Neural Network in Classifying Sonar Targets: Mines and Rocks

Ningyi Sun @u5976889
Research School of Computer Science, Australian National University

Abstract. A neural network has been designed to make classify two kinds of the sonar targets. The dataset is chosen from UCI machine learning repository. The network is designed on a binary model base and evaluated by using the confusion matrix. The testing accuracy of the neural network can be up to 86%. According to Gorman (1988), a better neural network can be designed to achieve 90% accuracy. However, the neural network can be improved by using the network pruning techniques. The result of the improved NN is worse than the result in the paper. The NN is modified again with evolutionary algorithm.

Keywords: classification, neural network, binary model, network pruning, evolutionary algorithm

1 Introduction

With the rapid development of the techniques in computer science, artificial neural network which in inspired by the bio-neural network is introduced to solve certain problems in real life. With years of development of the neural network technology, the neural network can be implemented to be capable of completing certain complicated tasks. For example, Apple Inc. started to use deep neural network for face detection and face ID. The new product iPhone X released by Apple in 2017 uses the deep neural network along with the deep camera system to recognize certain faces to unlock the phone, which is much more convenient to the finger prints in the previous generation iPhone. Neural network can also be used in many areas, which is a great value to the society, with the neural network, individuals can lead a convenient life.

The dataset called 'Connectionist Bench (Sonar, Mines vs. Rocks) Data Set' is chosen from UCI machine learning repository. It has 60 features and 208 instances and is used for classification task. This dataset is chosen because the data set contains only numeric data and the target values only contains 0 and 1, which meets the basic requirements of the neural network. Confusion matrix is used to evaluate to result of the network. There are still a large number of mines left in the sea, lakes or even rivers. It is a great threat to those people who works at marine industries. In this case, if a neural network is designed to distinguish between ordinary rocks and mines underwater. It can be of great value to the marine industries.

The problem modelled is to design a neural network to classify two different targets in a dataset, so the network is designed to classify the binary class whose target value contains only 0 or 1. In this case, a binary neural network is designed to distinguish two different classes of targets. Also, the features of the data are also required to be numeric as the network is designed only to accept numeric data.

In order to implement the neural network to do the classification task by using the chosen dataset, papers are investigated to determine the most appropriate method for this problem.

2 Method

The method used in the neural network is binary model neural network, which only accepts binary value for its target. The evaluation of performance of the network is measured by training accuracy, confusion matrix and testing accuracy. The network is implemented afterwards by pruning technique.

2.1 Basic Structure of the Neural Network

As is mentioned earlier, the dataset contains two different classes which are represented by 0 or 1. 0 stands for rock and 1 stands for mines (metal cylinder). In this case, the neural network should be designed to classify two target values. The dataset has 2 classes and 60 attributes (features). According to this, the basic structure of the neural network should contain 60 input neurons, which represent the 60 attributes. 2 output neurons represent the 2 different target classes. The neural network is designed to have 3 layers and 50 hidden neurons. Learning rate is set to 0.001 and epoch amount is set to 1000. The reason for choosing the certain number of hidden neurons is that according the rule-of-thumb, the optimal size of the hidden layer is between the size of the input layer and the size of the output layer. In this case, the optimal size should be between 2 and 60. After the range of the number is set, the range is to be split into 3 sets, which are 2 to 20, 20 to 40 and 40 to 60. Each set is tested to see the performance of each set. Then the performance is compared to

determine the best set to do this task. After the best set is determined, the best set is split into 3 sets again to determine the best set. After this process, the optimal number for the hidden neurons are 50.

2.2 Detailed Model of the Neural Network

After the basic structure is designed, a detailed design should be implemented to complete the required task. At the early phase of the design, the data loader method was considered to design the network. This method uses data loader to load the data and uses the batch training the train the data. After conducting investigations related to this model, it is believed that this model is more suitable for the classification tasks which need to classify more than two classes. For example, there is a certain dataset which contains 7 classes and the dataset is used for classification task. The model should be suitable for this task.

