Jurnal Ilmu Komputer dan Informasi (Journal of Computer Science and Information). 8/1 (2015), 11-18
DOI: http://dx.doi.org/10.21609/jiki.v8i1.279

STUDY COMPARISON OF SVM-, K-NN- AND BACKPROPAGATION-BASED CLASSIFIER FOR IMAGE RETRIEVAL

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Abstract

Classification is a method for compiling data systematically according to the rules that have been set previously. In recent years classification method has been proven to help many people's work, such as image classification, medical biology, traffic light, text classification etc. There are many methods to solve classification problem. This variation method makes the researchers find it difficult to determine which method is best for a problem. This framework is aimed to compare the ability of classification methods, such as Support Vector Machine (SVM), K-Nearest Neighbor (K-NN), and Backpropagation, especially in study cases of image retrieval with five category of image dataset. The result shows that K-NN has the best average result in accuracy with 82%. It is also the fastest in average computation time with 17.99 second during retrieve session for all categories class. The Backpropagation, however, is the slowest among three of them. In average it needed 883 second for training session and 41.7 second for retrieve session.

Keywords: *Backpropagation, Classification, Image Retrieval, K-NN, SVM*

Abstrak

Klasifikasi adalah metode untuk menyusun data secara sistematis menurut aturan-aturan yang telah ditetapkan sebelumnya. Dalam beberapa tahun terakhir metode klasifikasi telah terbukti membantu pekerjaan banyak orang, seperti klasifikasi citra, alat-alat medis, lampu lalu lintas, klasifikasi teks dll. Ada banyak metode yang dapat digunakan untuk memecahkan masalah klasifikasi, metode yang bervariasi ini membuat para peneliti menemukan kesulitan dalam menentukan metode manakah yang terbaik untuk menyelesaikan masalahnya. Artikel ini bertujuan untuk membandingkan kemampuan metode klasifikasi, seperti *Support Vector Machine* (SVM), *K-Nearest Neighbor* (K-NN), dan *Back-propagation* khususnya dalam studi kasus *image retrieval* (pencarian gambar) dengan lima kategori dataset citra. Hasil penelitian menunjukkan bahwa K-NN memiliki nilai rata-rata akurasi terbaik dengan 82% dan yang tercepat dengan rata-rata waktu komputasi selama 17,99 detik untuk proses pencarian gambar pada semua kategori kelas. Sebaliknya, *Backpropagation* merupakan metode paling lambat di antara ketiganya. Metode ini rata-rata memerlukan waktu 883 detik untuk sesi pelatihan dan 41,7 detik untuk sesi pencarian gambar.

Kata Kunci: *Backpropagation, Klasifikasi, Pencarian Gambar, K-NN, SVM*

1. Introduction

Classification is one of the most fundamental method to solve any problem especially big data problem. Classification is defined as a method to formulate data systematically by rules that defined before. Classification is supervised learning process. The difference between supervised learning and unsupervised learning is on supervised learning aims to discover new patterns in the data by connecting patterns existing data with new data. While on unsupervised learning, the data do not yet have any pattern, and the purpose unsupervised learning to find patterns in the data.

In recent years classification method has been proven helping many people's work, such as image classification [1], medical biology [2], traffic light [3], text classification [4,5] etc. There are many methods to solve classification problem such as Support Vector Machine (SVM), K-Nearest Neighbor, Backpropagation, Learning Vector Quantization (LVQ), Naive Bayes etc. Sometimes the number of these methods allow researchers find difficulty to determine which method is best in its use, especially for the first three methods mentioned which is these three methods are methods that are considered to be the most popular in solving classification problems.

The purpose of this framework is to compare the ability of classification methods Support Vector Machine (SVM), K-Nearest Neighbor, and Backpropagation for image retrieval. Image retrieval is a technique used to find images that have similar reference characters from the image (input). This application is solution for data retrieval has been dominated by text-based input. Because it is difficult for the user if the user only has an image as a reference without knowing the label or name of that image. In addition sometimes a text-based search engine like Google, Yahoo, etc has deliver a misinterpret result from the user input. For example, if you enter a keyword like "rose" then the search engine will display all matters relating to the word even a hotel or person named "rose" will appear whereas this object of the search not being sought by the user. Cases like this would not happen in image retrieval.

