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Combining modified Nearest Neighborhood and fuzzy K-Nearest Neighborhood methods for classification of urban areas (Case study: Shahriar, Tehran, Iran)

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Abstract. In this paper a method for combining classification of NN[1] and fuzzy k-NN[2] is represented. At first for reducing computation costs and noise elimination, some parts of training data which have the least value of dependency function, have been omitted. For classifying with modified NN method, an area is defined for each class, so that it comprises the entire training data belong to that class and the minimum possible amount of other classes. Pixels which have been in a defined area of one class would be labeled in that class and also pixels which have been in a defined area of more than one class would be labeled with fuzzy k-NN method. The main purpose of this task is to reduce computation costs compared to k-NN method and also to increase precision compared to NN method. This method (combining modified NN and fuzzy k-NN) is evaluated by data with 5 classes and it is been observed that computation time and classification precision have been improved by 14% and 2% respectively.

Keywords: remote sensing, combining classification methods, modified Nearest Neighborhood, k- Nearest Neighborhood, fuzzy logic.

1. INTRODUCTION

Digital images have an array of picture elements. It could be understood that in each array of these images, total reflected and emitted energy (from corresponding area on the ground) is recorded and stored after the influence of error factors [7]. These numeric values describe various phenomena. Hence, classification could be done and relevant information could be extracted from specific classes. In general, we can divide classification methods into two groups. Spectral information, available in image bands, is used in the first group and in other one texture information is applied.

Classification methods, based on spectral image information, are nominated as supervised and unsupervised according to use or non-use of training data [7]. One of the supervised image classification methods is k-NN which has been studied by Fix and Hodges [2]. In this method unknown pixels are classified according to maximum number of classes in "K" near training data in feature space.

The advantage of this method to other supervised methods (like maximum likelihood) is that k-NN doesn't depend on distribution of classes in training data [2]. However, its computation is much more costly due to the necessity of finding nearest training data to each pixel [6]. For reducing the computation cost we can use just one training data which is known as a specific type of k-NN and it's called Nearest Neighborhood [1]. Joswik [5] improved the results of this

[1] Nearest Neighborhood
[2] K-Nearest Neighborhood

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method with definition of area for each class. Meanwhile, computation costs were retained less than k-NN.

One way that improve the results of K-NN classification is to use fuzzy logic in classification which was suggested by Joswik [4] and was compared to previous method. Beside this, Fukunaga and Mantock [3] presented a method for reducing training data without great reduction in precision of NN classifier. Their purpose was also to reduce the computation cost.

Joswik [5] has recommended a method to keep the precision of k-NN classifier whereas, reducing computation cost, by combining his method with NN method. And Serpico [6] developed this method by using parallel networks.

In this paper fuzzy logic has been combined with Serpico [6] algorithm, and precision of algorithm has increases. Meanwhile, for reducing computation cost, training data decrease has been applied before execution of classification steps. Finally the results of precision in this work have been compared to NN, k-NN and combined k-NN with non-fuzzy NN methods on IKONOS satellite image from Shahriar region (Tehran, Iran).

2. PROCEDURE

In this paper, classification is based on modified NN although k-NN method is used in some sections for increasing the precision. Meanwhile, in some cases that NN classification is not efficient, fuzzy k-NN will be used.

Before starting to classify, few training data, which are probably noises in image, would be disregarded. The basis of training data is on accuracy however, in some cases, it is possible to have some training data as noises due to different reasons like sensor's error in those pixels or user's mistake in importing them.

2.1. First step: Training data reduction

In this step 5% of training data is disregarded so that the possibility of having noise will decrease. For reducing training data, the possibility that each data be placed in labeled class could be calculated with Equation 1: (with the assumption that data of each class is conforming gausian distribution function)

$$P(x) = \frac{1}{(2\pi)^{d/2}|\Sigma_i|^{1/2}} exp[-\frac{1}{2}(x-\mu_i)^T \Sigma_i^{-1}(x-\mu_i)] \tag{1}$$

In this equation d stands for number of bands, Σ_i stands for variance_covariance matrix of class i , μ stands for a average vector of each class data and x is for vector of the specific pixel.

