# 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

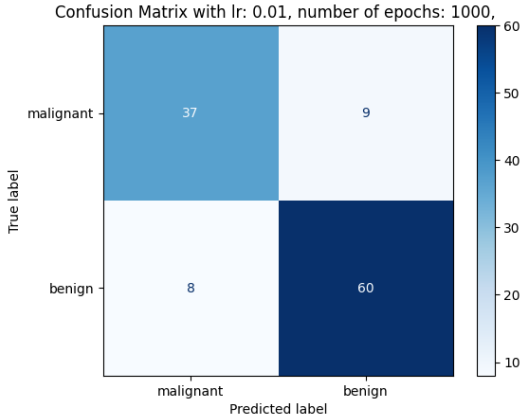


Figure 1: Confusion matrix with 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

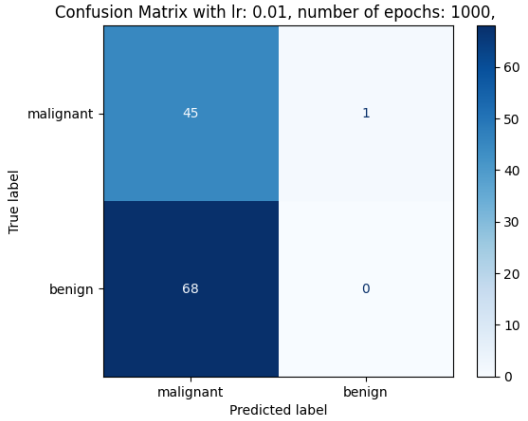


Figure 2: Confusion matrix with 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

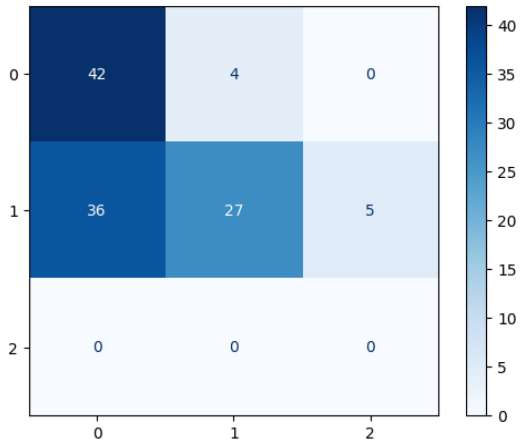


Figure 3: Confusion matrix with 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]. True malignant = 42, false malignant = 36, false benign = 4, true benign = 27, other =5

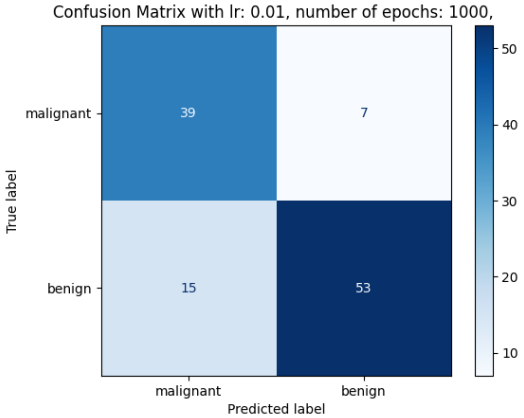


Figure 4: Confusion matrix with 1 hidden layer with 10 neurons and the activation functions [ReLU, sigmoid]

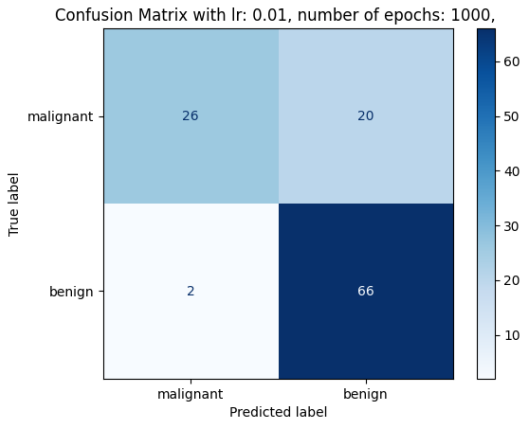


Figure 5: Confusion matrix with 1 hidden layer with 5 neurons and the activation functions [Sigmoid, sigmoid]

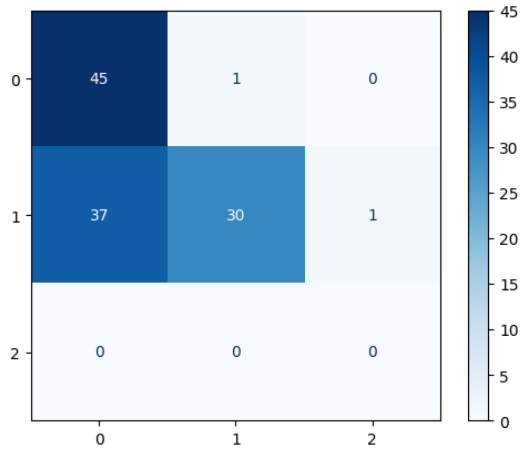


Figure 6: Confusion matrix with 1 hidden layer with 5 neurons and the activation functions [ReLU, ReLU]

