DIABETIC RETINOPATHY RECOGNITION USING MULTIPLE CLASSIFIER FUSION SYSTEM

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Abstract: *In recent year's researcher were approaching to a multiple classifier system (MCS) to improve the efficiency and robustness of a pattern recognition system instead of using single classifier. In this paper performance of automatic Diabetic retinopathy system is evaluated using MCS. MCS is designed by combining the result of ANN, RBF and SVM Classifier by majority voting technique to achieve the reliable and accurate result. The proposed experimental work has been done on DIARETDB0 130 and DIARETDB1 89 fundus (retinal) images dataset and from these retinal sample extracted the ophthalmic features like blood vessels, microaneurysms and exudates. These extracted features were given to ANN, RBF and SVM classifier to detect the test sample is diabetic or non-diabetic. MCS system achieved reliable and more accurate result with the sensitivity 0.846, specificity 0.04761 and accuracy 0.7350 for DIARETDB0 and sensitivity 0.9662, specificity 0.25 and accuracy 0.9354 for DIARETDB1 by using majority voting technique.*

Keywords: **Diabetic retinopathy, Multiple classifier system, Blood vessels, Microaneurysms, Exudates, ANN, RBF, SVM, Fundus image**

1. INTRODUCTION

Traditionally single classifier were used in pattern recognition system. However in recent years researchers are using multiple classifier system (MCS) in pattern recognition system. Multiple classifier system built by use of fusion mechanism. MCS system is build using more than one classifier and they are interconnected according to topological structure i.e. parallel or series. For parallel combination classifiers are arranged in parallel and each classifier is nourishing with the same input database. So that there outputs are combined and take final decision using fuser rule. For series combination an individual classifiers integrated in sequence. When the prior classifier cannot be trusted to classify a given database, then the features are given to next classifier. A primary classifier can be used. When it rejects a pattern, a secondary classifier is used, and so on. In such a way final result would get using decision fuser rule [1] [9].

There are different combination fuser scheme can be applied to take final decision of MCS. Some of the fusion rules are probability schemes, voting schemes (maximum, minimum, median, Nash average and product), rank based method, Bayes approach, Dempster-Shafer theory, fuzzy integral, fuzzy connectives, fuzzy template, applied information theory (a measure of closeness, conditional entropy, and minimum mutual information) and combination by neural network. By employing above strategy combines many classifier result to achieve better performance of MCS [2] [3] [4] [9].

The advantages of MCS are as follows: Idealistically, the fusion rule take benefit of the individual classifiers, avoid their weaknesses, and rise classification accuracy [9]. MCS perform healthy in the two extreme stages of data availability: when we have very uncommon data base for learning and when we have a huge number of them at our disposal. Combined classifier can outperform the best individual classifier under fuser rules; this improvement has been proven analytically. MCS can be easily implemented in efficient computing environment such as parallel and multithreaded computer architecture. Multi-Classifier Systems (MCS) emphasis on the combination of classifiers form heterogeneous or homogeneous modeling environments to give the last conclusion [1] [9].

This paper is arranged as Section 2 with Literature review, section 3 gives Architecture of Multiple classifier system and Majority voting scheme, Section 4 illustrates performance analysis and section 5 finally concluded this paper.

2. LITERATURE REVIEW

TL Pao et al. (2007) has work on "Combination of multiple classifiers for improving emotion recognition in Mandarin speech"; for experiment author combines KNN, WKNN, WCAP, W-DKNN and SVM classifiers and combining their output Majority Voting scheme. From the result author shows that combiner scheme is better than single classifier in terms of overall accuracy with improvements ranging from 0.9%~6.5% [5].

Sandhya Arora et al.(2008) has applied "Combining Multiple Feature Extraction Techniques for Handwritten Devnagari Character Recognition"; author got 92.80% overall recognition rate. Weighted majority voting technique were used to fusionof classification decision obtained from four Multi-Layer Perceptron (MLP) based classifier. Author matched this technique with other recent systems for Handwritten Devnagari Character Recognition and it has been detected that this method has improved success rate than other methods [6].

Md. Rabiul Islam (2014) had work on "Feature and Score Fusion Based Multiple Classifier Selection for Iris Recognition"; Likelihood ratio score fusion based has been applied in iris recognition system proposal to combine the classifier output non equally. The four different classifiers((i.e., unimodal left iris recognition classifier, unimodal right iris recognition classifier, left-right iris feature fusion based classifier, and left-right iris likelihood ratio score fusion based classifier)) outputs are combined with MCS based majority voting technique, and gives the highest recognition rate than other existing approaches. By observing its ROC curves we understand the performance of the proposed approach gives highest recognition rate [7].