Image retrieval is an interesting object for research. Proven from recent studies, such as Nishant et al. that introduce a new efficient technique for image retrieval [6] and some other methods that make this application work better than previous methods [7,8].

In general, the image retrieve process is divided into some parts of process. First pre-processing, at this stage the data set is converted into a matrix image which is then processed to obtain a histogram of the image matrix. Histogram will be calculated based on the proposed algorithm to generated classes as expected, the next stage is compute the input image and database image with classification method that has been built, the last stage is compare the results obtained both before and get image that matches to the input image. The detail of this process will be explained in the next chapter.

In this framework used an image dataset with 5 categories: aircraft, motorcycles, cat, car, and people face while for the validation of the model will be used cross-validation method with k-fold validation where the data is divided into 10 sections (k = 10), with the distribution of the data x numbered (k -1) group for training and y amounts to one group for testing. The conclusion of this classification method which is give the most excellent or worst result in this application will be obtained by compare their computation time, accuracy, precision and recall.

Support Vector Machine

Support vector machine is a fairly new classification technique and because of its ability in classification problem for many cases [1,9-11], in this day SVM is still remains a state-of-the-art in machine learning. SVM research also continues to grow with various modifications and improvements to make better results and learning process more simple and efficient as Xiyan et al. did at [12] with the multi-tasking learning, or Mamonjy [13] with SimpleMKL for more efficient SVM than SVM with ordinary multi-kernel, etc.

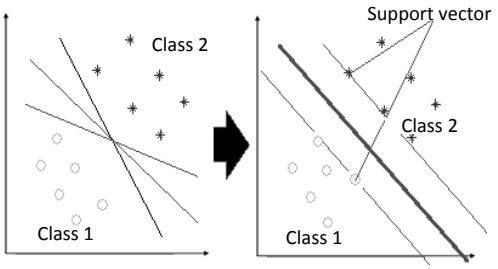

Figure 1. SVM separated class process.

From the function and process side, SVM can be categorized as part of the artificial neural network (ANN). Different from other neural networks that trying to find a hyper plane separation between classes, SVM find the best Hyper plane in input space (Figure 1).

As we see at Figure 1. When SVM separate class, it uses two dividing lines in the input space. A pair of this parallel planes is written by the following equation(1).

$$\begin{aligned} x_i.w + b &\geq +1 \text{ for } y_i = +1 \\ x_i.w + b &\geq -1 \text{ for } y_i = -1 \end{aligned} \quad (1)$$

With w is the normal space and b is the position relative to the center space coordinates. While data on that parallel planes is called the support vector. Problems of its can be optimized with the Lagrangian formula and quadratic programming [14]. After optimization problem is solved, then the class of test data x can be determined based on the value of the decision function, given by equation(2).

$$f(x_d) = \sum_{i=1}^{ns} \alpha_i y_i x_i x_d + b, \quad (2)$$

x_i is support vector, ns = number of support vector andx_d is data that will be classified.

K-Nearest Neighbor

K-Nearest Neighbor (K-NN) was first introduced by Fix and Hodges in 1951 and 1952 [15,16] and later developed by Cover and Hart in 1967 [17]. K-NN is a non-parametric classification method. This algorithm was developed with a basic assumption that "things that look alike must be alike" (Cover and Hart) [18]. We can say that this method was old, but recently it is still used by

many researchers in their research such as by Souza [19], Hsien Lie [20], Gang Li [21], Kacur [22] etc.

K-NN algorithm is a method of classification of data objects based on data that were located closest to the object. The main idea of the K-Nearest Neighbor is to find the shortest distance between the data which will be evaluated by the nearest K neighbors of the training data [23]. Thus it can be said that this method is a simple and easy to implement, because it does not build a classification model in the process, but as a consequence, K-NN generally requires more memory [24]. It because each of the data entered will be compared with all training data.

