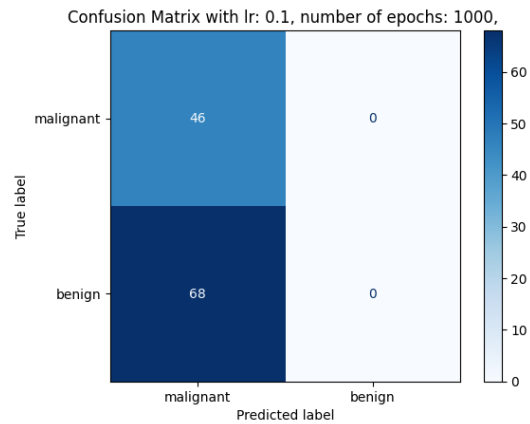


Figure 29: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 5 neurons and the activation functions [ReLU, ReLU]

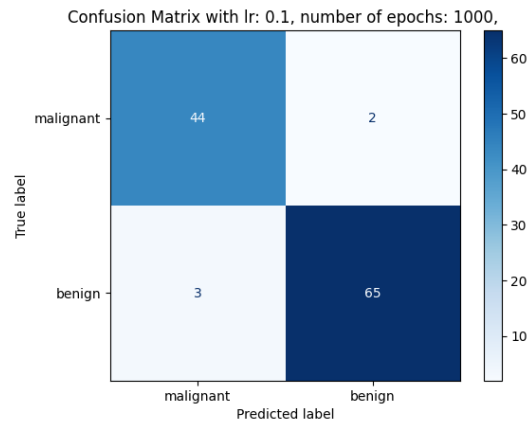


Figure 30: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 5 neurons and the activation functions [sigmoid, ReLU]

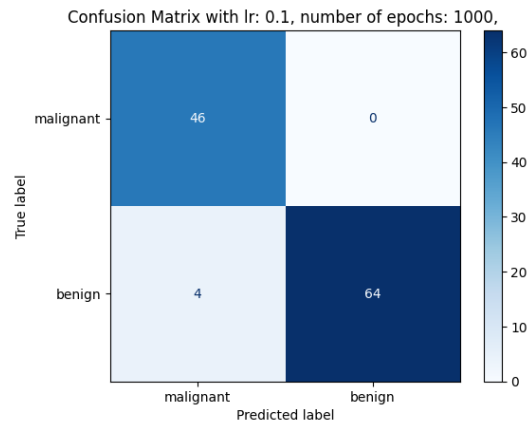


Figure 31: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 5 neurons and the activation functions [ReLU, sigmoid]

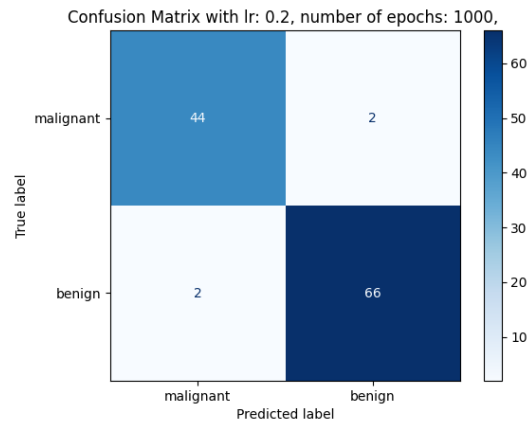


Figure 32: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 5 neurons and the activation functions [sigmoid, sigmoid]

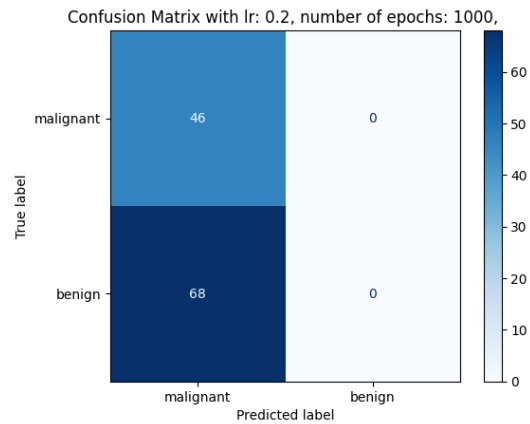


Figure 33: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 5 neurons and the activation functions [ReLU, ReLU]