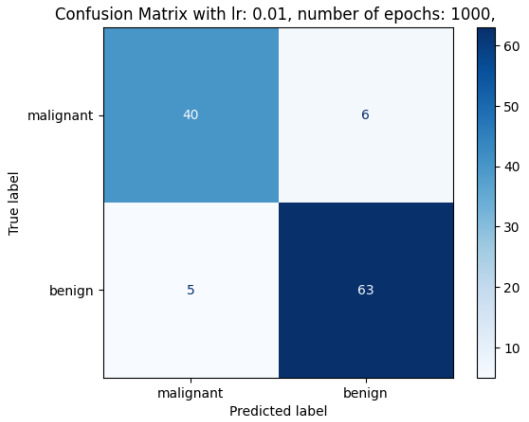


Figure 7: Confusion matrix with 1 hidden layer with 5 neurons and the activation functions [sigmoid, ReLU]

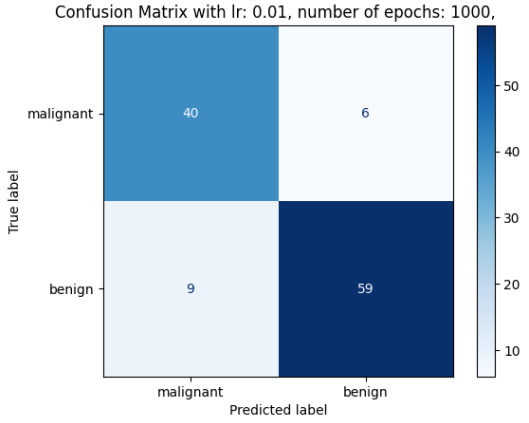


Figure 8: Confusion matrix with 1 hidden layer with 5 neurons and the activation functions [ReLU, sigmoid]

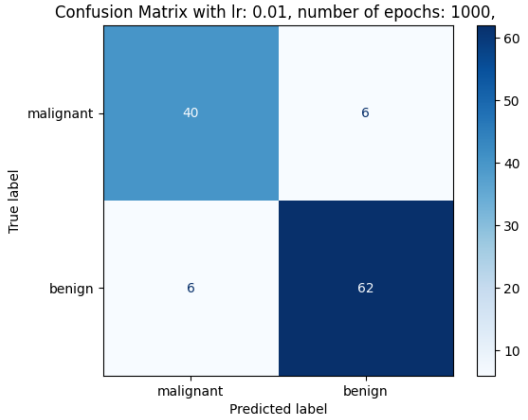


Figure 9: Confusion matrix with 2 hidden layers with 5 and 10 neurons and the activation functions [sigmoid, sigmoid, ReLU]

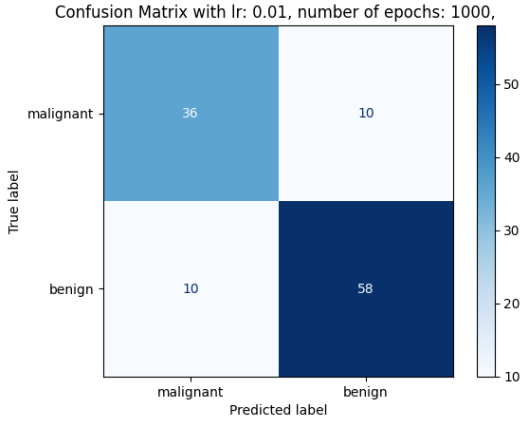


Figure 10: Confusion matrix with 2 hidden layers with 5 and 10 neurons and the activation functions [sigmoid, ReLU, sigmoid]

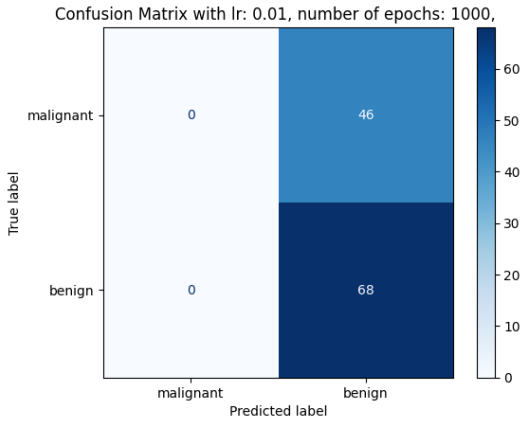


Figure 11: Confusion matrix with 2 hidden layers with 5 and 10 neurons and the activation functions [sigmoid, sigmoid, sigmoid]

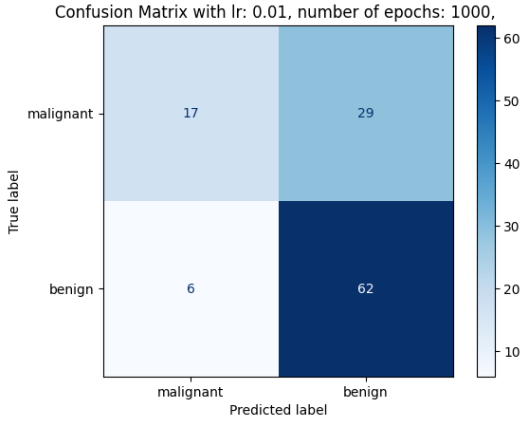


Figure 12: Confusion matrix with 2 hidden layers with 5 and 10 neurons and the activation functions [ReLU, sigmoid, sigmoid]