More research is conducted to determine the appropriate model to complete the classification task. After consideration, a binary model of the neural network is determined in order to address the dataset problem. In the binary model of the neural network, the network only accepts binary value which is 0 or 1 as target values. As is mentioned above, the target value of the dataset chosen only contains 0 or 1, which is suitable for the current circumstance.

As for the details in the neural network, the data is split randomly into training data (80%) and testing data (20%). Also, the data is shuffled at first to get rid of the inconsistency and some other random factors in the data. For the training sets, the training sets data is set as a fixed amount as it is selected from 80% of the whole dataset. Also, the hidden neurons in the neural network is also fixed, which means all the results will be generated with the same hidden neurons and will not be compared by setting different hidden neurons.

2.3 Evaluation Method for the Network Performance

The evaluation method used is confusion matrix and the testing data is used to determine the testing accuracy. Also, the loss function is to determine the training accuracy. In conclusion, the performance of the network performance is evaluated by confusion matrix, training accuracy and testing accuracy.

2.4 Improved Method Using Network Reduction Technique

The network reduction technique means that pruning the network. The basic concept for the pruning is that remove the similar neurons in the hidden layer to reduce the total size of the network. In order to determine the similar neurons, there are several ways to determine the similarity. According to Gedeon, there are several characteristics to determine the neurons, which are contributions, sensitivities, badness distinctiveness and taxonomy of undesirable units. In this case, the distinctiveness factor is used to remove the similar neurons.

The main idea for this technique is to construct a vector for each neuron, and then calculate the angle between each vector. The angle should be normalized to 0 to 180 degrees. If the angle is between less than 30 degrees. The two hidden neurons are similar. In this case, the hidden neurons should be removed. Based on this theory, in the improved neural network should have a function that calculate the angle between each hidden neuron and remove those whose angle is less than 30 degrees. By doing this, the redundant neurons in the neural network can be removed and the total size of the neural network can be reduced without worsen the accuracy of the classification task.

2.5 Evolutionary Algorithm

The evolutionary algorithm is inspired by biological evolution. It uses the mechanisms such as reproduction, mutation and selection. It can select the best performance of the neural network in this case.

Generally, the idea of using the evolutionary algorithm on the implemented neural network above is that the evolutionary algorithm will first generate the initial population of the individuals, which is input of the neural network in this case, randomly. After this step, the algorithm will generate new individuals through crossover and mutation functions to select the best accuracy of the neural network.

In detail, in the evolutionary algorithm(EA) there are several functions to use the EA to the neural network.

get_fitness function:

```
def get_fitness(prediction):
    return prediction + 1e-3 - np.min(prediction)
```

This function is used to grab the accuracy of the neural network. The population with the higher accuracy will have the higher chance to be selected to achieve the best performance of the neural network.

F function:

This function are used to put the accuracy of the neural network in the *fitness[]* list so that it can be passed into the function listed above. In order to do this, an empty list called fitness is created in order to pass the accuracy of the neural network into the EA.
After all the steps above are done, the EA will determine the best input for the neural network to train to achieve the best performance of the neural network.