According to the bazian theory relations, dependency function of data could be calculated with equation 2:

$$g(x) = P(w_i|x) = \frac{P(x|w_i)P(w_i)}{P(x)} = \ln P(x|w_i) + \ln P(w_i) = \tag{2}$$

$$= \frac{-1}{2}(x-\mu_i)^T \Sigma_i^{-1}(x-\mu_i) - \frac{d}{2}\ln 2\pi - \frac{1}{2}\ln|\Sigma_i| + \ln P(w_i)$$

After computing the dependency function of each pixel in labeled class, 5% of pixels which have the least amount of dependency function could be omitted from training data. These 5% data are those whose distances from center of class are too much. Regarding to the purpose of studying this dependency function which is only comparing data of a class with another one, we can consider just first part of the equation and disregard other parts.

2.2. Second step: Modified NN classification

In this step, data which have less complexity for decision making will be classified with modified NN. For doing this, at first, distance e is calculated with equation 3 for each class:

$$e_i = \max_{x_j \in X_i} d(X_i - x_j, x_j) \qquad (3)$$

In this equation, X_i is a vector for pixels of class i, d is distance function between x_j and set of X_i-x_j. It means d calculates x_j distance to nearest data from set of X_i-x_j.

After that area A_i is obtained from equation 4 for each class.

$$A_i = \{x | d(X_i, x) \leq e_i\} \qquad (4)$$

It means area A_i is computed via Euclidean distance to data of each class. A sample of areas for two classes has been shown in figure 1.

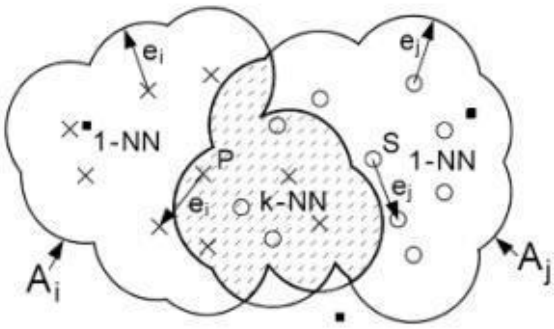


Figure1. Spaces belonged to each class

In this step classification can be done with following rules:

- Pixels placed in area of only a specific class, belong to that class.
- Pixels which are not placed in any class, are classified with k-NN method.
- Pixels placed in space of more than one class, are classified with k-NN method. Training data which are considered for classification, are only the data of those classes.

2.3. Third step: Fuzzy k-NN classification

In this step pixels whose NN classification hasn't been accomplished simply, would be classified with fuzzy k-NN. However, computation cost is much more in this method, regarding to use of training data of only specific classes for classification, computation cost decreases significantly.

In order to do this, dependency function of the pixel in each class is calculated through equation 5 [4]:

$$P_i(x) = \sum_{j=1}^{k_i} \frac{1}{d(x, x_j)} \tag{5}$$

In this relation k_i is number of training data belonging to class i per k-NN, and d stands for Euclidean distance function. Then pixel x would be classified in the class which has the maximum amount of P_i.

3. STUDY AREA

For studying and comparing mentioned method to NN, standard k-NN and combining non fuzzy k-NN with NN, IKONOS satellite data were used in red, green, blue and infrared bands with 4m resolution. The image has been obtained from Shahriar area in zone 39N and with 50 3' 54.5" longitude and 35 39'23.4" latitude. (Figure 2)

Figure 2. Study area

The number of training and test data, selected on this image, has been represented in table 1 and a part of feature space related to training data has been shown in figure 3.