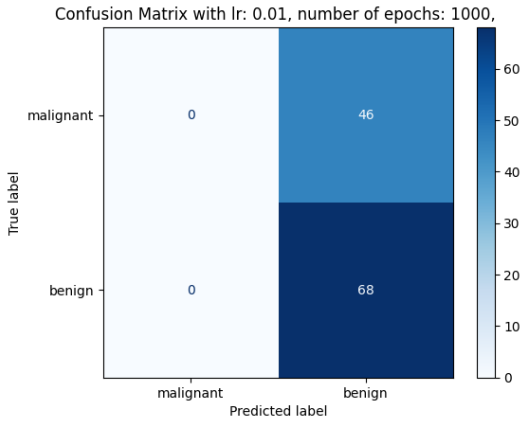


Figure 13: Confusion matrix with 4 hidden layers with 100 neurons in each layer and the activation functions [sigmoid, sigmoid, sigmoid, sigmoid, sigmoid]

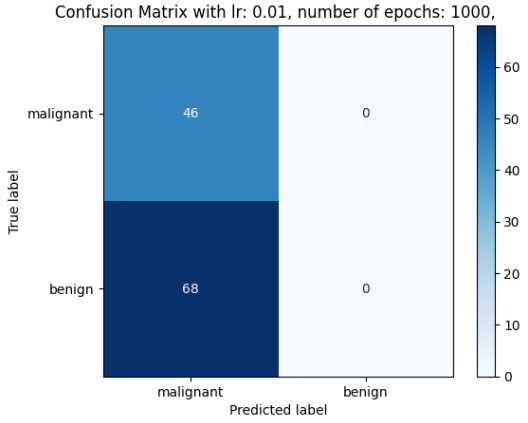


Figure 14: Confusion matrix with 4 hidden layers with 100 neurons in each layer and the activation functions [ReLU, ReLU, ReLU, ReLU, ReLU]

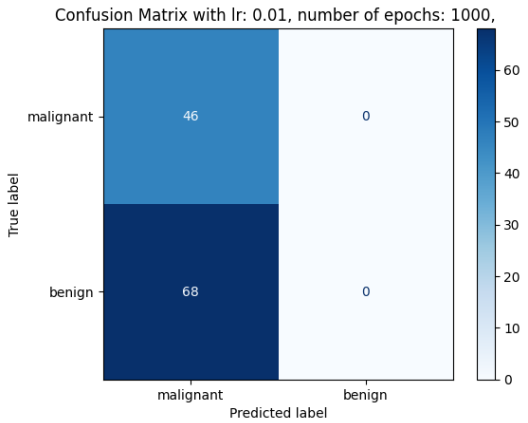


Figure 15: Confusion matrix with 4 hidden layers with 100 neurons in each layer and the activation functions [ReLU, ReLU, ReLU, ReLU, sigmoid]

# 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

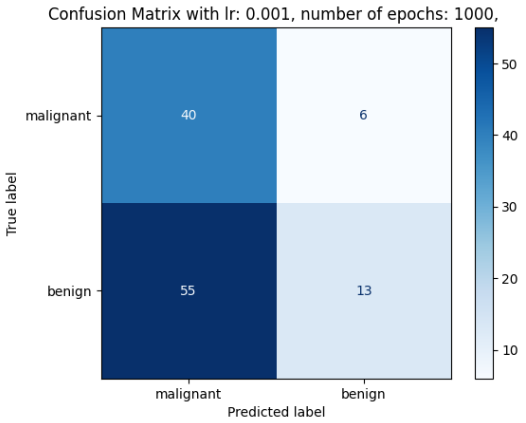


Figure 16: Confusion matrix with a learning rate of 0.001, 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

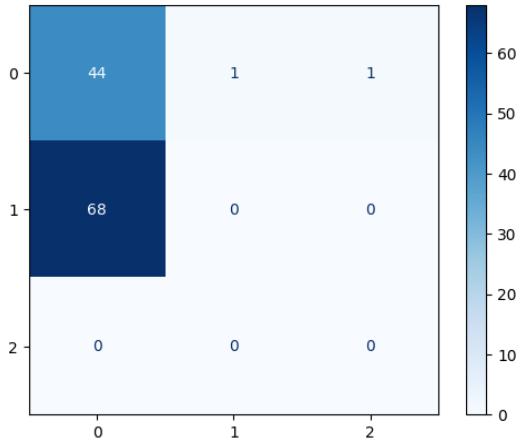


Figure 17: Confusion matrix with a learning rate of 0.001, 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