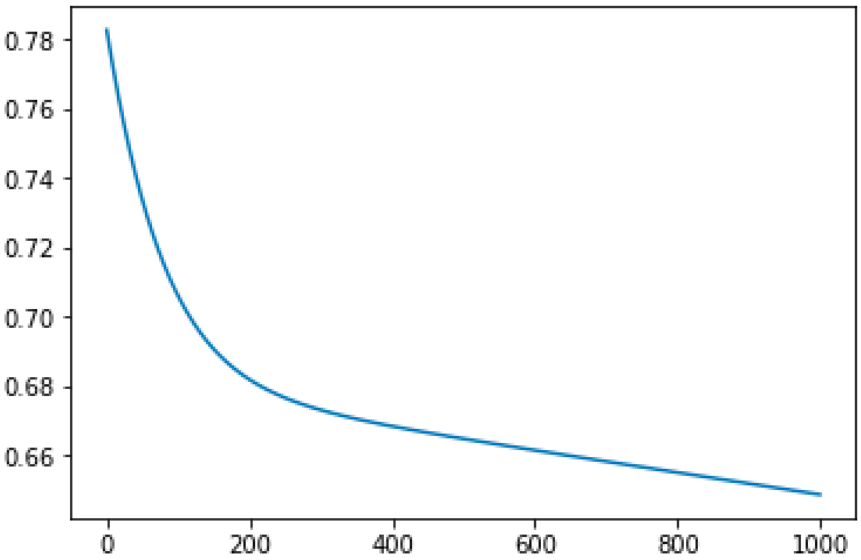
3 Results and Discussion

The result of the neural network is acceptable. The testing accuracy of the neural network can be up to 86%, which is really good for a 3-layer neural network with simple network structures. Comparing with the result of the study by Gorman (1987), the performance of the binary neural network is worse than the performance in the study. The testing accuracy of the study can be up to 100% with 24 hidden neurons.

After the network is modified by the network reduction techniques, the training accuracy of the network has changed from originally 75% to 74%. The testing accuracy of the network has changed from 86% to 75.79%. Comparing to the results from the study, the modified network is still unable to achieve the accuracy level of the performance.

3.1 Performance of the Binary Model Network

```
  if epoch % 50 == 0:
Epoch [1/1000] Loss: 0.7827  Accuracy: 50.30 %
Epoch [51/1000] Loss: 0.7336  Accuracy: 50.30 %
Epoch [101/1000] Loss: 0.7060  Accuracy: 50.30 %
Epoch [151/1000] Loss: 0.6906  Accuracy: 50.30 %
Epoch [201/1000] Loss: 0.6819  Accuracy: 52.12 %
Epoch [251/1000] Loss: 0.6766  Accuracy: 54.55 %
Epoch [301/1000] Loss: 0.6731  Accuracy: 58.18 %
Epoch [351/1000] Loss: 0.6705  Accuracy: 64.24 %
Epoch [401/1000] Loss: 0.6684  Accuracy: 67.27 %
Epoch [451/1000] Loss: 0.6665  Accuracy: 70.30 %
Epoch [501/1000] Loss: 0.6648  Accuracy: 70.91 %
Epoch [551/1000] Loss: 0.6631  Accuracy: 70.30 %
Epoch [601/1000] Loss: 0.6615  Accuracy: 70.30 %
Epoch [651/1000] Loss: 0.6598  Accuracy: 72.12 %
Epoch [701/1000] Loss: 0.6582  Accuracy: 72.12 %
Epoch [751/1000] Loss: 0.6566  Accuracy: 72.73 %
Epoch [801/1000] Loss: 0.6550  Accuracy: 72.73 %
Epoch [851/1000] Loss: 0.6534  Accuracy: 73.33 %
Epoch [901/1000] Loss: 0.6519  Accuracy: 74.55 %
Epoch [951/1000] Loss: 0.6503  Accuracy: 75.15 %
```



Two diagrams above show the summery of the overall evaluation of the neural network. As you can see in the diagrams above, the training accuracy of the neural network can be up to 75.15%. Also, the plotting loss can also be

observed in the diagram above. By evaluating all the results generated from the designed neural network, the result is acceptable. All the result including training accuracy and testing accuracy is at a satisfactory level. The testing accuracy is on average 75% and the training accuracy is on average 70%.

3.2 Comparing to the Results from the Study

As is mentioned above, there is another research conducted by Gorman which used the same dataset. The task of the data is also to classify two different types of classes, which are mines and rocks. The performance of the neural network in the study can be extraordinary. According to the training accuracy table from the study, the average accuracy can be up to 99.8%. Also, the testing accuracy can be 87% on average. This means the overall performance of the network from the study is far better than the binary model designed in this study.

After modifying the network by reducing the 5 of the hidden units of the network, the training accuracy of the binary model neural network reduced to 74% and the testing accuracy reduced to 75.79%.

3.3 Results and Discussion

The performance of the binary neural network is worse than the neural network in the study. After deep investigation to the report of the study. There are several factors that can have influence on the performance of the result.

First of all, according to the study, the performance of the neural network is evaluated with different hidden neurons. There are 6 different number of hidden neurons they used, 0, 2, 3, 6, 12 and 24 different number of hidden neurons are used. These hidden neurons are different because they wanted to find the best performance with the hidden neurons. In this case, the neural network achieved the best performance with 24 hidden neurons. In the binary model of the neural network, the neurons in the hidden layer is fixed to 50 randomly. No methods are used to determine the appropriate amount of the hidden neurons, which can lead to the overall bad performance of the whole neural network.