Table 1. The number of training and test data, selected on Shahriar area image

	agricultural	building	road	tree	Soil	total
Number of training data	253	221	219	210	214	1117
Number of test data	221	201	203	208	209	1042

All 4 bands were used in all classification methods and choosing the best bands was not put on agenda. By comparing some amounts of K to each other in k-NN method, 4 were selected as the optimum status for this method and combining case. And also classification was carried out with this amount.

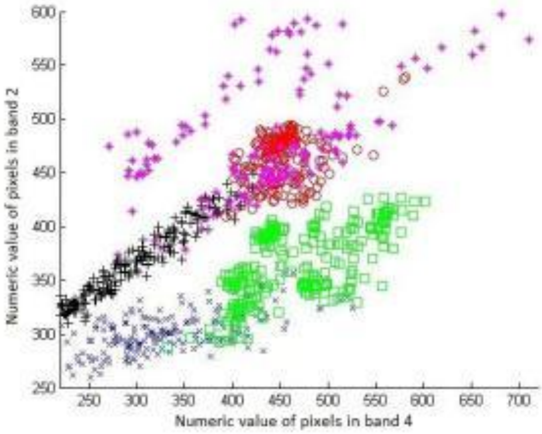


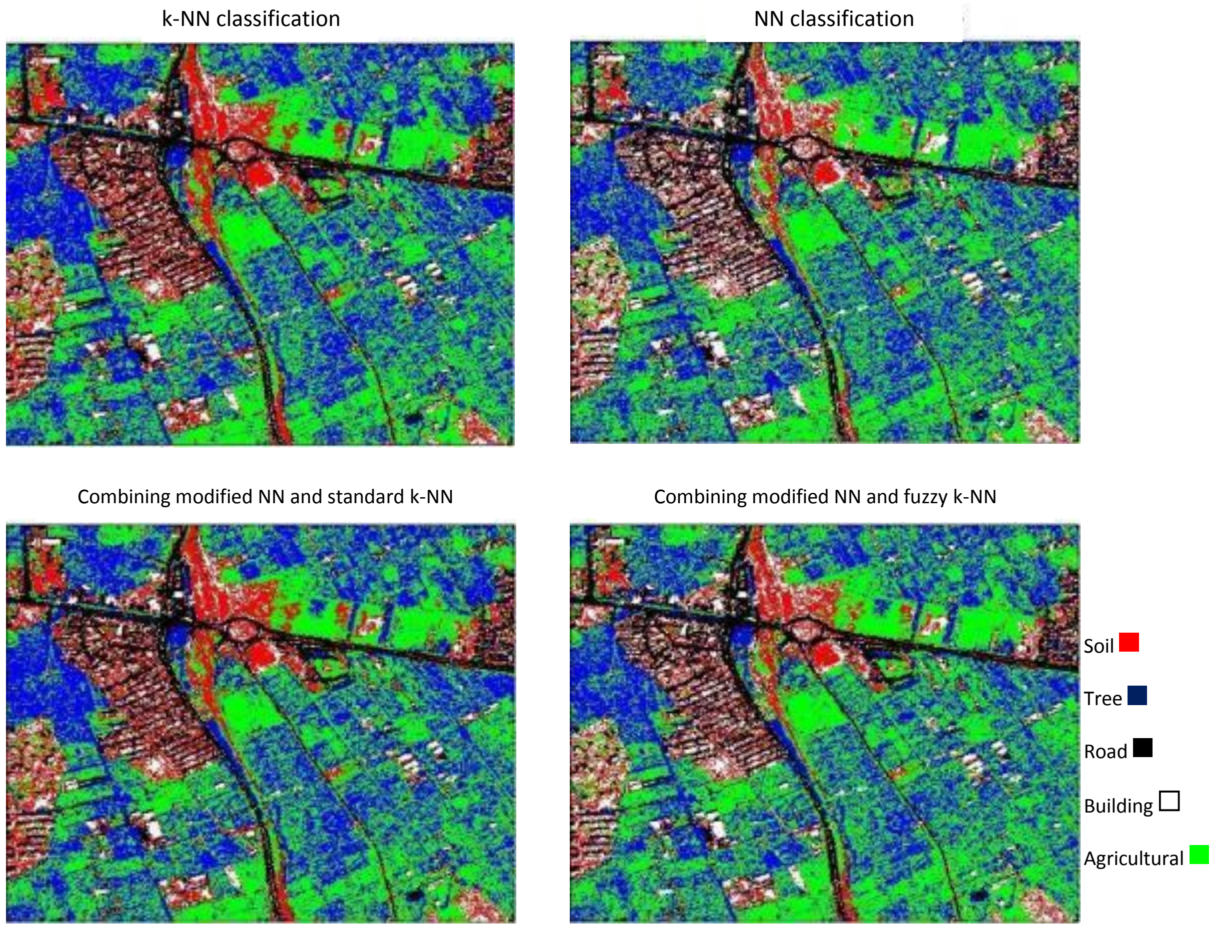
Figure 3. A part of feature space for training data