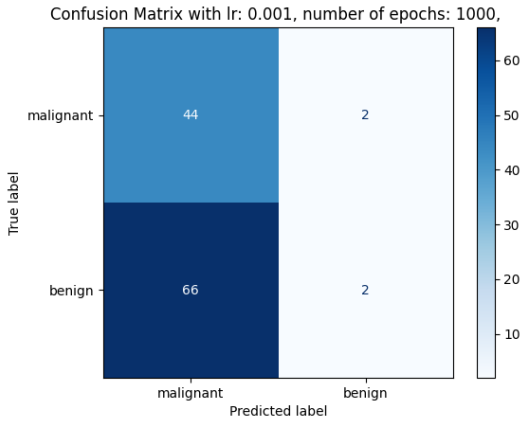


Figure 18: Confusion matrix with a learning rate of 0.001, 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]

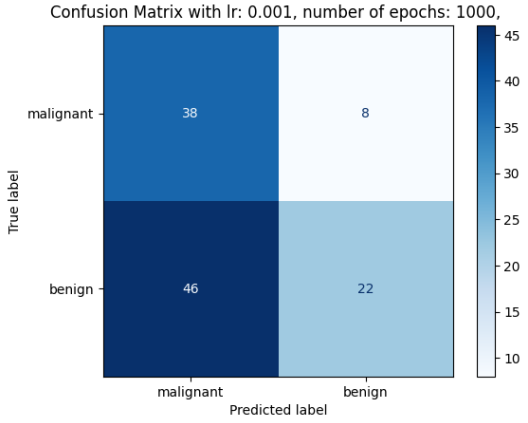


Figure 19: Confusion matrix with a learning rate of 0.001, 1 hidden layer with 10 neurons and the activation functions [ReLU, sigmoid]

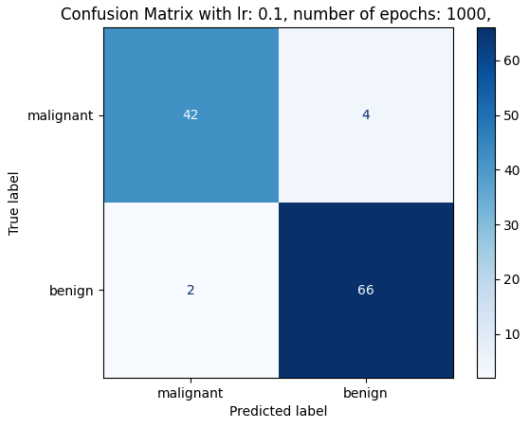


Figure 20: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

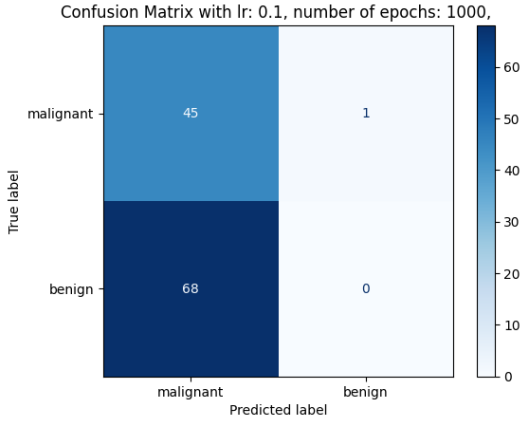


Figure 21: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

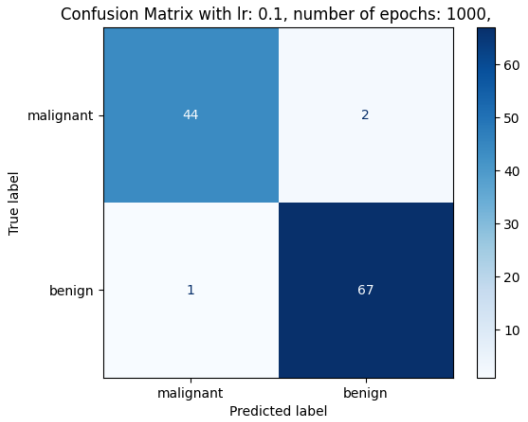


Figure 22: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]

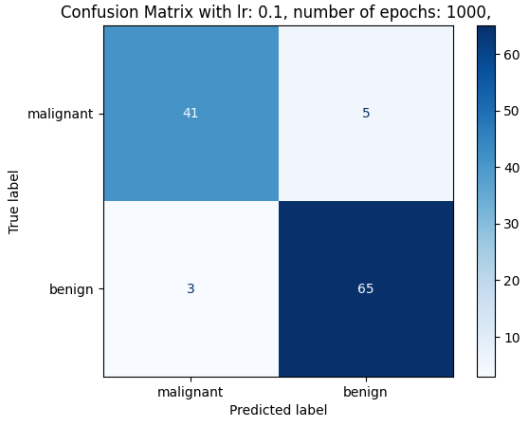


Figure 23: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 10 neurons and the activation functions [ReLU, sigmoid]

