Computer-Aided Diagnosis (CAD) to Detect Brain Abnormality from PET Image using Artificial Neural Network (ANN)

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Abstract. PET imaging is powerful to diagnose the presence of abnormalities, staging cancer, and evaluating radiotherapy treatment results. Sometimes, small uptake is not easily visual recognized, hence an additional supporting method for its detection is needed. In this study, Computer-Aided Diagnosis (CAD) of brain abnormalities from PET images using segmentation and classification methods based on a feature in the form of Gray Level Co-Occurrence Matrix (GLCM) was developed. Artificial Neural Network (ANN) is used to deal with the classification problems arising in this application. We develop CAD in this study using MATLAB. A total number of samples were 360 images with 180 abnormal (14 patient) and 180 normal (20 patient) images were used as training and testing data. The result based on Receiver Operating Characteristic (ROC) illustrated that the training error was 4.22 ± 2.37 % and the test error was 12.30 ± 3.47%. These results mean that this developed CAD system can recognize normal and abnormal brain images.

1. Introduction
Brain tumor is one of the abnormalities in the brain which cells grow abnormally. It makes the volume (mass) of brain tissue decreases when the skull cavity gets press that impact damage to nerve tissue, so that brain function will be disrupted. Brain tumors are divided into two types, brain tumors and malignant brain tumors [1]. Various modalities can be used to detect the presence of tumors, one of which is Positron Emission Tomography (PET). By using 2-Deoxy-2-[18F] fluoroglucose (FDG), glucose metabolism in the brain can be measured, then it can be used to assess tissue abnormalities in brain tissue and the Central Neural System (CNS) [2]. FDG PET is widely used clinically for imaging brain tumors because it can provide diagnostic, staging, restaging, and response information to radiotherapy treatments [3]–[5]. The use of PET is signficant when tumors are in the early stages because it can detect tumors that might not been visually seen by other modalities. This is because the absorption of FDG by the tumor is much higher than that which occurs in normal tissue [6].

Currently, there is a very rapid development in radio-diagnostic modalities, one of which is digital image processing. The developments can help doctors diagnose PET images of patients' brains accurately and precisely. The initial study of quantitative analysis of medical images with computers began in the 1960s. At that time, it was assumed that computers could assist doctors in detecting...
abnormalities. Artificial Neural Network (ANN) is one of the Artificial Intelligent (AI) techniques that is able to learn a series of data and arrange the weight of the matrix to represent the pattern of learning. ANN had great success in many applications including pattern classification, decision making, forecasting, and adaptive control. Many research studies have been carried out in the medical field that utilizes ANN medical images [7]–[12].

In this initial study, a computerized system with ANN was used to help diagnose PET brain images. Diagnosis using ANN recognizes data in the program to detect the character of the brain image. The results of which are used to test for the presence of abnormalities.

2. Methodology
In this study, we used PET/CT Philips Gemini and 18F-FDG sources for any patient. PET image dimension for each slice is 128 pixels × 128 pixels. In general, there were three processes, namely pre-processing, main processing, and post-processing (evaluation). In pre-processing, format conversion, cropping, and resizing of brain PET images were performed. In the main processing, the MATLAB program was used to extract the Gray-Level Co-occurrence Matrix (GLCM) feature. The results of the GLCM extraction were selected manually, by looking at features that provide significant differences in the characteristics of brain PET images. These features were then used as inputs to ANN for classification. The classification uses ANN and give a result, a normal brain class or an abnormal brain class. The performance of ANN-based classification was determined by the using parameter "Receiver Operating Characteristic (ROC)" , with the steps as shown in Figure 1.

![Figure 1. Image classification workflow utilising ANNs](image)

Overall in this study 360 secondary samples of brain images in the form of DICOM had been used with varying amounts of images from some patient. It consisted of 180 normal brain images and 180 abnormal brain images, which are derived from 20 patients with normal brain conditions and 14 patients with abnormal brain conditions. Abnormal brain patients consist of 6 dementia patients, 4 tumor patients, 2 epilepsy patients, 1 degenerative patient, and 1 meningioma patient. The images were obtained from male and female patients in the age group of 20 to 81 years of all. Figure 2 shows an example of the image used in this study.

Pre-processing technique is used to reduce noise in the image. It is done in three stages, namely changing the DICOM format to TIFF using Micro Dicom, cropping the image using ImageJ, and the last resizing using MATLAB. Changing the format to TIFF aimed to speed up and simplify the processing of PET images without changing image information. The results of the image that has been in TIFF format is then cropped so that the PET image is only centered on the brain image. The cropping
is done as close as possible to the scalp seen in the image. The last step in this pre-processing technique was to resize the image. The image was resized by following the smallest image size (37 pixels × 41 pixels). this is done to get the entire similar image.

2.1. Extract Features

The main process of this research is to extract features using GLCM. GLCM is used as a method that can determine the texture characteristics of an image, that is how often the pixels relate to specific values found in the image. Through the variation of the angle, the statistical value of the image is reflected in the formed matrix. In GLCM, there are four features produced, namely contrast, correlation, energy, and homogeneity.

Contrast is used to measure local variations in GLCM by measuring the intensity of the contrast between a pixel and its neighbors in all parts of the image. The maximum value of this feature is one if the contrast intensity of each neighbor's pixel is the same. The correlation feature is used to calculate the correlation of a pixel with its neighbors in all parts of the image. The maximum value of this correlation feature is one. The more noise it has the lower the correlation value will be. Energy is used to give texture uniformity to the image. The maximum value of this feature is one if the texture is constant. And the last is homogeneity, used to measure the density distribution of elements in the GLCM against the diagonal of the GLCM. The maximum value of a feature is one if the image elements are same. For all features, the minimum value is zero [12].

