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Extreme Learning Machine based weighting for decision rule in Collaborative Representation Classifier

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Abstract

Sparse representation based classification (SRC) has been widely used for pattern recognition especially to face recognition due to its robustness to illumination change, noise and occlusion in face images. SRC method emphasizes the role of parsimonious representation in achieving robustness and accurate classification. To enforce sparsity, the linear representation of query sample and training samples is computed using l_1-minimization which is complex and time consuming. Recently, many studies have proved the robustness of SRC is achieved by the collaborative representation mechanism and not the l_1 sparsity constraint. Thus, the l_1-norm based representation in SRC classification framework could be replaced by l_2-norm based representation which is computationally more efficient. This type of classification method is called Collaborative representation based classification (CRC) in the literature. In this paper, an output weight computed from extreme learning machine ELM regarded as a class membership is utilized in conjunction with the classification decision in collaborative representation classifier to improve high classification accuracy over various public available face and speech recognition datasets. The role of ELM is to provide the class membership which denotes the nonlinear similarity of the query sample to training samples from each class. Whereas the CRC provides the linear representation of the query sample and training. The collaborative representation from CRC and class membership from ELM are applied in the regularized residual classification decision to classify the query sample. Experimental results prove that the classification accuracy of the proposed algorithm i.e. CRC-ELM is greatly improved the baseline performances.

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Keywords: Extreme learning machine (ELM); collaborative representation based classification (CRC); sparse representation based classification (SRC); classification; l_2-norm minimization

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1. Introduction

The study and development of sparse representation of signals for classification purpose have getting high attention especially in face recognition. Sparse representation based classification (SRC) methods utilized the sparse code computed by l_1-minimization to determine the degree of similarity between the query sample and all of the training samples. SRC shows its robustness to occlusion and noise in face recognition by many researchers. However, there is some arguments in the literature that the key role to the success of SRC is relied on the collaborative representation mechanism which utilized all of the training samples to represent the testing sample rather than l_1- sparsity constraint. Consequently, the time-consuming l_1-minimization problem could be replaced by a less complex method such as least square or l_2 minimization to compute the "less sparse" representation between the query sample and all of the training samples.

Collaborative representation based classification with regularized least square (CRC-RLS) proposed by Zhang et al.[1,2] has shown remarkable result and outperforms the SRC in face recognition problem. They claimed that representing the testing sample using all of the training samples in the dictionary is the reason of accurate performance of SRC. Hence, the l_1-norm is replaced by the l_2-norm and the solution can be solved using regularized least square which is faster and relatively simpler to implement. Similar to Zhang approach, Imran et al.[3] proposed Linear Regression Classifier (LRC) for face recognition. LRC differs from CRC as it represents the query sample as a linear combination of the training samples of each class whereas CRC uses all of the training samples to represent the query sample. Shi et al.[4] suggested that l_2-minimization solved using least square is more effective than l_1 minimization in face recognition with noise, occlusion and disguise. They stated that optimal solution can be recovered using least square even when the dictionary is under-complete. They carried out several experiments to prove that l_1-sparsity is not the key to improve the noise and occlusion robustness of the classifier and is frequently beaten by l_2-norm solution which its computation is faster and more robust. Moreover, Yang et al.[5] presented relaxed collaborative representation (RCR) which can effectively exploit the similarity and distinctiveness of features by incorporating the iteratively learned weight matrix which denotes the similarity between two data points into the coding process. Jadoos et al.[6] introduced Euclidean distance between query points and dictionary into the CRC coding process based on the assumption of locally linear embedding (LLE). Besides that, Xi et al.[7] presented locality constrained collaborative representation by incorporating local consistency into coding process. In this approach, the average of K-nearest neighbors (KNN) training features is added proportionally to the query feature with the assumption of similar inputs will result in similar collaborative representation[8].

Huang et al.[9,10] proposed Extreme Learning Machine (ELM) for single hidden layer feed-forward networks training which can learned faster than conventional Neural Networks (NN) and achieved better generalization with minimal human intervention and iterative tuning. The weights and hidden layer biases of ANN are adjusted using tuning approach such as gradient descent based methods. This method is generally time consuming and has great possibility to converge to a local maxima. ELM inherits the ability of ANN in capabilities for nonlinear mappings while get rid of the slow learning process by assigning the weight and hidden layer biases randomly and determining the output weight analytically. Zong and Huang[11] solved face recognition problem by using ELM as the classifier. Their experiments shows that ELM based classification produces comparable recognition accuracy and learning time to SVM. ELM has been applied in conjunction with SRC in[12] for classification. The output weight of ELM is applied to the computation of decision rule in SRC to obtained better classification result. Later, Zhang and Luo[13] implemented a hybrid classifier based on ELM and SRC for image classification. The aim of this approach is to combine the speed advantage of ELM and accuracy advantage of SRC for image classification. In this approach, a testing image will first classified using ELM and if misclassification occurs, the testing image will be classified using SRC instead. Iosifidis et al.[14] proposed sparsity based learning machine for human action recognition problem. In their method, they train the ELM by using the sparse representation obtained from SRC.

In this paper, we propose a new variant of CRC coined CRC-ELM which includes the output weight from ELM model to the decision function of CRC in order to enhance the classification performance on face and speech recognition problem. The CRC-ELM performs reasonably well compared to CRC-RLS and several state of art classifiers in several face and speech recognition datasets. The rest of the paper is organized as the following: Section 2 briefly discusses three related approaches i.e. SRC, CRC and ELM. Section 3 presents and provides novel insights into the working of the proposed method that is CRC-ELM. Section 4 reports the results of evaluation on the proposed method in face and speech datasets. Section 5 concludes the paper.