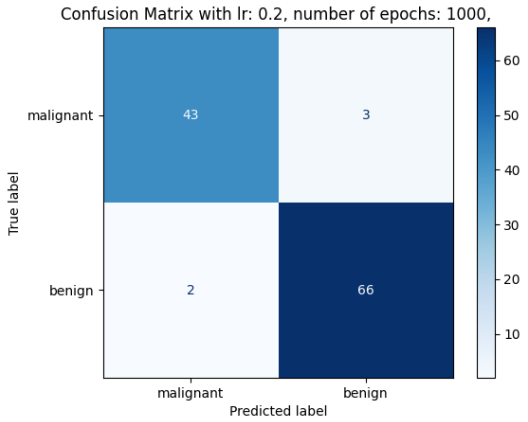


Figure 24: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

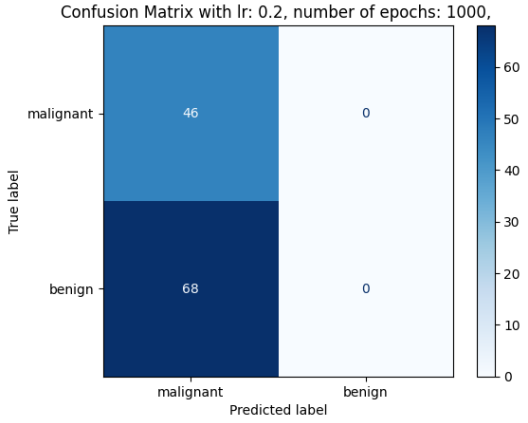


Figure 25: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

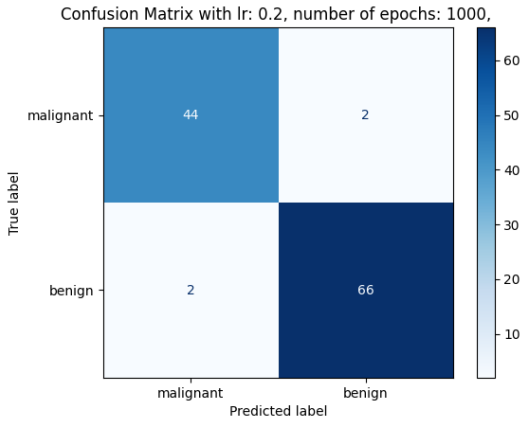


Figure 26: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]

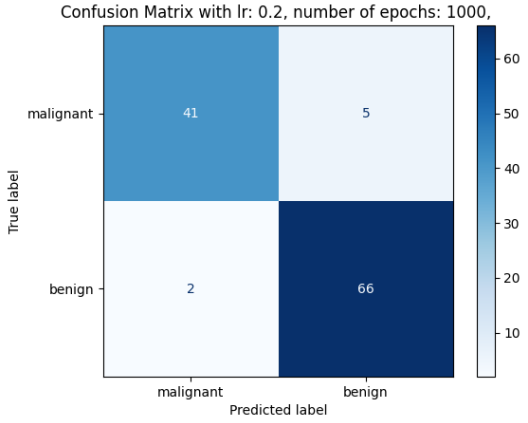


Figure 27: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 10 neurons and the activation functions [ReLU, sigmoid]

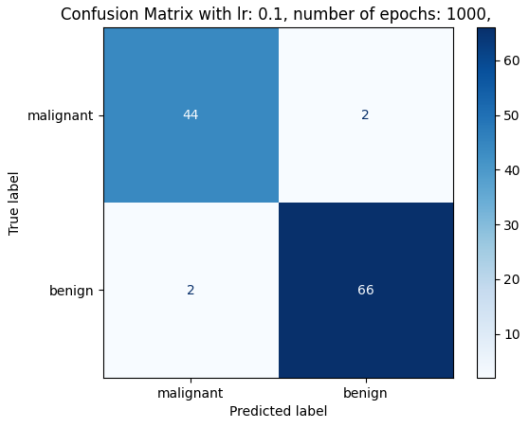


Figure 28: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 5 neurons and the activation functions [sigmoid, sigmoid]

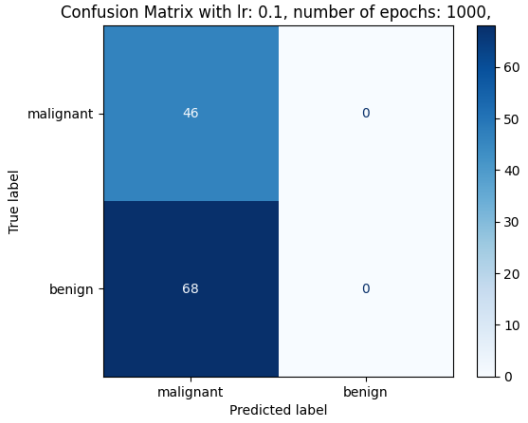


Figure 29: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 5 neurons and the activation functions [ReLU, ReLU]

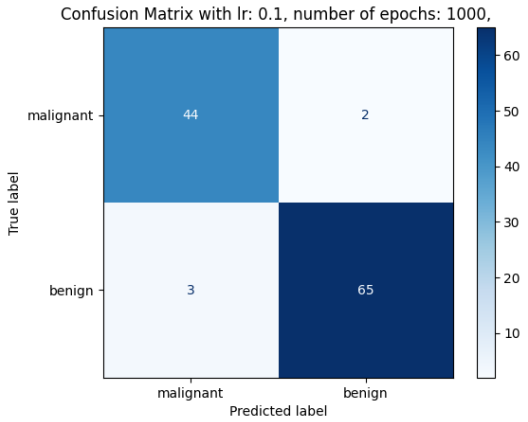


Figure 30: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 5 neurons and the activation functions [sigmoid, ReLU]