In the learning process, this algorithm only stores feature vectors and classification of learning data. While in the process of classification, the same features are calculated for test data (which classification is unknown). The distance of this new vector is calculated to all learning data vector, and a number *k* closest taken. The new classification point predicted includes the classification of the most of these points.

This K-NN algorithm, the best *k* value depends on the data. Generally, a high *k* value will reduce the effect of noise on the classification, but makes the boundary between each classification becomes more blurred. Good *k* value can be selected with parameter optimization, for example by cross-validation. The special case in which the predicted classification based learning data closest (in other words, k = 1) is called the k-nearest neighbor algorithm.

According to the basic principles of K-NN which is to find the shortest distance between the data that will be evaluated with nearest *k* neighbors on the training data, it can use euclidean distance equations that are formulated as follows:

$$d(x,y) = \|x-y\|^2 = \sqrt{\sum_{i=1}^{n}(x_i-y_i)^2} \quad (3)$$

Note:
x = Sample data
y = Test data
i = Variable data
d = Distance
n = Data dimension.

Backpropagation

Backpropagation is one of the algorithms in neural network family. Generally, Back-propagation has good ability in terms of prediction, but this algorithm can also be used and have had good results too in terms of data classification [25,26]. Navneel et al. [27] proved that back-propagation has a high accuracy for classifying spam on e-mail.

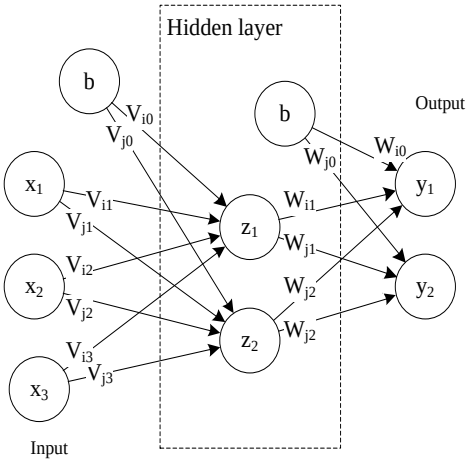

Figure 2. Backpropagation architecture.

The main idea of this algorithm can be illustrated as follows: if the output pattern of results does not match the pattern of the desired target, then the weight will be corrected so that the error can be minimized furthermore the response of the network is expected to be closer to an appropriate value.

Backpropagation is a neural network algorithm with a hidden layer scheme. Figure 2 shows a schematic for architecture of the back-propagation algorithm, it is seen that this algorithm has some hidden layer units. v_{ij} is the weight of a input line units to the hidden layer units, while w_{ij} is the weight of the hidden layer units to the output units

There are three stages in the training process in this algorithm, that is: feed-forward process of training input pattern, then calculate the propagation of errors and adjustments to the value of the weight. At this stage the weight changes both from the input layer to the hidden layer or from the hidden layer to the output. If there is more than one hidden layer then there is also the weighting between the hidden layers [28]. The last is testing process, this process is testing the data with the weight that obtain in the process before.

2. Methods

The procedure in this framework conducted in several stages. That is pre-processing, the implementation of the propose method in image retrieval application, analysis results and comparing

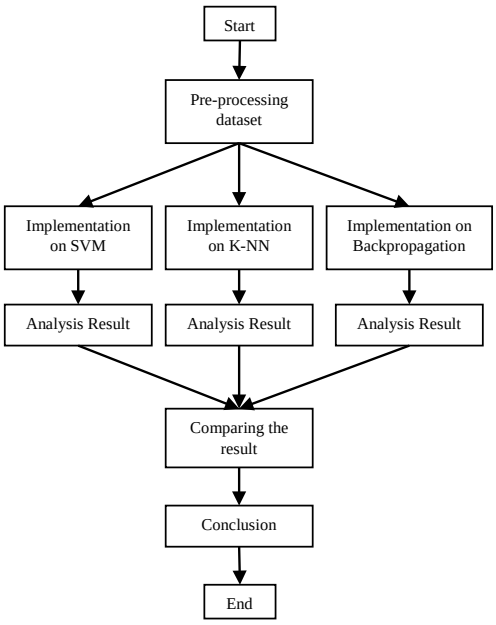

Figure 3. Framework methodology scheme.

analysis results. Here scheme of this framework methodology.

