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Optimization of Neural Network with Genetic Algorithm for Breast Cancer Classification

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***Abstract*—Proper diagnosis of breast cancer is one of the main issues in a medical sector. The neural network could overcome the issue, but weak in determining parameter value, therefore it requires optimization. A genetic algorithm is one of the optimization methods, due to that matter, attribute parameter value of neural network will be optimized by using Genetic Algorithm to acquire the best predictor attributes. Genetic-based Neural Network algorithm has higher accuracy compared to the application of Neural Network algorithm alone. This notion is proven through the increasing rate of accuracy value for Neural Network algorithm which amounted to 96.57 % and 97.24 % for Genetic-Based Neural Network Algorithm as well as the decreasing rate of error classification of Neural Network algorithm model from 3.43 % rate to 2.86 % due to the application of Genetic-Based Neural Network Algorithm. Therefore, it can be concluded that the application of the optimization technique of Genetic Algorithm can enhance the accuracy value and decrease the error value of the Neural Network algorithm on breast cancer classification.**

Keywords*—Breast cancer, neural network, Genetic Algorithm

I. INTRODUCTION

One of the dangerous diseases is cancer. For women, the terrifying cancer is breast cancer. Breast cancer is the most diagnosed cancer in the United States; moreover, breast cancer is the second most common cause of death of women in the United States and Asia [1]. Early detection of breast cancer holds an essential role in anticipating the spread of disease. Through early detection, the occurrence of cancer cells can be immediately overcome and prevented the spreading. Comprehensively, the accuracy of detection is depending on three factors: quality of instruments, the expertise of the doctor in conducting the procedure and in interpreting and using a multi-disciplinary approach for detecting breast cancer. Due to that matter, it is essential that some disciplines keep giving their contributions especially data mining or Artificial Intelligence.

According to World Health Organization (WHO), early detection can increase the chances of successful treatment in cases of cancer. Diagnosis of breast cancer can be made by biopsy or screening method. Screening methods include physical examination, MRI, and mammography. If the screening results are inconclusive, then a biopsy through microscopic analysis such as fine needle aspiration (FNA) can be used to determine the diagnosis. Fine Needle Aspiration (FNA) is the easiest and fastest ways to obtain breast biopsy and effective for women who have cyst filled with liquid. FNA uses a small needle which injected through breast skin, and a tissue sample is taken from the tip of the needle to be studied under the microscope [2]. One of the institutions that use the application of FNA in detecting breast cancer is University of Wisconsin Hospital. Wisconsin Breast Cancer Database (WBCD) and Wisconsin Diagnostic Breast Cancer (WDBC) are the data set acquired from the FNA's results of breast biopsy from the patient in University of Wisconsin Hospital. According to the results of the FNA sample that being taken, nine parameters are determined based on the characteristics of a cell, such as a clump thickness, uniformity of cell size, uniformity of cell shape, marginal adhesion, single epithelial cell size, bare nuclei, bland chromatin, normal nucleoli, and mitoses. Those nine parameters are the content of the data set from Wisconsin Breast Cancer Database (WBCD), while the characteristics of cell nucleus from a digital image of breast mass are obtained from the data of Wisconsin Diagnostic Breast Cancer (WDBC), therefore, according to the results of FNA sample that being taken, ten parameters with the range of 1-10 are acquired from WDBC data, including radius, texture, perimeter, area, compactness, smoothness, concavity, concave points, symmetry, and fractal dimension. Both of these data types classify breast tumor into two classes, such as benign and malignant [3] [4]

The aim of this research to examine the performance of the neural network and optimized neural network by using Genetic Algorithm based on Wisconsin Breast Cancer Database (WBCD). The seventh attribute mentioned as Bare Nuclei of WBCD has 16 missing values, some researchers remove the missing data during the application of WBCD to diagnose breast cancer. Eliminating some data will impact the diagnosis accuracy. This paper presents the classification results after replacing the missing values by using average method for WBCD dataset and implementing the Genetic Algorithm optimization technique to increase the accuracy value and decrease the error value of Neural Network on breast cancer classification.

II. RELATED WORK

The studies about breast cancer diagnosis through the application of data mining have been commonly conducted. The research data source used in testing the accuracy of breast cancer diagnosis is mostly using the public data from UCI Machine Learning Repository dataset breast cancer. Research on the determination of breast cancer using data mining or Artificial Intelligence has been carried out by many researchers, as listed in Table I.