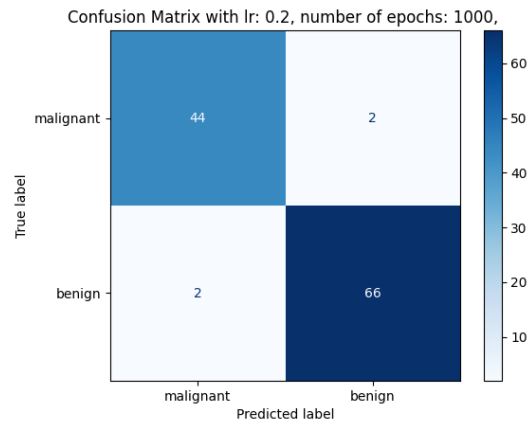


Figure 34: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 5 neurons and the activation functions [sigmoid, ReLU]

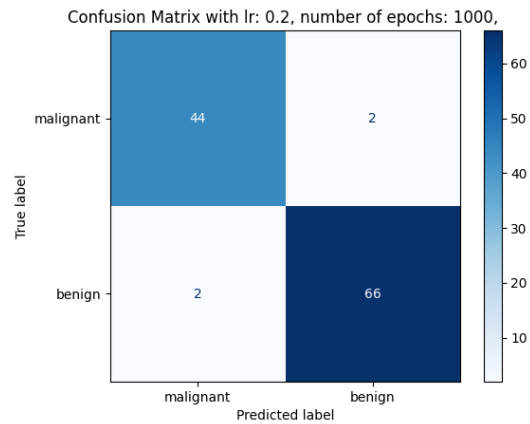


Figure 35: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 5 neurons and the activation functions [ReLU, sigmoid]

### 3 Section 3 : Variations in number of epochs

#### 3.1 Tables

Number of epochs	Activation functions	Accuracy	Confusion matrix
100	Sigmoid, Sigmoid	0.465	Figure 36
100	ReLU, ReLU	0.386	Figure 37
100	Sigmoid, ReLU	0.404	Figure 38
100	ReLU, Sigmoid	0.526	Figure 39
2000	Sigmoid, Sigmoid	0.886	Figure 40
2000	ReLU, ReLU	0.395	Figure 41
2000	Sigmoid, ReLU	0.781	Figure 42
2000	ReLU, Sigmoid	0.816	Figure 43

Table 6: FFNN with 1 hidden layer with 10 nodes and learning rate = 0.01.

#### 3.2 Confusion matrices

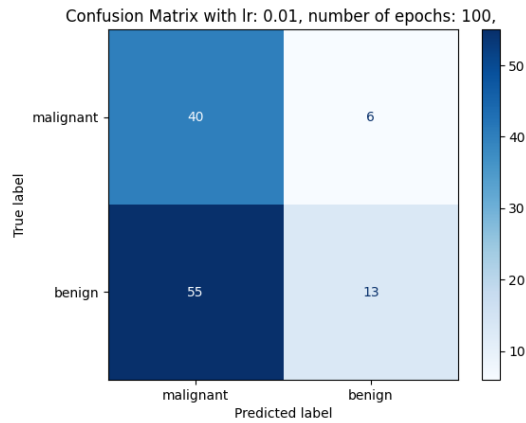


Figure 36: Confusion matrix with a learning rate of 0.001, 100 epochs, 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

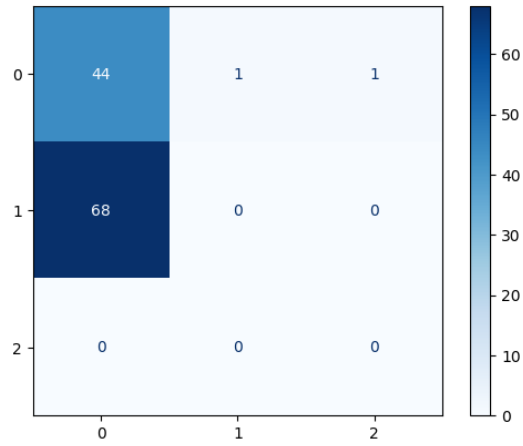


Figure 37: Confusion matrix with a learning rate of 0.001, 100 epochs, 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