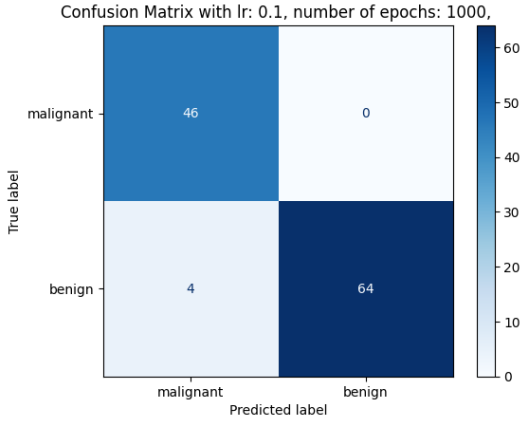


Figure 31: Confusion matrix with a learning rate of 0.1, 1 hidden layer with 5 neurons and the activation functions [ReLU, sigmoid]

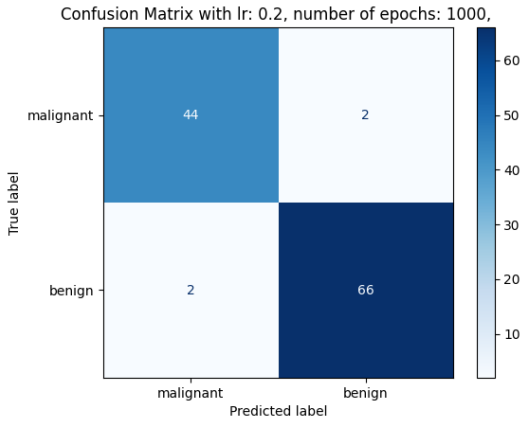


Figure 32: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 5 neurons and the activation functions [sigmoid, sigmoid]

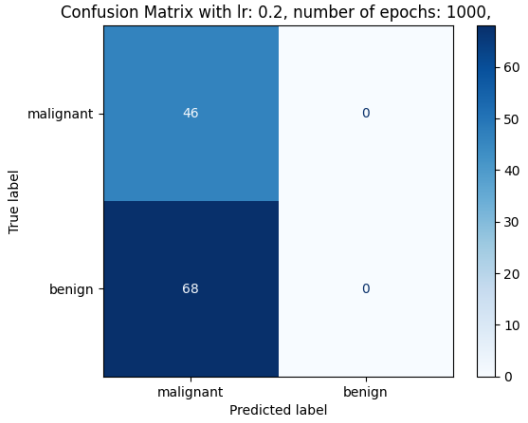


Figure 33: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 5 neurons and the activation functions [ReLU, ReLU]

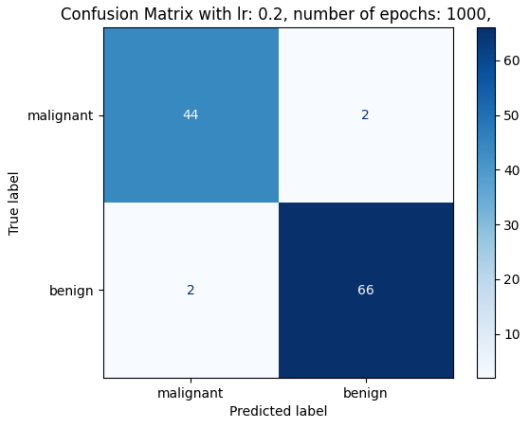


Figure 34: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 5 neurons and the activation functions [sigmoid, ReLU]

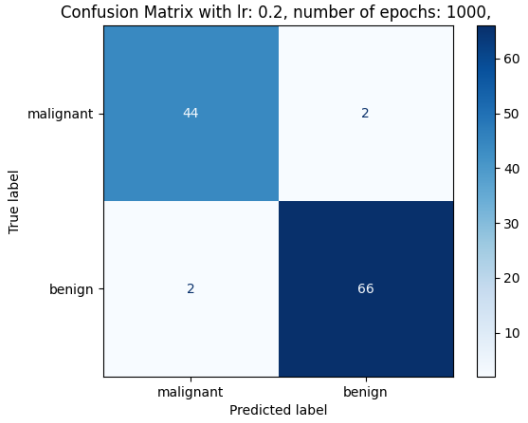


Figure 35: Confusion matrix with a learning rate of 0.2, 1 hidden layer with 5 neurons and the activation functions [ReLU, sigmoid]