TABLE I. RESEARCH IN THE DIAGNOSIS OF BREAST CANCER

Number	Researcher	Method & Accuracy
1	Aalaei, S [5]	Aalaei, S [5] produces the comparison of average accuracy for three classifications (ANN=96.8%, PS-classifier=96.2%, GA-classifier=96.08%). The dataset of WBC shows that the accuracy of ANN (96.8%) is the best
2	Ghosh, S [6]	Ghosh, S [6] acquires that the accurate comparison of Neuro-Fuzzy is 97.8%, Multilayer Perceptron is 86.3%, Support Vector Machine is 87.6% on the database of WBC
3	Asri, H., [7]	Asri, H., [7] compares Support Vector Machine (SVM), Decision Tree (C4.5), Naive Bayes (NB), and k Nearest Neighbors (k-NN) with Wisconsin Breast Cancer, the acquired result shows that SVM gives the highest accuracy (97.13%) with the lowest error rate
4	Agrawal, S [8]	a survey by Agrawal, S [8] acquires MLP (Multi-Layer Perceptron) with 97.1% of accuracy and PPN (Probabilistic Neural Network) with 96% of accuracy, Perceptron with 93% and ART1 that shows 92% of accuracy by removing the missing values from the dataset
5	Lakshmi, KR, [9]	Lakshmi, KR, [9] compares the method of C4.5, SVM, k-NN, BLR, MLR, PLS-DA, PLS-LDA, k-means and Apriori, PLS-DA Method provides 96.66% of accuracy which the highest compared to the other methods
6	Yu, C.-T [10]	Yu, C.-T [10] compares three techniques; Artificial Neural Networks (ANNs), Support Vector Machine (SVM), and Bayesian classifier on the dataset of central education hospital of Taiwan, each of them gives 90.31%, 89.79%, and 88.64% of accuracy. The classification result of SVM is slightly better compared to the classifications of ANN and Bayesian, however, from lower variances, the result shows that SVM will be the best prognosis in the clinical practice
7	Ma'arif, F [11]	in which has been studied in Indonesia by Ma'arif, F [11] who combine the figure selection algorithm of Backward Elimination and Support Vector Machine (SVM) that generates 97.14% of final accuracy

From the experiment of Aalaei, S [5], it has been acquired that the accuracy of ANN (96.8%) is the best compared to PS-classifier (96.2%) and GA-classifier (96.08%). Therefore, the ANN method will be used in this research. Artificial Neural Network (ANN) has been commonly used in various sectors as the intelligence tools for the last couple years, such as artificial intelligence, pattern recognition, medical diagnosis, machine learning, and others. The neural network has become a popular instrument in Cancer Dataset classification due to its capability to represent the linear behavior or not-linear multidimensional and complex function, by the form of non-linear cancer cells. The neural network could overcome the issue. However, the neural network is weak in determining the parameter value. Therefore, it needs optimization. Genetic Algorithm is one of the proper optimization methods. Therefore, the parameter values of the neural network will be optimized by using Genetic Algorithm to acquire the best parameter value.

III. PROPOSED METHOD

The research method used in this study is an experimental method. This research is using public dataset, such as Wisconsin breast cancer data which taken from the UCI repository. The dataset has been proved and widely used by research for modeling and application of breast cancer classification. In general, this method will perform calculation towards dataset by using Rapidminer. The breast cancer dataset of Wisconsin that used has 699 records with 11 attributes. One attribute becomes a label, namely class attribute with two entries for benign cancer and four entries for cancer. The other ten attributes are including id, clump thickness, uniformity of cell size, uniformity of cell shape, marginal adhesion, single epithelial cell size, bare nuclei, bland chromatin, normal nucleoli, and mitoses.

After the entire initial values are initialized, then the input, output and error are calculated. The output then raised for knot by using sigmoid activation function. After the value from activation function is acquired an error value between the predicted and actual values. After the error value is calculated, then backpropagation is conducted. The error value produced from the previous step is used to update the relation weight. In RapidMiner, the amount of neuron in the hidden layer can be set by default or not. In default, the amount of neuron in a hidden layer is eight which acquired from some attributes add some classes divided two plus one that shown in Figure 2.

