

Tongue Image Classification Based on the TSVM

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Abstract—Tongue image classification plays a very important role in the Traditional Chinese Medicine (TCM) modernization. However, the number of training samples labeled by the authoritative TCM experts is small since it is a hard work to confirm the type of the samples, which need a lot of time and human labor. Meantime the separable boundary obtained by these labeled samples is rough and imprecise. Meantime unlabeled samples are abundant and easy to obtain. Transductive support vector machine (TSVM) is a method to reduce human labor and improve accuracy since the unlabeled samples can be joined to train the classifier to provide much more classification information during training. The experimental results show that the TSVM classifier can improve the right classification rate so it is a promising method in the TCM study.

Keywords—Tongue image classification, Traditional Chinese Medicine, Transductive support vector machine

I. INTRODUCTION

Tongue diagnosis is an important part of the inquiry diagnosis in TCM. Physicians examine the tongue color, shape, textures and so on to judge the patient's health conditions. Based on tongue image and other information, the possible causes of diseases can be concluded and the treatment is then implemented.

However, tongue diagnosis is usually based on the inspection from the eye. The environmental factors, such as different light sources and brightness, can affect the physicians in making accurate diagnosis. In addition, the examination outcome in traditional tongue diagnosis could not be described scientifically and quantitatively.

In recent years, the studies on tongue image characterization in TCM have been widely emphasized [1]. Quantitative analysis of tongue images based on image processing and pattern recognition is a trend in TCM Modernization. The first exploratory experiment about this was carried out in 1985 by the University of Science and Technology of China. Their work shows that it is feasible to study the tongue image by this means. Nevertheless, at that time most of the existing research work could not solve the color distortion in tongue image acquisition and did not implement the automatic classification of tongue features.

To improve the research of tongue characterization, we applied the image analysis in characterizing tongue diagnosis in 1990s. An objective tongue analysis instrument named Tongue Image Analysis Instrument (TIAI) was developed [2]. Several

algorithms on color calibration, tongue image segmentation, quantitative analysis and qualitative description and so on have been presented in [2]. Their effectiveness has been verified by more than 3000 tongue images in hospitals.

However, since the number of training samples labeled by the authoritative TCM experts is small, support vector machine (SVM) is selected to classify the tongue images. The labels of training samples must be decided by 3-5 experts with rich experience, which need a lot of time and efforts. A large amount of labeled samples could not be obtained under this condition. As far as the recognition is concerned, the classification information from these labeled samples is not enough and the separable boundary by them is rough and imprecise. At the same time, the unlabelled samples are easy to obtain for us. For example a large amount of unlabeled samples can be collected if a physical examination is carried out. So if the classification information from these unlabeled samples is used, the performance of the SVM classifier can be improved. This is so-called the idea of semi-supervised learning. In the semi-supervised learning, the unlabeled samples are jointed to train the classifier to improve its generalization performance. Since the classification on the tongue proper and tongue coating by SVM has been made some achievements in [2], in this paper SVM [3-5] and transductive SVM (TSVM) [6-8] is selected to improve the performance of the original classifier.

The rest of this paper is organized into three sections. Section 2 shows the basic theory on the SVM and TSVM. In section 3, the experiment on tongue image classification based on TSVM is proposed. Section 4 conclusions are given.

II. SVM AND TSVM

A. SVM

SVM is a state-of-the-art method and has been applied to many fields such as face recognition, text classification and so on in the machine learning. Compared to the artificial neural network it is based on the structure risk minimization and has the better generalization performance. Its basic theory is described as following.

Suppose there are two kinds of samples and their types are positive class and negative class respectively. As Figure 1 the black points represent the positive samples and the blank points represent the negative ones. The classifier H with maximal margin is called a support vector classifier, in which the samples which lie in the margin are called support vectors. To

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the nonlinearly separable problems, the kernel function ϕ is introduced to map the samples to a new space in which they are linearly separable completely or linearly separable approximately as figure 2 which is from [5]. In fact the inner is calculated by the kernel function rather than is obtained in the mapping space. That is why SVM can solve the problems with high dimension features and can avoid the “dimension Disaster”. Since the labeled samples are small in some cases such as the labeled tongue images in TCM, the SVM classifier trained by them cannot reflect the distribution of the whole samples.