Secondly, the neural network in the study paper is more complicated than the simple binary model designed in this paper, which means in the study there exists a more complicated learning algorithm. In other words, the neural network is implemented to be more suitable to determine the rocks and mines. In this case, it is obvious that the neural network in the study by Gorman will have a better performance due to detailed design of the network structure and a clearer learning algorithm.

Last but not least, in the binary model network, when it comes to preprocessing the data, the data is only shuffled randomly and split into training data and testing data. In the study, the preprocessing process is used to obtain spectral envelop of the metal cylinder (mines) and rock. The spectral envelop gives a more detailed presentation of the two different classes, which makes the training and testing process for the network easier and clearer.

As for the results of the modified network using the network reduction techniques, the performance of the modified network is even worse than the performance of the unmodified version. After a deeper investigation into the technique, the paper related to reducing the hidden neurons has different techniques related to different methods. For example, when it comes to removing the unnecessary neurons in a network, different characteristics of the neurons should be determined. According to Gedeon and Harris, relevance, contributions, sensitivity, distinctiveness and badness should be determined in order to decide which sets of hidden neurons should be removed. However, due to the lack of related method, contribution analysis, for instance, it is hard to determine which sets of hidden neurons should be removed. In this case, when we randomly removed 5 neurons from the 50 original hidden neurons, it is highly possible to remove the necessary neurons instead of the unnecessary neurons. This can lead to the worse performance of the neural network.

3.4 Benefits and Weakness of the Network Reduction Techniques

After the discussion above, the benefits and the weakness of the network reduction technique is obvious.

As is mentioned above, the network reduction technique is about removing unnecessary hidden neurons in the network. By doing so, the weight of the network can be greatly reduced, and the structure of the network can be more concise and clearer because the amount of the neurons is greatly reduced.

However, the network reduction technique also has some drawbacks. As is mentioned in the paper before, in order to identify the similar hidden neurons, the angles of the vectors between different hidden neurons should be calculated. If there are a large amount of the angles of the vectors to calculate, there will be a large amount of computing as well. In this case, the computational complexity is high if there is a large number of hidden neurons in the neural network.

4 Conclusion and Future Work

In conclusion, the designed binary neural network achieved a satisfactory performance. However, compared to the study conveyed by Gorman and Sejnowski(1988), the performance of the binary neural network is worse than the one in the study. Several factors can have influence on the performance. After modifying the binary network with network reduction technique, the performance is even worse than the original version. This is because of the lack of relevant method to determine the unnecessary neurons.

In terms of the evolutional algorithm applied to the NN implemented in this paper, the difficulty of applying the EA to the current NN is that the NN needs to be implemented to different functions for the EA to get the data, which is accuracy of the NN in this case. This can be inconvenient when the NN is designed and implemented before the EA is implemented.

Future work still need to be done related to the binary model. As is mentioned above, the neural network in the study is well designed no matter at the preprocessing phase or the learning algorithm phase. In this case, more research needs to be done to improve the learning algorithm. What's more, in regard to the network reduction technique, more research should be conducted in order to determine the unnecessary neurons in the hidden layer.

In terms of the pruning techniques, it is mentioned above that the distinctiveness method can have a high computational complexity if there is a large number of hidden neurons in the neural network. In this case, other method of determining the similarity of the hidden neurons should be researched to see whether the level of the computational complexity can be reduced.

A list of the future work:

- More research into determining the unnecessary hidden units
- A more complicated and detailed algorithm for the learning phase
- More research needs to be done to improve the preprocessing phase

5 The References Section

ReferGorman, R. and Sejnowski, T. (1988). Analysis of hidden units in a layered network trained to classify sonar targets. Neural Networks, 1(1), pp.75-89.ences

Gedeon, T.D. and Harris, D. (n.d.). NETWORK REDUCTION TECHNIQUES.

Appendix:

Testing accuracy of the two versions of the neural network:

Version 1.0: 86%
Version 2.0: 75.79%