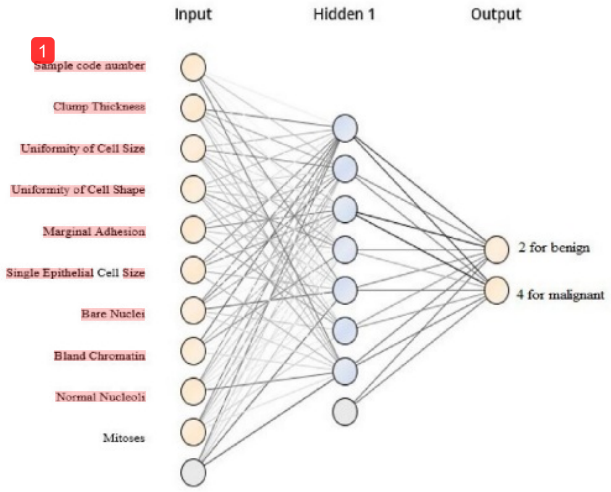

Fig. 2. The architecture of Artificial Neural Network

From the existing dataset, the next step is conducting accuracy level calculation for each algorithm. The process in this step includes the validation through K-Fold Cross Validation to seek and obtain the best model which in this validation process, the research dataset is divided into 90% used for practice data while the rest 10% is used for testing data.

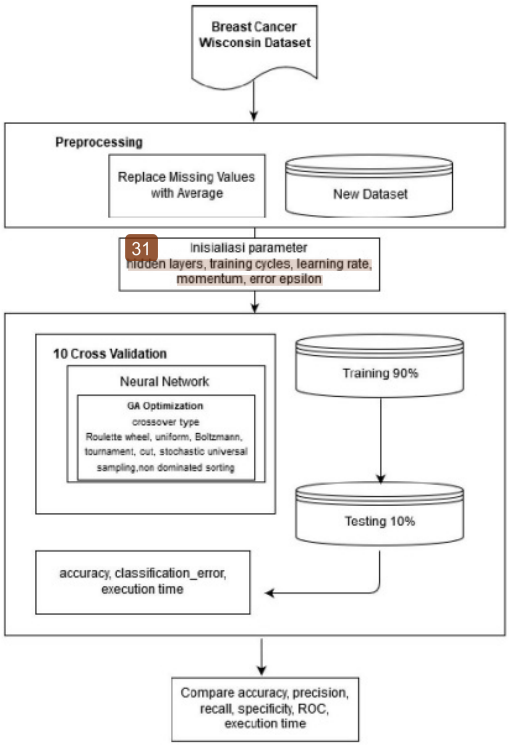

Fig. 3. Proposed research method

The evaluation of the established model will be performed through accuracy measurement. Accuracy is measured by using a confusion matrix. Confusion matrix will describe the accuracy results started from right positive prediction, wrong positive prediction, right negative prediction, and wrong negative prediction. The accuracy value of the model will be compared between the established model and the neural network algorithm that has been optimized.

TABLE II. PERFORMANCE MEASUREMENT

Measure	Formula
Precision	$Precision = \frac{TP}{TP + FP}$
Recall / Sensitivity	$Recall/Sensitivity = \frac{TP}{TP + FN}$
Selectivity	$Selectivity = \frac{TN}{FP + TN}$
Accuracy	$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$
F-Measure	$F - Measure = \frac{2 * Precision * Recall}{Precision + Recall}$

IV. EXPERIMENTAL RESULT

The experiment is conducted by using RapidMiner to acquire the result from the proposed model by using JST algorithm. To acquire the desired JS model, the JST parameter value then being determined. The value of neural network practice is determined by the parameters of hidden layers, learning rate, training cycles, and momentum.

The application of a neural network algorithm is conducted by determining the hidden layer value first. In principle, Backpropagation with one hidden layer is sufficient to be able to recognize any pair of input and target. However, the addition of a hidden layer sometimes makes the practice to be much easier [12]. The testing of the determination of hidden layer parameter then developed on the values of 1, 2, 3, 4, and 5. The results can be seen in Table III. The highest accuracy value is on the third hidden layer.