4. RESULTS

After the implementation of mentioned algorithm for every pixel in the image, classification precision is calculated regarding to test data. For doing this, 5% of test data can be reduced according to the logic of training data reduction. However, this would not have an impressive effect on results.

By computing a section of training data which have been classified correctly, classification precision of each class and the whole precision can be obtained.

Classified image has been shown in figure 4 with four methods (NN, standard k-NN, non fuzzy combining, and fuzzy combining). As it's clear from comparing images, k-NN classification, visually presents weaker results compared to others. Many areas specially urban area do not have an appropriate resolution for different classes in this method. In the results from NN method, proper resolution has been presented in urban area which has occurred because of labeling too many pixels in building class. This outcome is also appropriate in fuzzy combining method. However, because of labeling irrelevant pixels as building in NN method, it can be said that the results of fuzzy combining method are somewhat better.



The precision obtained from different classification methods, has been shown in table 2. As it's clear from comparison of data in the table, fuzzy combining method represents maximum precision. The precision of this method has the maximum percent only in 2 classes between 5, but given that the precision of all classes is nearly appropriate through this method, it can be said that the results will be better compared to 3 other methods. For instance, the precision of soil and building class have inverse relation in other methods all the time, but in this method appropriate level of precision has been represented for both.

Table 2. Classification precision for each class.

Classification method	Precision of class soil	Precision of class building	Precision of class road	Precision of class tree	Precision of class agricultural	Total precision
Nearest Neighborhood	68.90	75.96	95.57	79.10	95.02	83.01
K-Nearest Neighborhood	84.21	64.90	98.03	79.60	88.69	83.11
Non fuzzy combining	88.38	67.94	98.96	78.95	90.91	84.08
Fuzzy combining	76.26	73.60	99.48	78.95	97.61	85.29

Meanwhile, classification runtime on a PC with CPU core i5 quad-core using MATLAB, in similar programming methods, has been shown in table 3.

Table 3. Program runtime.

Classification method	Nearest Neighborhood	K-Nearest Neighborhood	Non-fuzzy combining	Fuzzy combining
Runtime(s)	32.06	48.78	40.37	41.27

5. CONCLUSIONS

Computation cost for k-NN method increases with addiction in number of training data. One method for reducing this cost is to classify inefficient part of training data and ignore its ineffective part. On the other hand, k-NN method could be specified to complex data and simpler data can be classified with other methods whose computation cost is low. For doing this, an area is defined around each training class in feature space so that the points inside it can belong to relevant class. This will eliminate the necessity to long calculation in k-NN method and also computation time will decrease.

As it's clear from table 2 and 3, the program runtime for fuzzy combining is partly more than NN method. But regarding to high precision of this method, its computation cost can be considered acceptable. This method is more precise than NN method and also faster than k-NN.

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