# 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

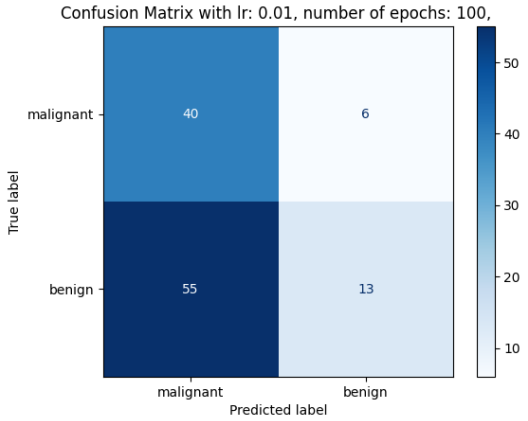


Figure 36: Confusion matrix with a learning rate of 0.001, 100 epochs, 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

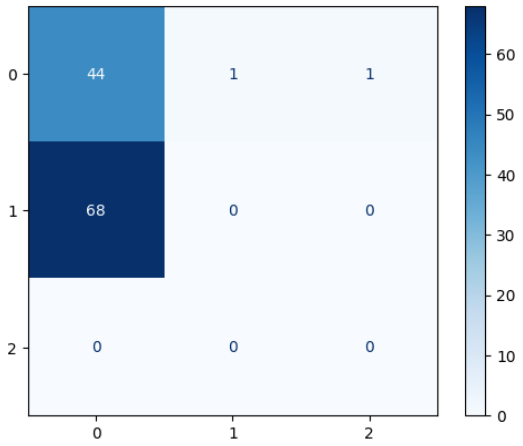


Figure 37: Confusion matrix with a learning rate of 0.001, 100 epochs, 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

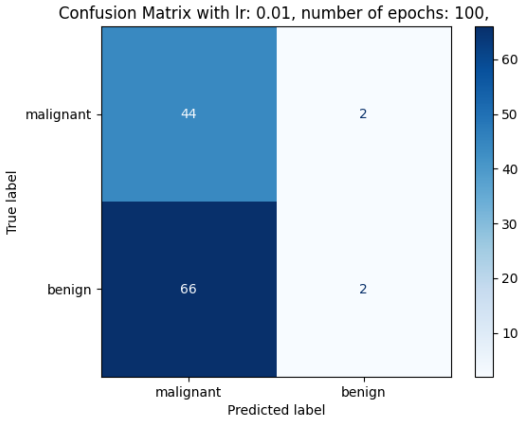


Figure 38: Confusion matrix with a learning rate of 0.001, 100 epochs, 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]

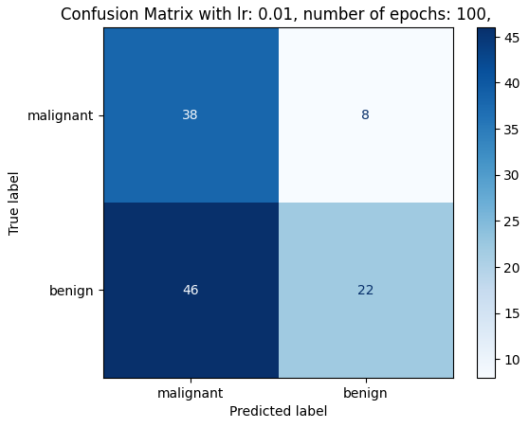


Figure 39: Confusion matrix with a learning rate of 0.001, 100 epochs, 1 hidden layer with 10 neurons and the activation functions [relu, sigmoid]

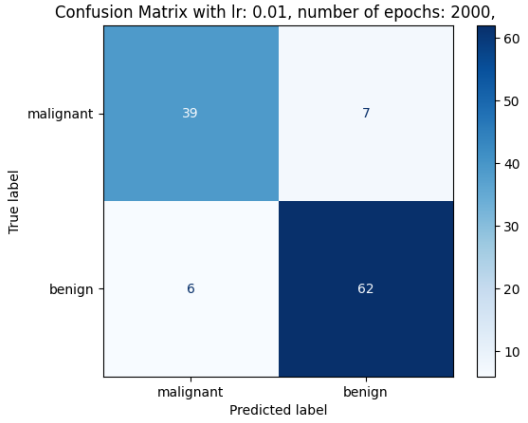


Figure 40: Confusion matrix with a learning rate of 0.001, 2000 epochs, 1 hidden layer with 10 neurons and the activation functions [sigmoid, sigmoid]

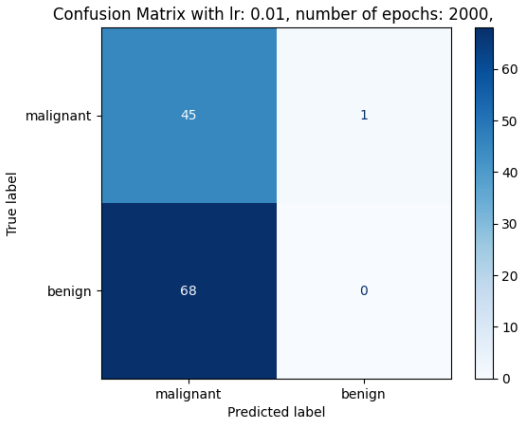


Figure 41: Confusion matrix with a learning rate of 0.001, 2000 epochs, 1 hidden layer with 10 neurons and the activation functions [ReLU, ReLU]