TABLE III. VARIATION OF HIDDEN LAYER

	Hidden Layers	1	2	3	4	5
Input	training cycles	500	500	500	500	500
	learning rate	0,3	0,3	0,3	0,3	0,3
	momentum	0,2	0,2	0,2	0,2	0,2
	error epsilon	0,00001	0,00001	0,00001	0,00001	0,00001
Output	accuracy	96.14%	95.99%	96.28%	95.99%	65.52%
	classification_error	3.86%	4.01%	3.72%	4.01%	34.48%
	AUC	0.985	0.987	0.993	0.992	0.811
	execution time (second)	7	13	18	23	29

Learning rate is acquired by inserting the variation of 0.1;0.2;0.3;0.4;0.5 learning rate value with 500 training cycles standard and 0.2 of momentum. According to the results, the best accuracies achieved are 0.4 of learning rate and hidden layers 1 with 96.42% accuracy as well as 0.5 of learning rate and hidden layers 3 with 96.57% accuracy.

In the stage of the determination of training cycles value, an experiment is conducted to acquire the best parameter value of training cycle with 400, 500, 600, 700, 1000 of variation with 0.4 of constant learning rate value and 0.2 of constant momentum. The best accuracy level is 96.42% on 500 training cycles.

Momentum values are determined through an experiment by entering the variation of value namely 0.1;0.2;0.3;0.4;0.5. The 500 training cycles value and 0.5 learning rate are selected based on the previous experiment. The best accuracy rate is 96.57% for 500 training cycles and 0.5 learning rate.

The testing of accuracy level is conducted by using confusion matrix and ROC/AUC (Area Under Curve). ROC describes the tradeoff between True Positive (TP) and False Positive (FP). In ROC curve, there a two curve dimensions, true positive (TP) value is placed on the Y-axis, and false positive (FP) is placed on the Y-axis. T entire accuracies from the testing can be explained in the area under the ROC curve. The wider the area, the better test result would become. To acquire predictive accuracy value, the calculation of the number of case that correctly predicted and the number of case that incorrectly predicted are required. The calculation is tabulated into the table mentioned as a confusion matrix.

TABLE IV. CONFUSION MATRIX

	true 2	true 4	class precision
pred. 2	442	11	97.57%
pred. 4	16	230	93.50%
class recall	96.51%	95.44%	

The evaluation shows that the ROC graphic with AUC (Area Under Curve) values that amounted to 0.987 which illustrated in Figure 8 with the red line is the ROC curve with 0.987 value, including the classification with excellent classification value, while the blue line is the Threshold curve. AUC in ROC curve has the diagnose value levels as follows:

1) 0.90 – 1.00 of accuracy = excellent classification
2) 0.80 – 0.90 of accuracy = good classification
3) 0.70 – 0.80 of accuracy = fair classification
4) 0.60 – 0.70 = poor classification
5) 0.50 – 0.60 = failure

According to the conducted research, neural network algorithm is working excellently in the breast cancer classification.

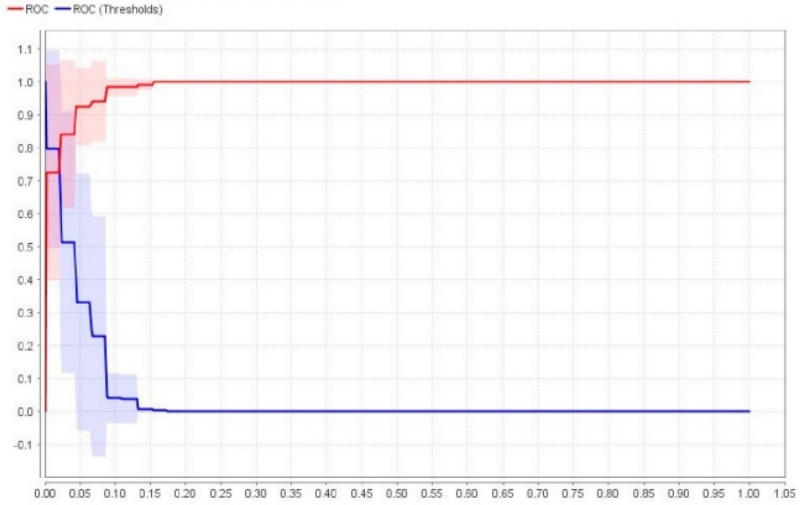

Fig. 4. ROC Curve

Furthermore, the steps which frequently conducted to solve the optimization problems in the genetic algorithm are:

1. Initialization of population.
2. Evaluation of Population.
3. Selection of Population.
4. Crossover process of a certain chromosome.
5. Evaluation of a new population.