This framework will started with pre-processing data, the image dataset that was obtained will be processed in such a way, so that the data can be used for the next step, this process will be explained further in the next chapter. Secondly, after the data is processed, the data will be implemented in three methods proposed, and applied in image retrieval as described in chapter 4. After running the application, the next stage is analysis results, the results of this stage will be obtained from analyst of computing time, accuracy, precision and recall at any methods proposed applied in image retrieval. After that stage, the final step is compare the analysis results among each other so we get the conclusions of this framework, what is the best method or not.

Dataset

In the image retrieval applications to be built dataset used is the dataset of a colored image with .jpg extension totaling 2500 with five categories that is aircraft, motorcycles, cat, car, and people face. This category will be classified with different methods proposed.

For the validation of the model will be used cross-validation method with k-fold validation where the data is divided into 10 sections ($k = 10$), with the distribution of the data x numbered$(k-1)$ group for training and y amounts to one group for testing. Then the process will be repeated k times, the training data and testing are always different during each process. The scheme for the experiment as follows: the first trials use the data $x = (k_1, k_2, \ldots, k_9)$ while data is $y = k_{10}$ then for second experiment the data $x = (k_{10}, k_1, k_2 \ldots, k_8)$ while data is $y = k_9$ and so on.

Implementation

The first stage of built an image retrieval application is a pre-processing of image data. The data set is converted into a matrix image which is then processed to obtain a histogram of the image matrix, it is because the color features that differentiate each image are generally represented by the color histogram [29]. Histogram is what will be calculated based on the algorithm so that each generated classes as expected. For back-propagation, classification of data need to be normalized first in order to be in the range of 0 to 1 as the range of output function is a binary function. Once the dataset is processed for training and testing data, the next thing is to deter-mine the target:

$$T = \begin{cases} Y_1 \\ Y_2 \\ Y_3 \\ Y_4 \\ Y_5 \end{cases} \quad (4)$$

Note:

Y_1 = Aircraft Class
Y_2 = Motorcycle Class
Y_3 = Cat Class
Y_4 = Car Class
Y_5= People Face Class

The training and testing process for each method must be different, it depends on characteristics of the network model. There is no training process in K-NN Method as described in subsection K-Nearest Neighbor, in this method the training and testing dataset is used only for comparing process with *Euclidean* distance function in testing stage. While the backpropagation and SVM method as both an outline ANN family the training and testing process is not much different.

In backpropagation method, several parameters that need to be considered is the activation function, contribution threshold training, training rate, momentum training, training RMS, exit criteria, the number of hidden layers, maximal number of iterations (epoch), and the minimum output activation threshold. The number of hidden layers and the number of iterations affect the computation time, but does not guarantee accuracy. The number of iterations also affect the RMS error, in which the more iterations will reduce the RMS error, unless the training process

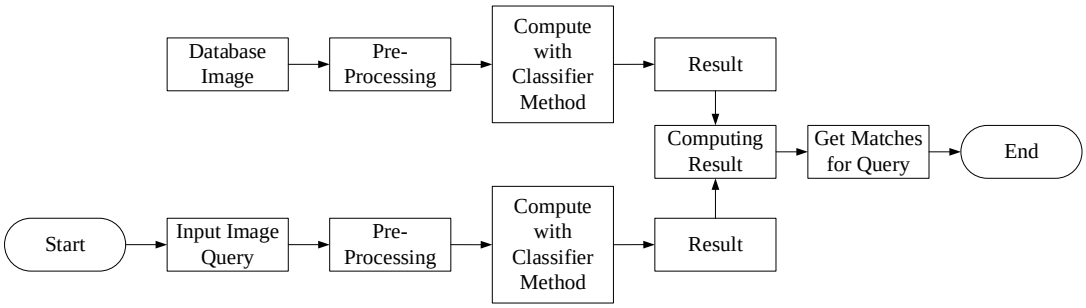

Figure 4. Scheme of image retrieval process.

Figure 5. Image Retrieval UI.

already meet the balance condition or training experience oscillations [26].