Reza Ebrahimpour (2005) has studied "Face Recognition by Multiple Classifiers, a Divide-and-Conquer Approach"; combination of neural network classifiers (CNNC) is implemented on human face recognition. The binary classification and max rule combination was used to achieve improved result. They obtained the recognition rate of 100% for ORL and Yale database [8].

Buket D. Barkana et al. (2016) has done "Performance analysis of descriptive statistical features in retinal vessel segmentation via fuzzy logic, ANN, SVM, and classifier fusion"; experimental work done on the publicly available DRIVE and STARE databases. The majority voting rule is used for evaluation combining the fuzzy, ANN, and SVM classifier. Classifier fusion achieved 95.53% of overall accuracy with 70.14% of sensitivity and 98.46% of specificity [15].

3. SYSTEM OVERVIEW

The proposed system i.e. Automatic diabetic retinopathy system using multiple classifier system shown in fig 1. System consist of various blocks such as fundus image database, Features extraction, classifiers, multiple classifier system i.e. majority voting classifier fusion technique

Database DIARETDB0 and DIARETDB1 with 130 and 89 images respectively examined in this experimental work to detect early diabetic retinopathy. Database DIARETDB0 & DIARETDB1 gets easily accessible by a site www.it.lut.fi/project/imageret [10].

Features that helps in experiment to understand and distinguish them from other characteristics in retinal images. The experimental work concentrate on extracting Ophthalmic/clinical feature like exudate, blood vessels, & microaneurysms. 2D median filter, multilevel histogram analysis and intensity transformation techniques are used to extract and calculate the feature vectors [11] [12] [13].

These same extracted features are given to artificial neural networks (ANN), Radial Basis Function (RBF) and Support vector machine (SVM) classifiers. ANN classifier system achieved sensitivity 0.83 and specificity 0.045 for DIARETDB0 and sensitivity 0.95 and specificity 0.2 for DIARETDB1 [11]. RBF classifier system perceive the accuracy of 71.2%, Sensitivity 0.83 & Specificity 0.043 for DIARETDB0 and the accuracy of 89.4% Sensitivity 0.94 & Specificity 0.16 for DIARETDB1 [12]. SVM classifier system observed the 0.955 sensitivity and 0.2 specificity for DIARETDB1 and 0.838 sensitivity and 0.045 specificity DIARETDB0 [13]. There are different multiple classifier fusion technique but here we are using majority fusion technique to combine the result of ANN, RBF and SVM classifier to get more accurate result.

Majority voting rule is considered as a one of the most common used rules in MCS [14]. There are three types of majority voting based on a method used in decision making. The first method called "Unanimous" voting, this rule selects a class that all classifiers are in agreement. The second type is called simple majority, in this case, a class is chosen if it is at least one more than half number of classifiers are agreed on that class. The third type is called "majority voting", in this type, the class received the heights number of votes will be chosen. The majority voting rule is the most popular used rule among others. The class selection procedure is described as follows. A class ω_j will be chosen if

$$\sum_{i=1}^{N} d_{i,j} = \max_{j=1}^{M} \sum_{i=1}^{N} d_{i,j} \quad (1)$$

Where N is the number of classifiers in the ensemble, M is the number of classes and $d_{i,j} \in \{0,1\}$ is the decision of the i^{th} classifier for j^{th} class. Theoretical result shown that as $N \to \infty$ the probability of classification error approaches 0, when a single base classifier error probability is less than $0.5 (p_e < 0.5)$ and approaches 1 when $0.5 (p_e > 0.5)$[14].

