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THE APPLICATION OF DEEP NEURAL NETWORK FOR BREAST CANCER CLASSIFICATION

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Abstract

Breast cancer is one of the most common cancers, especially for women. Early detection of breast cancer may increase the survival rate of patients significantly. Detecting breast cancer from breast image can be done by classification process. There are so many classification models which can be used for the classification process, such as neural network, fuzzy, neuro fuzzy, wavelet neural network, wavelet neuro fuzzy, etc. This research propose one of the neural network variant, i.e. Deep Neural Network. This kind of neural network model is using at least two hidden layers on the network. The more hidden layers used the deeper the neural network will be. The architecture of Deep Neural Network used in this research is feedforward network. Classification of breast tumor using Deep Neural Network model provides results with sensitivity, specificity, and accuracy were respectively 100%, 100%, and 66.67% for training data and 100%, 20%, and 60% for testing data.

Keywords: breast cancer, Deep Neural Network

Introduction

Breast cancer is one of the global burden of cancer, especially for women. Results from World Health Organizations (WHO) [1] show that estimated numbers of cancer cases among women is dominated by breast cancer as much as 25.2% of total cancers cases among women and estimated the total deaths caused by cancers is also dominated by breast cancers as much as 14.7% of total deaths caused by cancers among women for all ages [1]. Early detection may increase the survival rate of patients significantly. Breast cancer commonly detected by mammography test (breast image). Breast image will show different results between normal breast and non-normal breast. Non-normal breast can be categorized in two category, i.e. non-cancerous nodule (benign) and cancerous nodule (malignant). Classifying breast cancer (normal, benign, and malignant) can be done by classification process with Deep Neural Network model. This model is one of the neural networks variant that has more than one hidden layer on the network. The more hidden layers used, the deeper the neural network will be.

Experiment

Image. Image is a matrix of pixel arranged in rows and columns. The pixel describes the row and column location. It also has intensity, symbolized as $p(x, y)$, where x is the row location and y is the column location of the pixel. Based on its intensity, image can be categorized in three types:

1. RGB Image
   Each pixel in RGB image has three base color, i.e. red, green and blue. Each base color has minimum intensity value 0 and maximum intensity value 255. Mathematically, the intensity of each base color written as follows.
   $$0 \le p_i(x, y) \le 255; i = red, green, blue \quad (1)$$
2. Grayscale Image
   Grayscale image is monochrome digital image with one intensity value per pixel [2]. Each pixel of grayscale image has intensity from 0 to 255. Mathematically, the intensity of each base color written as follows.
   $$0 \le p(x, y) \le 255 \quad (2)$$
3. Binary image
   Binary image is digital image with all pixel value 0 or 1 [2]. The value 0 represents black and the value 1 represent white.

Mathematically, the intensity of binary image written as follows.

$$p(x,y) = \begin{cases} 0, black \\ 1, white \end{cases} \quad (3)$$

Image extraxtion. Image extraction is a technique for getting features from an image. The method for image extraction in this research is Gray Level Co-occurrence Matrix (GLCM). This image extractions method results 14 features, i.e. energy, contrast, correlation, sum of square variance, Inverse Difference Moment (IDM), sum average, sum entropy, sum variance, entropy, difference variance, difference entropy, maximum probability, homogeneity and dissimilarity [3]. Table 1 show the features extraction formulas.

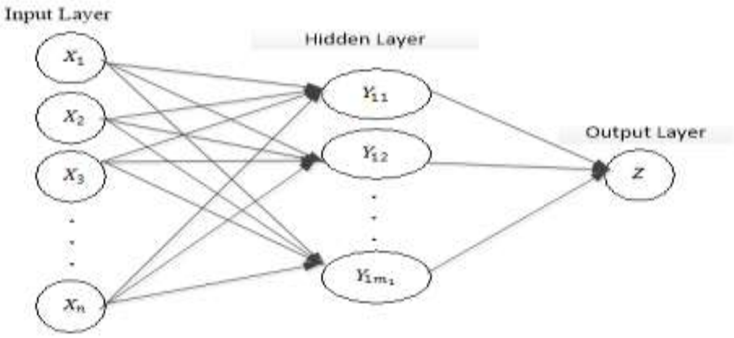
Basic Concept of Deep Neural Network (DNN). A simple neural network, as shown in Fig.1 (a), use only one hidden layer on the network. Meanwhile, Deep Neural Network uses more than one hidden layers on the network, so that the number of network layers depends on the number of hidden layers used in the network. The more hidden layers on the network are expected intuitively makes the network more powerful [4]. Figure 1 (b) is one of the DNN models with 3 hidden layers on the network. Both Fig.1 (a) and Fig.2 (b) use feedforward network on the architecture, the signal from input layer is sent to output layer through the hidden layer. Signal from one layer to another layer is activated by activation function, $f(x)$, such as:

1. Linear function,: $f(x) = x$
2. Sigmoid function : $f(x) = \frac{1}{1+e^{-x}}$
3. Hard limit function: $f(x) = \begin{cases} 1, & x \geq 0 \\ 0, & lainnya \end{cases}$

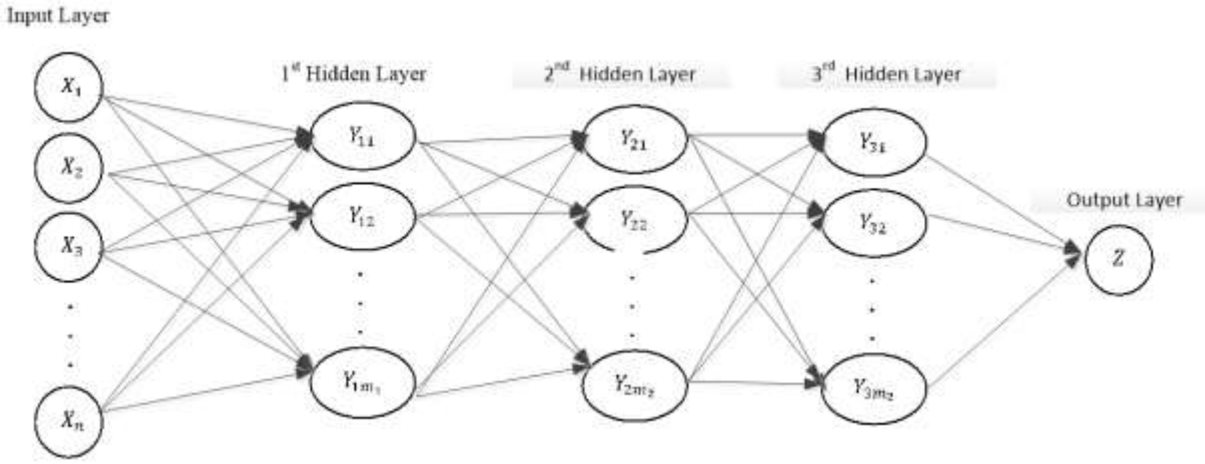
Sensitivity, Spesificity, and Accuracy. The possibility that can be happened in diagnostic test are shown in TABLE 2. There are 4 results for diagnostic tests. There are true positive (a) which means that sick patients correctly identified as sick, false positive (b) which means that healthy patients incorrectly identified as sick, false negative (c) which means that sick patients incorrectly identified as healthy, and true negative (d) which means that healthy patients correctly identified as healthy. The sensitivity, specificity and accuracy measured respectively by $\frac{a}{a+c}$, $\frac{d}{b+d}$, and $\frac{a+d}{a+b+c+d}$.