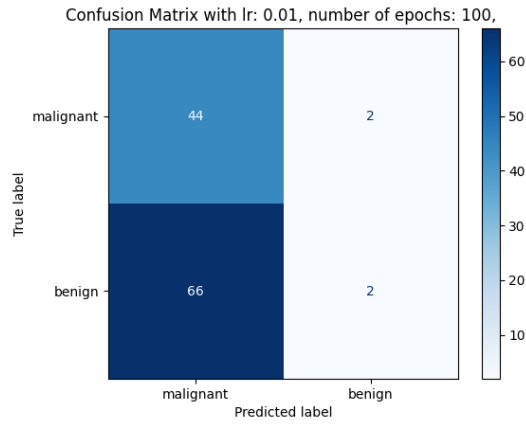


Figure 38: Confusion matrix with a learning rate of 0.001, 100 epochs, 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]

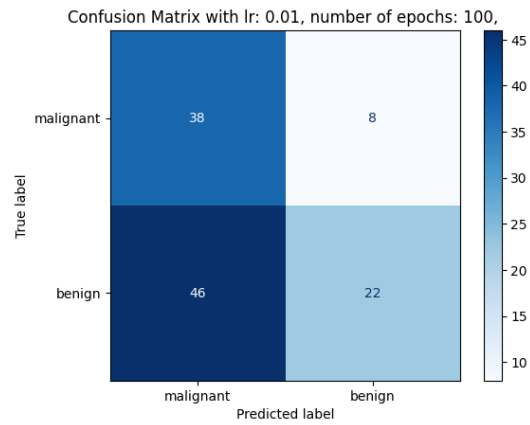


Figure 39: Confusion matrix with a learning rate of 0.001, 100 epochs, 1 hidden layer with 10 neurons and the activation functions [relu, sigmoid]

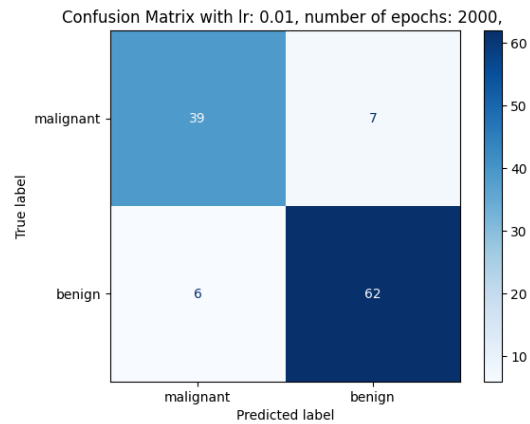


Figure 40: Confusion matrix with a learning rate of 0.001, 2000 epochs, 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]



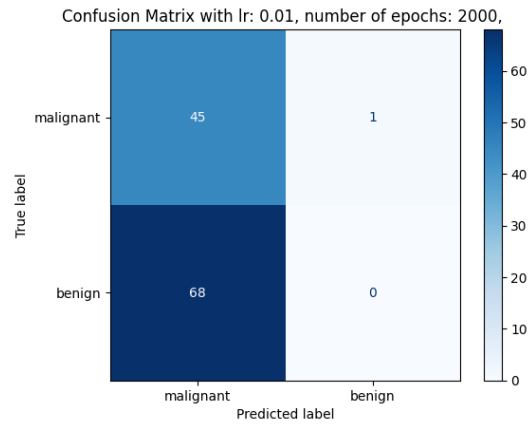


Figure 41: Confusion matrix with a learning rate of 0.001, 2000 epochs, 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

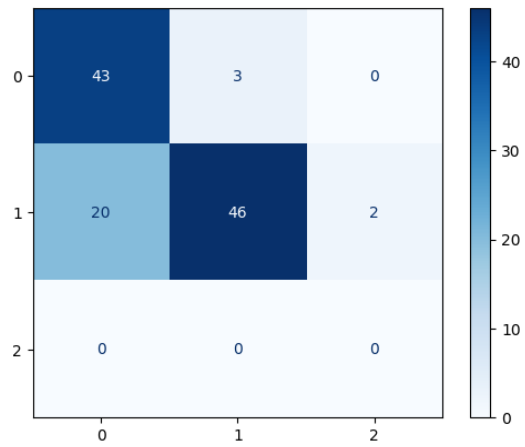


Figure 42: Confusion matrix with a learning rate of 0.001, 2000 epochs, 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]