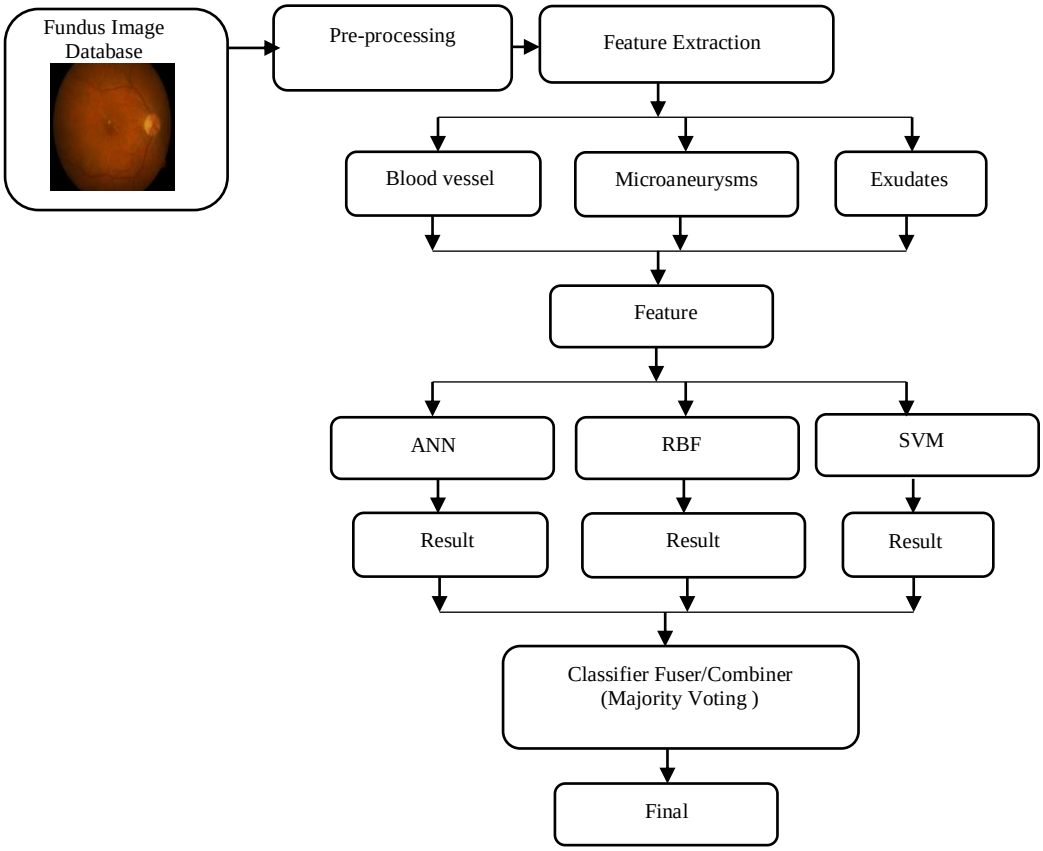


Figure 1. Architecture of proposed diabetic retinopathy recognition system

4. PERFORMANCE ANALYSIS

Performance analysis of proposed system is executed on MATLAB platform. A graphical user interface (GUI) is designed shown in fig 2. The performance of classifier fusion depends on the classifiers to be combined. Here we combined the three classifiers i.e. ANN, RBF and SVM. These three classifiers trained by using same training set of features and tested on same testing set. In classifier fusion, we employed majority voting as a technique which uses crisp labels. In our work, the crisp decision of ANN, RBF and SVM are fused by using majority vote [15]. For instance

If ANN_label(i)=0 and RBF_label(i)=0 and SVM_label(i)=1 then classifier_fusion(i)=1
Or
If ANN_label(i)=1 and RBF_label(i)=0 and SVM_label(i)=1 then classifier_fusion(i)=1
Where *i=1, 2, …, N* and *N* is the total test sample size [15].

The performance evaluation of the projected system in this paper has been studied in terms of sensitivity, specificity and accuracy shown in table 1. Sensitivity means disease diagnosis is correct (Diabetic retinopathy recognition is positive i.e. DR characteristics present in retinal images). Specificity means disease diagnosis is incorrect (Diabetic retinopathy recognition is negative i.e. Non DR characteristics present in retinal images) [11] [12] [13].