The GLCM matrix is formed from four angles in the image, namely 0°, 45°, 90°, and 135°. GLCM is a symmetrical matrix, so there is no need to form a matrix for angles of 180°, 225°, 270°, and 315°. The GLCM feature is also called a "matrix that depends on gray level", N is a square matrix which is a 2D matrix “p(i,j)”, with each matrix element describing the possibility of a combination of intensities “k” and “1” in certain distance “d” and angle “θ”. “p(i,j)” is a normalized GLCM gray tone matrix element row and column (i, j). Mean (μ) and standard deviation (σi,σj) for rows and columns of the 2D matrix can be calculated using [10]:

\[
\mu = \sum_{i,j=0}^{N-1} ip(i,j) \\
\sigma_i\sigma_j = \sum_{i,j=0}^{N-1} p(i,j)(i-\mu)^2 \\
\text{Contrast} = \sum_{i,j} |i-j|^d p(i,j) \\
\text{Correlation} = \sum_{i,j} \frac{(i-\mu)(j-\mu)p(i,j)}{\sigma_i\sigma_j} \\
\text{Energy} = \sum_{i,j} p(i,j)^2
\]
Homogeneity = \sum_{i,j} p(i,j) \frac{1+|i-j|}{i+j} \quad (6)

2.2. Feature Selection
Feature selection is used to view the distribution of feature data obtained from GLCM extraction using 3D scatter plots. In Figure 3, it can be seen that the overall data distribution of features in the form of correlation, energy, and homogeneity has its own pattern. Data held by abnormal (red) images is more diffuse than normal (green) images. This can provide opportunities for the classification process using ANN because the data already had its own pattern of three features used.

2.3. Artificial Neural Network
The next process is the classification process. The classification process is used to categorize data into normal and abnormal groups based on the data matrix. The used classification is ANN to build an existing system model and to learn from the previous sample set and to let the network to reaches the target with minimum errors. ANN is a concept of engineering knowledge in the field of artificial intelligence that is designed by adopting the human nervous system, where the main processing nervous system of the human is in the brain. The smallest part of the human brain is a nerve cell which is to be the basic unit of information processing. This unit is often referred to as a neuron. There are about 10 billion neurons in the human brain and around 60 trillion connections (called synapses) between neurons in the human brain.

The back-propagation algorithm was chosen because of the network's ability to study and store the mapping of input and output with the input activation function in the form of binary sigmoid and the output activation function in the form of linear. MLP usually has two phases, the first phase is the input data entered at the input layer and then forwarded to the first hidden layer and then forwarded again to the next hidden layer until finally passed on to the output layer to generate the output value. In the second phase, if the output pattern differs from the expected output value, the error is calculated and then passed back from the output layer to the input layer. Neurons in the hidden layer function to detect hidden features [13].

The algorithm used in this study has five layers consisting of input layer, hidden layer 1 (15 neurons), hidden layer 2 (5 neurons), output layer, and output with a learning rate of 0.01. In the same algorithm, ten repetitions were performed for each combination, because the data used are random data, so the values always change.

The images used were 360 images consisting of 180 abnormal brain images and 180 normal brain images. They divided into two, the data used for training and the data used for the test. The training data used 260 images consisting of 130 abnormal brain images and 130 normal brain images, while the test data used 100 image data consisting of abnormal and normal images of 50 images each. Image data used for training and test data are chosen randomly.

3. Results and Discussion
A method must be assessed statistically to know the performance of solving problems. The most widely used approach is Receiver Operating Characteristics (ROC), which is useful for managing classifiers and visualizing performance. ROC graphics are generally used in medical decision-makers, and in recent years have been used in machine learning and data mining research [14].

The ROC parameters are used to measure were accuracy, sensitivity, specifications, precision, and error. This accuracy refers to the ability of the model to correctly predict data classes. Sensitivity is the ability of models made to recognize normal images, whereas for specifications is the ability of models made to recognize abnormal images. In this study, each ROC parameters were calculated from TP (True Positive), TN (True Negative), FN (False Negative), and FP (False Negative) [15]. TP means the image detected and diagnosed as abnormal images by the program and the Doctors. TN is images that are detected and diagnosed normally by programs and Doctors. FN is images detected normally
by a program but diagnosed as abnormal images by a Doctors. FP is images that are detected as abnormal images by the program, but the Doctors diagnose it as normal images. From the training and testing data, the ANN results were calculated with the value of the ROC parameters as shown in Figure 4.

In Figure 4, it appears that the accuracy of the model created at the training stage gave a value of $95.73 \pm 2.18\%$, for the ability to recognize normal images $96.15 \pm 3.08\%$, the ability to recognize abnormal images by $95.31 \pm 2.89\%$, precision by $95.41 \pm 2.73\%$, and with an error value of $4.27 \pm 2.18\%$. Whereas, for the testing phase using a model that was made gave an accuracy value of $87.70 \pm 3.47\%$, for the ability to recognize normal images $96.00 \pm 5.25\%$, the ability to recognize abnormal images of $79.40 \pm 7.49\%$, precision of $82.70 \pm 5.11\%$, and with error values at $12.30 \pm 3.47\%$.

**Figure 3.** 3D scatter plots between homogeneity, correlation, and energy. (a) The first view, (b) Display rotated 30° to the side the first display, (c) Display rotated 60° to the side the first display, (d) Display rotated 30° down from the first display, and (e) Display rotated 60° down from the first display.

**Figure 4.** The value of ROC parameters
4. Conclusion
This research shows that the proposed method can classify brain abnormalities with relatively high accuracy even though the real or original images are difficult to distinguish visually. The result of this research will benefit to support the physician's diagnosis.

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