Under that there are some unlabelled samples, how to add them to train a classifier becomes an important problem in machine learning. TSVM is a promising method to solve it.

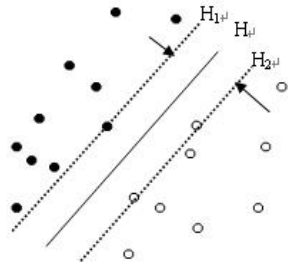


Figure 1. An example on support vector classification

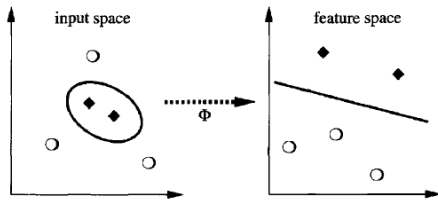


Figure 2. The idea of solving the nonlinearly separable problem in SVM

B. TSVM

Suppose there are l labeled samples and u unlabelled samples in data set. The feature vector of i -th labeled sample is \vec{x}_i and its class label is y_i , where $y_i \in \{1, -1\}$. y_i^* is the class label of the i -th unlabelled sample and it needs to be decided after training TSVM classifier. ξ_i and ξ_i^* are the slack variable corresponding to i -th labeled sample and i -th unlabelled sample respectively.

$$(\vec{x}_1, y_1), (\vec{x}_2, y_2), \dots, (\vec{x}_l, y_l)$$

represents the training set with labels and

$$(\vec{x}_1^*, y_1^*), (\vec{x}_2^*, y_2^*), \dots, (\vec{x}_u^*, y_u^*)$$

is the data set without class labels. A binary TSVM in [6] is proposed and its formulation is as equation (1).

$$\begin{aligned} \min_{\mathbf{w}, b, \xi_i} & \frac{1}{2} \mathbf{w}^T \mathbf{w} + C \sum_{i=1}^l \xi_i + C^* \sum_{i=1}^u \xi_i^* \\ & y_i (\mathbf{w} \cdot \mathbf{x}_i + b) - 1 + \xi_i \geq 0 \\ & y_i^* (\mathbf{w} \cdot \mathbf{x}_i^* + b) - 1 + \xi_i^* \geq 0 \\ & \xi_i \geq 0, \xi_i^* \geq 0 \end{aligned} \quad (1)$$

To non-separable case by the linear classifier, the kernel function is introduced to map the samples into a new space in which the samples are separable fully or approximately separable by the linear classifier. In nature, TSVM is an extension of standard SVM with unlabelled samples. Figure 3 from [5] shows an example on TSVM, in which the labeled samples are marked as $+/-$, the unlabeled samples as dots. The dashed line is the solution of the inductive SVM (Standard SVM). The solid line shows the TSVM. It can be seen that unlabeled samples can provide some classification information so as to improve the classifier's performance. It is noted that not all the classification problems with unlabelled samples can be solved by TSVM. The condition that the samples need to satisfy is given in [6]. The experiment in next part shows it is valid for tongue image classification.

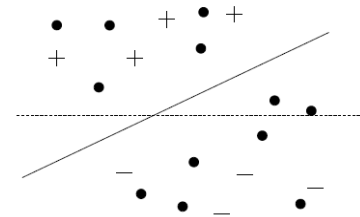


Figure 3. An example on the TSVM

III. TONGUE IMAGE CLASSIFICATION EXPERIMENT

The data experiments on the tongue proper color and tongue coating color are carried out. The RGB is selected to the feature space for classification. Before the experiment the testing data is first calibrated to the standard space to make the tongue color approach the real tongue as soon as possible [2]. According to suggestions of several TCM experts, the tongue proper color is classified to 6 types such as red tongue, light red tongue, dark red tongue and so on and the color of tongue coating is classified 9 types such as thin white coating, white coating and so on [2]. In this experiment, the light red tongues and other types of tongues are organized into 5 binary-category classification problems and the thin white coating and other coatings are organized into 8 binary-category classification problems. Thus there are 13 binary-classification problems. The radius base function

$$K(x, y) = e^{-g \|x - y\|^2}$$

is selected to train the SVM classifier. Here the parameter $g = 0.1$. The condition on the experimental data sets is as chart 1, in which the “labeled”, “unlabeled” and “testing” represent the

number of labeled samples, unlabeled ones and testing ones respectively.

