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PCA transformation and Support Vector Machine for recognition of the noisy images

Summary

Recognition of images, especially distorted one, belongs to difficult numerical problems, especially when the distortions are of high level. In this paper we will present the Principal Component Analysis (PCA) based technique combined with Support Vector Machine (SVM) for recognition of the images. PCA is a well known technique enhancing the most important elements of the data and suppressing the least important portion of the information. It is described as the linear transformation

(1) $$\mathbf{y}=\mathbf{W}\mathbf{x}$$

mapping the N-dimensional original vector **x** into K-dimensional output vector **y**, where K<N. The vector **y** preserves all most important elements of original information contained in **x**. The $K \times N$ matrix **W** is the PCA transformation matrix composed of the eigenvectors of the eigen-decomposition of the correlation matrix $\mathbf{R}_{xx}$ associated with the set of input vectors.

In our approach we will consider the set of images belonging to *M* classes. Each image is represented the *N*-dimensional vector. For typical 512x512 images the size of this vector $N=512^2=262144$ is extremely high and the correlation matrix of such size will be impossible to process even in modern computer system. Let us assume that the number of image vectors is *p*, where usually $p<<N$. They are arranged in the form of the matrix **X** of the size *pxN*. To avoid the problem of processing the *NxN* dimension correlation matrix $\mathbf{R}_{xx}$ we form the small dimension matrix $\mathbf{RS}_{xx}$ of the size *pxp*. The PCA is created on the basis of this small dimension matrix using the eigen-decomposition of $\mathbf{RS}_{xx}$. This decomposition generates the set of small size eigen-vectors $\mathbf{vs}_1$, $\mathbf{vs}_2$,...$\mathbf{vs}_p$. The PCA matrix is built on the basis of *K* ($K<<N$) eigenvectors $\mathbf{vs}_i$ associated with *K* the largest eigen values λ_i, forming the matrix **VS.** Return to the normal (high) size of these vectors is achieved by the transformation

(2) $$\mathbf{V}=\mathbf{X}^T*\mathbf{VS}$$

where **V** is the eigenvalues matrix representing the original (high size) eigen-vectors. Then the PCA matrix **W** is determined as follows $\mathbf{W}=[\mathbf{V}_1,\mathbf{V}_2,...,\mathbf{V}_K]^T$, where $\mathbf{V}_i$ represent the first succeeding columns of the matrix **V** (up to *K*). Thanks to this approach we avoid the problem of processing very high dimensional matrices in eigen-value decomposition.

The eigen value decomposition will be used to generate the numerical descriptors of the image. The original image described by the vector **x** is transformed to the less dimensional vector **y** using equation (1). The elements of vector **y** form the input signals to the classifier. In our solution we use the Support Vector Machine of the Gaussian kernel as the working horse of the classification system. SVM is known from its high efficiency in classification tasks.

In the experimental part of the research we will present the results of recognition of the few classes of images. The experiments will be aimed on the recognition of the distorted representatives of these classes at different distortion level and various types of distortion (salt and paper, Gaussian, etc.). The experiments show that application of PCA in combination with SVM classifier represents efficient approach to the image recognition problem.