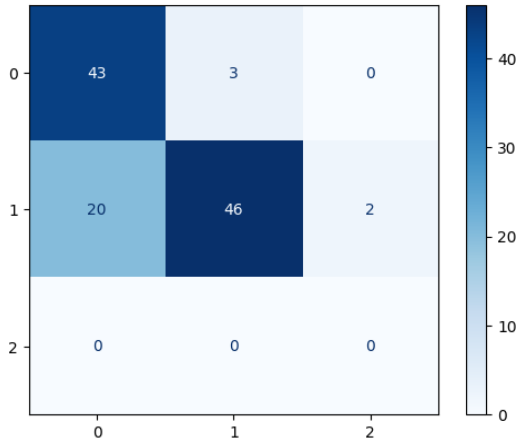


Figure 42: Confusion matrix with a learning rate of 0.001, 2000 epochs, 1 hidden layer with 10 neurons and the activation functions [sigmoid, ReLU]

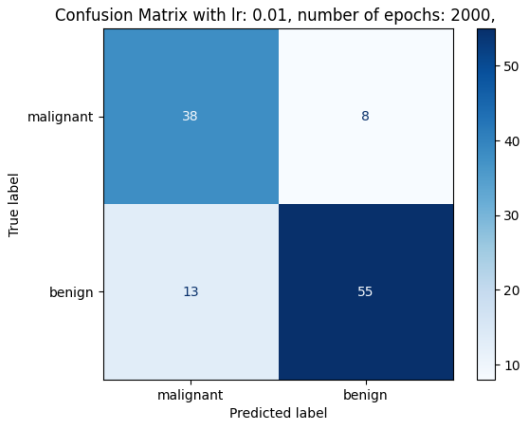


Figure 43: Confusion matrix with a learning rate of 0.001, 2000 epochs, 1 hidden layer with 10 neurons and the activation functions [relu, sigmoid]

# 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

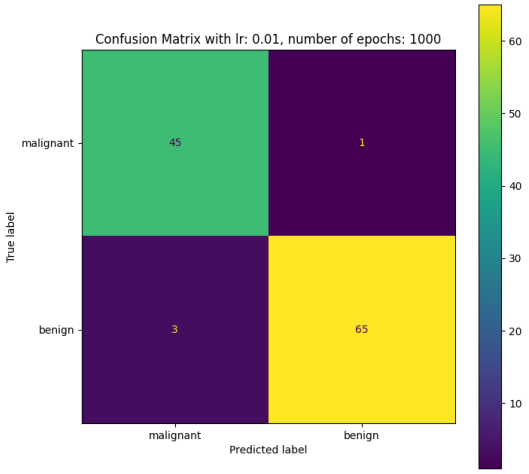


Figure 44: Confusion matrix using tensorflow with the activation functions [sigmoid, sigmoid]. The learning rate=0.1, number of epochs=1000, there is one hidden layer with 10 nodes.

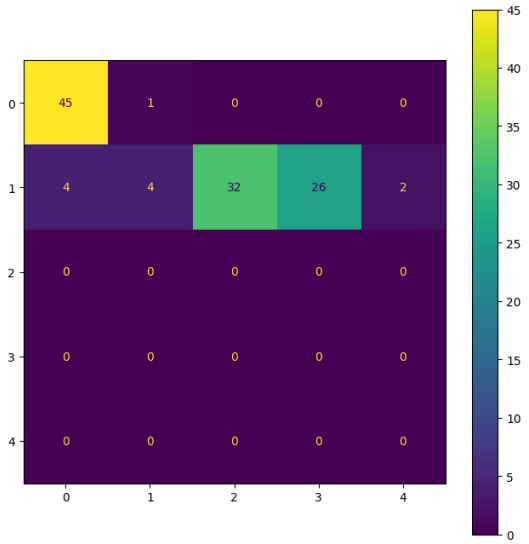


Figure 45: Confusion matrix using tensorflow with the activation functions [sigmoid, ReLU]. The learning rate=0.1, number of epochs=1000, there is one hidden layer with 10 nodes

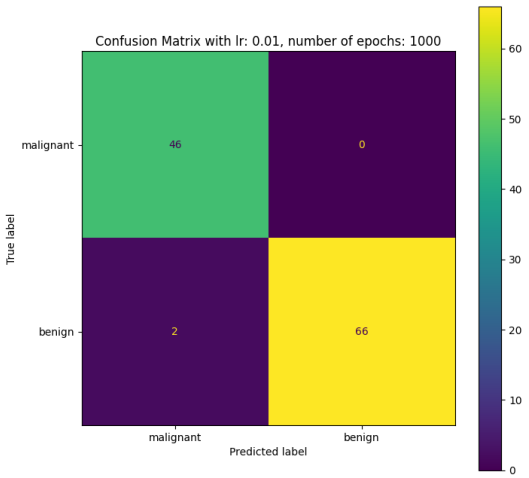


Figure 46: Confusion matrix using tensorflow with the activation functions [ReLU, sigmoid]. The learning rate=0.1, number of epochs=1000, there is one hidden layer with 10 nodes