Started by entering the data file such as breast cancer dataset, then the data with ten attributes will be selected by the genetic algorithm. What kind of attribute that will be used for the prediction process of breast cancer, therefore, the accuracy of prediction can be improved? Before the selection process, the parameters of the genetic algorithm namely population size, the probability of crossover, and the probability of mutation have to be determined in prior.

- ✓ The selection methods which available on the RapidMiner are Roulette wheel, uniform, Boltzmann, tournament, cut, stochastic universal sampling, and non dominated sorting.
- ✓ min number of 1
- ✓ population size:5
- ✓ maximum number:30
- ✓ p initialize: 0.5
- ✓ p mutation: -1.0
- ✓ p crossover: 0.5
- ✓ crossover type: uniform

After the attributes which determined as the predictor are selected, training and testing on the data by using a neural network algorithm are performed. The reduction result of the attribute with GA can be seen in Figure 5.

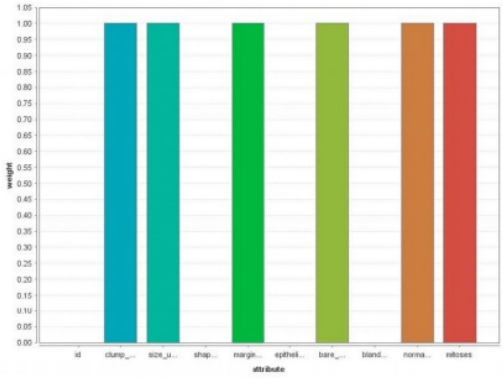

Fig. 5. Attributes of breast cancer data reduced by GA

By conducting the testing with seven types of crossover, the highest cut method from the perspectives of Accuracy, Precision, Recall, and Specificity is acquired. The testing results can be seen in Table V.

TABLE V. COMPARISON OF CROSSOVER TYPE

	Performance Vector	Crossover Type						
		Roulette wheel	Uniform	Boltzmann	Tournament	Cut	Stochastic universal sampling	Non dominated sorting
1	Accuracy	97%	97%	97%	97%	97%	97%	97%
2	Precision	94%	94%	94%	94%	95%	93%	94%
3	Recall	98%	98%	98%	98%	98%	98%	98%
4	Specificity	97%	97%	97%	97%	97%	96%	97%
5	Execution time (minute)	21	22	20	23	20	22	25

The results of a conducted experiment in this research can be concluded as follows Table VI:

a) The results of the performed evaluation through the application of Neural Network method for breast cancer classification have produced 96.57% of accuracy value with 0.987 of AUC and classified as an Excellent value.

b) The results of the performed evaluation through the application of Neural Network method which have been optimized through the utilization of Genetic Algorithm that generates 97.42% accuracy value and 0.991 of AUC classified as excellent for diagnosing value which higher for breast cancer classification. According to that condition, thus, it can be concluded that the application of Genetic Algorithm optimization will increase 0.57% of accuracy as well as enhancing 0.004 of AUC value compared to the Neural Network method alone.

TABLE VI. THE RESULTS OF PERFORMANCE VECTOR COMPARISON

		Neural Network	Neural Network + Genetic Algorithm
Input	hidden layers	1	1
	training cycles	500	500
	learning rate	0,5	0,5
	momentum	0,2	0,2
	error epsilon	0,00001	0,00001
Output	accuracy	96,57%	97,14%
	classification_error	3,43%	2,86%
	AUC	0,987	0,991
	precision	95,02%	94,74%

	recall	95,02%	97,10%
	specificity	97,38%	97,16%
	Execution time (minute)	6 second	20,12 minute

V. Conclusion

Genetic Algorithm is proven as capable to improve the prediction accuracy on breast cancer disease. The model that established by Genetic-based neural network algorithm produces better accuracy compared to the non-optimization neural network. The improvement can be seen from the increasing rate of accuracy value for Neural Network algorithm model which amounted to 96.57%, after the optimization; the value of Genetic-Based Neural Network Algorithm has increased to 97.42% with 0.57% of accuracy difference. The evaluation is using the ROC curve. Therefore, it produces AUC (Area Under Curve) which for Neural Network algorithm generates 0.987 value, while Genetic Based Neural Network algorithm acquires 0.991 value with the diagnose value of Excellent Classification with 0.004 of deviation value for both. Although the application of neural network algorithm model through GA optimization has been provided better results, however, this method still has some weaknesses, such as requiring computation time which longer from 6 seconds to 20.33 minutes.

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