TABLE I. CONDITION ON THE EXPERIMENTAL DATA

	labeled	unlabeled	testing
1	31	1394	356
2	27	1211	312
3	21	823	213
4	56	2647	669
5	23	924	240
6	31	3631	1121
7	34	3250	1150
8	22	2329	791
9	19	1866	675
10	19	1880	680
11	25	2650	907
12	51	4518	1421
13	17	1740	643

The labeled samples are selected from the hospital and their labels are decided by 3 authoritative TCM experts. The testing samples are collected in physical examinations and their labels are obtained by a TCM doctor.

The experiment includes three parts.

- 1) Labeled samples are trained and then testing samples are classified
- 2) Labeled samples and unlabelled samples are trained and then testing samples are classified
- 3) Labeled samples and testing samples are trained and then testing samples are classified.

In the 3rd part, we assume the testing samples as the unlabeled ones in order to improve their right classification rate. Note that this method is unsuitable to the real-time classification in this case.

The experimental results are as Fig.4 and Fig.5 respectively. In these two figures, the yellow rectangle represents the right classification rate of testing samples by TSVM and the green rectangle shows the right classification rate by Inductive SVM (Standard SVM).

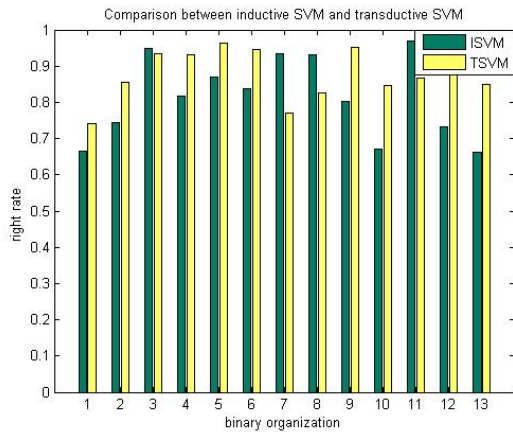


Figure 4. Unlabeled samples are trained

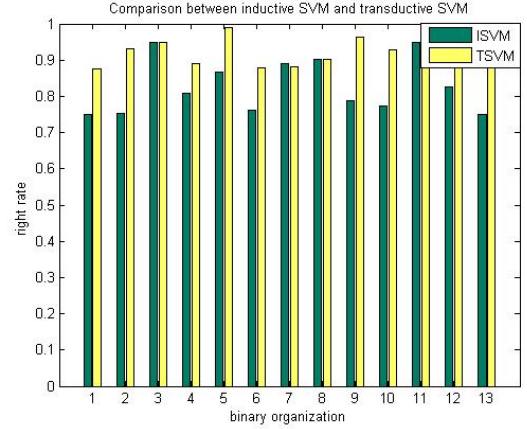


Figure 5. Testing samples are as the unlabeled ones

From the experimental results we can see that the testing results by the TSVM are better than the ones by the standard SVM in most cases. However, there are three bad cases who are 3th, 7th and 8th binary-category classification problems in these experiments. The main reasons are as following.

- 1) The 7th, 8th and 9th binary classification problem is difficult to separate and their separating boundary is fuzzy. That is to say, these samples don't satisfy the low density assumption fully.
- 2) The kernel function parameter selection is not carried out in training TSVM classifier. If the model selection is done, the results should be better than the ones described as above.

In addition, TSVM is a NP hard problem in maths and it is very difficult to obtain the optimal solution, which has an effect on the experiments results.

From the experiments on the tongue color and coating color, TSVM is a potential method in TCM characterization and modernization. We can also see that if much more unlabeled samples are joined to train, the right classification rate can be lower. So the selection on the unlabeled samples is also an important issue to study further.

IV. CONCLUSION

Tongue image classification is an important part in TCM modernization. However, it is difficult to obtain the labeled samples since a lot of time and human labor is needed. Meantime the unlabeled samples are easy to obtain and TSVM is a promising method in which the classification inform provided by unlabeled samples can be used. The Experimental results show that TSVM can improve the right rate of tongue image classification in most cases. We will study the optimization of TSVM and the selection of unlabeled samples which are joined to train to obtain the better performance.

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