The backpropagation method built with best parameter according to Feriyawan et al. works at [26], which amounts to single hidden layer with 3 nodes, iteration (epoch) is 1500, the learning rate is 0.01, while for the activation function using *logsig* function because the data range between 0 to 1. For SVM the parameters to note is the kernel function, it uses *polynomial* kernel function with order 3. This kernel function is selected because it gives the best accuracy in classification problem than others kernel, based on Hussain et al. research [30], besides that, since SVM is a binary classification that is can only classify two class, it will be solved by combining several binary classifier called *one-against-all* approaches. Suppose we have a multiclass problem with *P* classes, for a *one-against-all* multiclass SVM, we need to train *P* binary SVM classifiers, where the *p*-th classifier is trained by considering all examples of class *p* as positive examples while all other examples are considered negative [13]. For testing process, input data (images) will be processed and calculate with the network model which has been set up earlier then testing results will be compared with the results of testing the images on the testing dataset.

3. Results and Analysis

Image retrieval is a technique used to find images that have similar reference characters from the image (input). In general, the image retrieve process is divided into some parts of the process. The scheme of image retrieval process can be shown in Figure 4.

This image retrieval machine process begins with the user that input the image query, furthermore, the image will be processed according to the pre-processing process in the previous chapter. After the input data processed, the result data will be classified according to the proposed method. The machine will also process the testing database that has been stored before with the same process of input data's process. After the classification results of the second part is obtained, next, machine will compare the results of the classification of the database with the results of the input data. Having obtained the results of this comparison, then the machine will display the image that are in the testing database that mat-

TABLE 1
VALUE OF OUTPUT AND ACTUAL IMAGE

		Actual Value	
		True	False
Output Value	True	True Trues	True False
	False	False True	False False

TABLE 2
AVERAGE ABILITY OF SVM

Class	P	R	A	C
Aircraft	47	33	79	22,30
Motocycle	49	71	80	28,69
Cat	37	28	76	24,18
Car	50	44	80	24,23
People Face	53	63	81	27,29
Average	47	48	79	25,29

TABLE 3
AVERAGE ABILITY OF BACKPROPAGATION

Class	P	R	A	C
Aircraft	17	54	38	92,78
Motocycle	53	80	80	36,83
Cat	13	3	77	25,78
Car	20	3	80	26,86
People Face	43	8	80	26,26
Average	27	29	71	41,70

TABLE 4
AVERAGE ABILITY OF K-NN

Class	P	R	A	C
Aircraft	77	56	88	21,70
Motocycle	73	78	90	17,08
Cat	35	45	72	18,95
Car	48	43	79	15,72
People Face	55	56	82	16,49
Average	58	56	82	17,99

Note:
P = Precision, R = Recall, A = Accuracy,
C = Computation Time,
*Value of precision, accuracy, and recall in %,
*Computation Time in Second

ches to the input image as a result of the retrieve process of image retrieval machine. And here is the user interface (UI) of the application has been made.

To compare the ability of third-classifier in image retrieval. The Application will be compared include computation time, accuracy, precision and recall. Computation time is calculated during the process of training and testing process, but since KNN do not have the training process then this comparison will be done only for Back-propagation and SVM. The result shows that computation time for training Back-propagation is much longer when compared with SVM where Back-propagation need 883 second (average) for every training than SVM that just need about 94 second (average), while the value of accuracy, precision

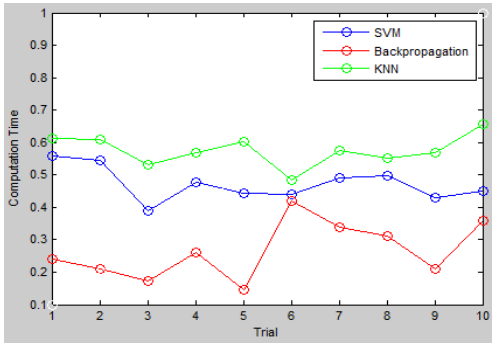

Figure 6. Precision comparison.