Table 1. Image Features Extraction

Feature	Formula	Features	Formula
Energy(X_1)	$\sum_i \sum_j \{p(i,j)\}^2$	Sum entropy(X_8)	$-\sum_i \sum_j p(i,j) log_2\{p(i,j)\}$
Contrast (X_2)	$\sum_i \sum_j \{p(i,j)\}^2$	Entropy (X_9)	$-\sum_i \sum_j p(i,j) log_2\{p(i,j)\}$
Correlation(X_3)	$\sum_i \sum_j \{p(i,j)\}^2$	Difference variance (X_{10})	$varians\ dari\ p_{x-y}{}_{(k)}$
Sum of square(X_4)	$\sum_i \sum_j p(i,j)(i-\mu)^2$	*Difference entropy*(X_{11})	$-\sum_k (p_{x-y}{}_{(k)}) \log(p_{x-y}{}_{(k)})$
Sum average(X_5)	$-\sum_k \{(k)\,(p_{x+y}{}_{(k)})\}$	*Maximum probability*(X_{12})	$max_{i,j}\{p(i,j)\}$
Inverse Difference Moment (X_6)	$\sum_i \sum_j \frac{p(i,j)}{1+(i-j)^2}$	*Homogeneity* (X_{13})	$\sum_i \sum_j \frac{p(i,j)}{1+\lvert i-j \rvert}$
Sum variance (X_7)	$\sum_k (i-SE)^2 p_{x+y}{}_{(k)}$	*Dissimilarity* (X_{14})	$\sum_i \sum_j p(i,j)\lvert i-j \rvert$



(a)



(b)

Figure 1. (a) Simple Neural Network Architecture and (b) Deep Neural Network Architecture

Table 2. Diagnostic Test

Test/Measure	**True Situation**		**Total**
	Performance Indicator Present	**Performance Indicator Absent**	
Positive	True Positive (a)	False Positive (b)	a+b
Negative	False Negative (c)	True Negative (d)	c+d
Total	a+c	b+d	a+b+c+d

Results and Discussions

The Application of DNN for Breast Cancer Classification

There are 25 breast images Information Society Technologies [3] used in this paper (10 normal breast images, 8 benign breast images, and 7 malignant breast images). It is divided as training data (15 breast images) and testing data (10 breast images). The first step for applying DNN for breast cancer classification is extracting the original image with GLCM technique. The result of GLCM extraction is used for classification with DNN model.

The DNN is started by choosing how many hidden layer will be used for the breast image classification. The error of the DNN learnings for training data and testing data are shown in TABLE 3. As shown in TABLE 3, RNN model with 3 hidden layers provides smallest MSE for training data and smallest MSE for testing data, so that for the next process, i.e. elimination input, will use DNN with 3 hidden layers.

As shown in TABLE 4, DNN model with 3 hidden layers and 14 features extraction as input variables provide smallest MSE for training data and smallest MSE for testing data, so that for the next process will use DNN with 3 hidden layers and 14 features extraction as the input variables.

The last step is measuring the sensitivity, specificity and accuracy of the model to show how good is DNN model for breast cancer classification.

Table 3. Number of Hidden Layer in Deep Feedforward Neural Network

Deep Feedforward Neural Network		
Number of Hidden Layers	**MSE Training**	**MSE Testing**
2	0.016345	1.3912
3	0.016296	1.1866*)
4	*)	1.2408
5	0.017252	1.4599
6	0.016854	1.3764
7	0.017057	1.3962
8	0.017087	1.5787
	0.017304	

Note: *) chosen model

Table 4. Input Elimination

Eliminated Input	**Number of Input**	**MSE Training**	**MSE Testing**
-	14 Features	0.016296*)	1.1866*)
X_{14}	13 Features	0.016401	1.3581
X_{13}	13 Features	0.016708	1.2496
X_5	13 Features	0.016483	1.4538
X_5 and X_{14}	12 Features	0.016411	1.7922
X_5 and X_{13}	12 Features	0.016414	1.2022
X_{13} and X_{14}	12 Features	0.016785	1.2192

Note: *) chosen model

Table 5. Sensitivity, Specificity, and Accuracy

Data	**Sensitivity**	**Specificity**	**Accuracy**
Training Data	100%	100%	66.67%
Testing Data	100%	20%	60%

As shown in TABLE 5, DNN model for breast cancer classification provides results with sensitivity, specificity, and accuracy were respectively 100%, 100%, and 66.67% for training data and 100%, 20%, and 60% for testing data.

Conclusion

This research using Deep Neural Network with feed forward architecture for breast image classification. The best DNN model for breast classification is DNN with 3 hidden layers and 14 features extraction as the input variables. It provide results with sensitivity, specificity, and accuracy were respectively 100%, 100%, and 66.67% for training data and 100%, 20%, and 60% for testing data.

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