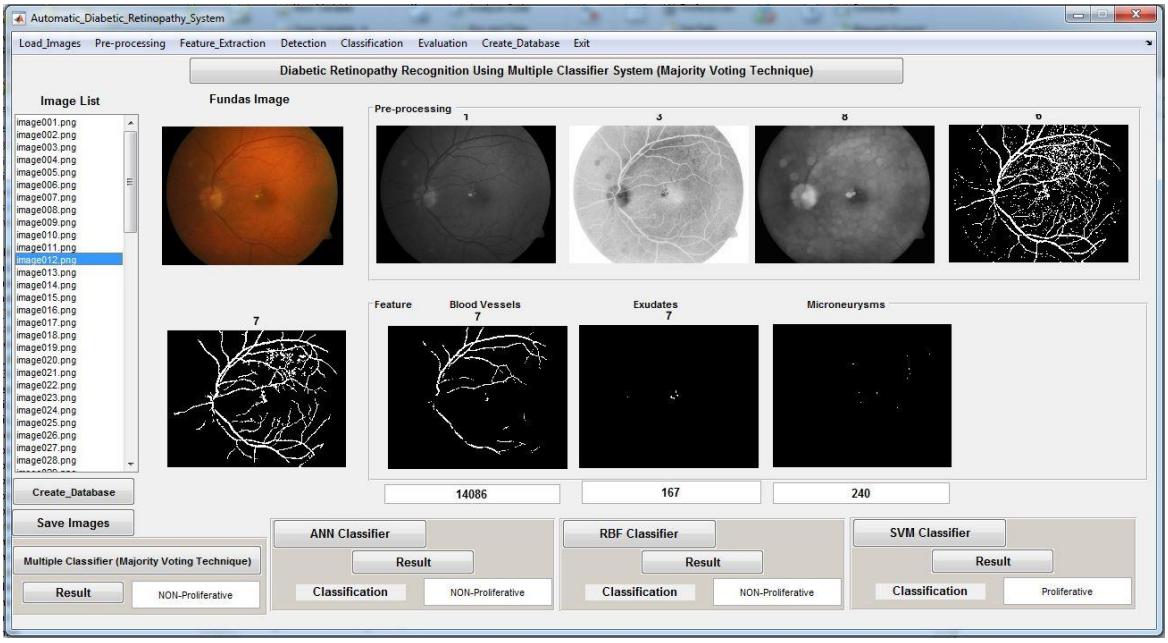


Figure 2. Design of GUI for proposed system.

Table -1 Performance Evaluation for DIARETDB1 and DIARETDB0 database

Classifier	Database	Positive		Negative		Sensitivity	Specificity	Accuracy
		True positive (TP= no of retinal images correctly identified)	False positive (FP= no of retinal images incorrectly identified)	True negative (TN= no of retinal images correctly rejected)	False negative (FN= no of retinal images incorrectly rejected)	Sensitivity = $\frac{TP}{(TP+FN)}$	Specificity = $\frac{TN}{(TN+FP)}$	Accuracy = $\frac{TP+TN}{(TP+TN+FP+FN)}$
ANN [Vaibhav V. Kamble et al. (2017)]	Db1 (89)	84	4	1	4	0.95	0.2	0.9148
	Db0 (130)	109	21	1	21	0.83	0/045	0.7236
RBF [Vaibhav V. Kamble et al. (2020)]	Db1 (89)	84	5	1	5	0.943	0.16	0.894
	Db0 (130)	108	22	1	22	0.830	0.043	0.712
SVM [Vaibhav V. Kamble et al. (2021)]	Db1 (89)	85	4	1	4	0.955	0.2	0.9148
	Db0 (130)	109	21	1	21	0.838	0.045	0.7236
Multiple classifier system (Majority voting rule)	Db1 (89)	86	3	1	3	0.9662	0.25	0.9354
	Db0 (130)	110	20	1	20	0.846	0.04761	0.7350

Consequent parameters (Sensitivity, Specificity, accuracy) of proposed system are compared with the previously published papers as shown in table 2.

Table -2 Comparison result of the proposed system with previously published papers

Author	Database	Extracted Ophthalmic features	Classifier	Result
Buket D. Barkana et al. (2016) [15]	**DRIVE database**	**blood vessels**	**Classifier fusion : Majority voting (Fuzzy+ANN+SVM)**	**Sensitivity: 0.7224 Specificity: 0.9840 Accuracy: 0.9532**
Buket D. Barkana et al. (2016) [15]	**STARE database**	**blood vessels**	**Classifier fusion : Majority voting (Fuzzy+ANN+SVM)**	**Sensitivity: 0.7014 Specificity: 0.9846 Accuracy: 0.9430**
Proposed system	**DIARETDB1(Db1)**	**Exudates, blood vessels & micro aneurysms**	**Classifier fusion : Majority voting (ANN+RBF+SVM)**	**Sensitivity: 0.9662 Specificity: 0.25 Accuracy: 0.9354**
	DIARETDB0(Db0)	**Exudates, blood vessels & micro aneurysms**	**Classifier fusion : Majority voting (ANN+RBF+SVM)**	**Sensitivity: 0.846 Specificity: 0.04761 Accuracy: 0.7350**

5. CONCLUSION

Performance of automatic Diabetic retinopathy system is evaluated by combining the result of ANN, RBF and SVM Classifier by majority voting technique to achieve the reliable and accurate result. The proposed experimental work has been done on DIARETDB0 130 and DIARETDB1 89 fundus (retinal) images dataset and from these retinal sample extracted the ophthalmic features like blood vessels, microaneurysms and exudates. These extracted futures were given to ANN, RBF and SVM classifier to detect the test sample is diabetic or non-diabetic. MCS system achieved reliable and more accurate result with the sensitivity 0.846, specificity 0.04761 and accuracy 0.7350 for DIARETDB0 and sensitivity 0.9662, specificity 0.25 and accuracy 0.9354 for DIARETDB1 by using majority voting technique.

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