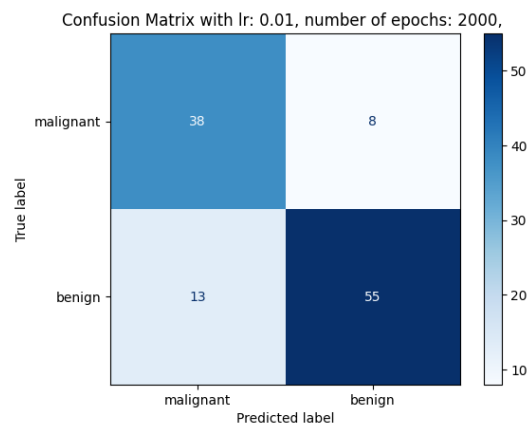


Figure 43: Confusion matrix with a learning rate of 0.001, 2000 epochs, 1 hidden layer with 10 neurons and the activation functions [relu, sigmoid]

## 4 Section 4: Tensorflow

### 4.1 Tables

Activation functions	Accuracy	Confusion matrix
sigmoid, sigmoid	0.965	Figure 44
sigmoid, ReLU	0.430	Figure 45
ReLU, sigmoid	0.983	Figure 46

Table 7: FFNN with 1 hidden layer with 1000 epochs, 10 nodes and learning rate = 0.01.

### 4.2 Confusion matrices

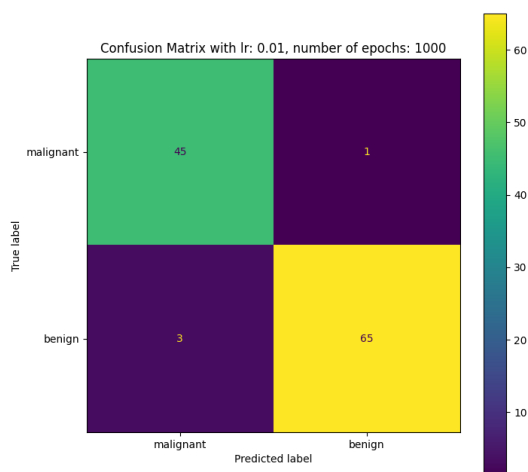


Figure 44: Confusion matrix using tensorflow with the activation functions [sigmoid, sigmoid]. The learning rate=0.1, number of epochs=1000, there is one hidden layer with 10 nodes.

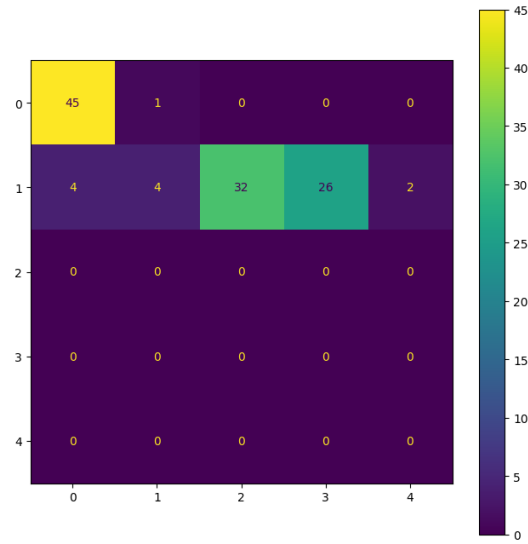


Figure 45: Confusion matrix using tensorflow with the activation functions [sigmoid, ReLU]. The learning rate=0.1, number of epochs=1000, there is one hidden layer with 10 nodes

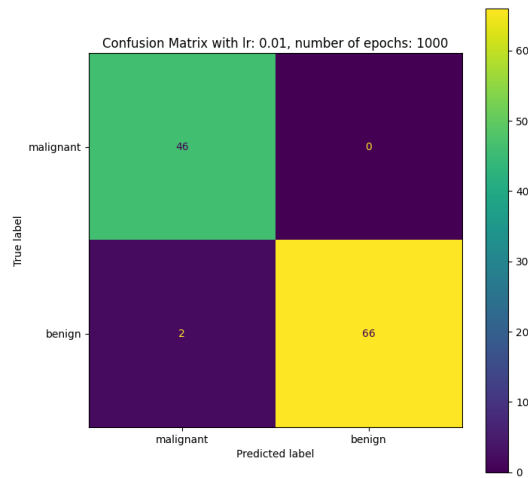


Figure 46: Confusion matrix using tensorflow with the activation functions [ReLU, sigmoid]. The learning rate=0.1, number of epochs=1000, there is one hidden layer with 10 nodes