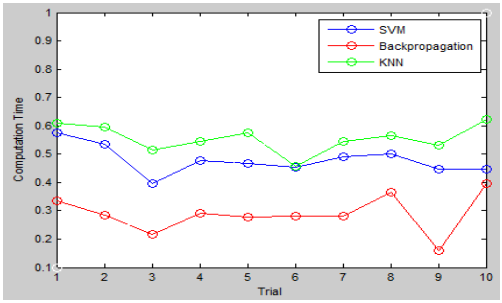

Figure 7. Recall comparison.

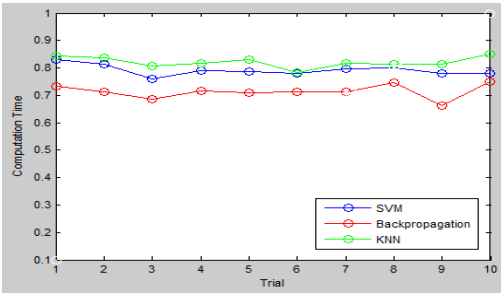

Figure 8. Accuracy comparison.

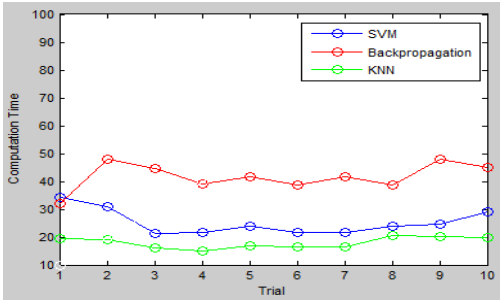

Figure 9. Computation time comparison.

and recall is calculated with the following equation:

$$Precision = \frac{True\ True}{True\ True + True\ False}\ x\ 100\% \quad (5)$$

$$Recall = \frac{True\ True}{True\ True + False\ True}\ x\ 100\% \quad (6)$$

$$Accuracy = \frac{True\ True + False\ False}{Totall\ of\ data\ sample} x\ 100\% \quad (7)$$

For example, the value of output and the actual value of the image retrieval is as shown by Table 1. For the results of the calculation values of accuracy, precision and recall at retrieve session for every category will be presented in the Table 2 (in average of all trial).

As we see at Table 2 until 4, K-NN has the best value for precision, recall and accuracy than others method, it is about 58%, 56%, 82%. From the table we also know that the K-NN method for computing time has the fastest time, the computation time is influenced by the amount of output image, the more images is displayed as output then the longer computation time need.

In Figure 6 – 8 we see that overall, SVM and K-NN method has average value in precision and recall while Backpropagation has a bad one. For accuracy every method has a good value, its more than about 70%, the value is also quite constant for every trial except backpropagation which is in the 5th trial that method has a bad value that is about 10% but in 6th trial has about 40% in precision and this not constant also happen in recall value at 8th, 9th and 10th trial. While in Figure 9 shows that backpropagation has slowest computation time for retrieve image process, it quite big different with two others method which is less than 30 second for all trial, back-propagation has slowest time is not just because the testing time that slower than another but also it cause in every retrieve process, back-propagation has to normalize the image input first before testing process.

4. Conclusion

In this framework we present a comparison of three comparison of the three methods for classification, Support Vector Machine (SVM), K-Nearest Neighbor (K-NN), Backpropagation applied to image retrieval. The image retrieval is contain five category of dataset and the experimental used cross-validation method with k-fold validation where k=10.

Generally all three methods have good accuracy and short computation time. As the result K-NN has the best results among the three, the average accuracy is 82 % and the average computation time is 17,99 seconds, also K-NN method does not need training process like SVM and Back-propagation. Otherwise in terms of computation time. Backpropagation has the longest average time both in terms of training with 883 seconds and testing that is about 41,7 second.

Future Work

Basically, all of the framework classification algorithm can recognize and classify image well, but in the context of search engines in general, sometimes the result of classification raises new image which is not a member in all classes who have been trained in the model classifier, to add new data and get new class the new training process is needs to be done from the beginning. It is certainly an impact on the computation time of the machine and make the all process before will look in vain, so the future research is expected to create a more dynamic classification method for addition of new data or classes.

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