Application of improved symmetric incremental learning algorithm in glass defect classification

Xun Lian

1 Department of Mechanical and Electrical Engineering, Wenhua College, Wuhan City, Hubei Province, 430070, China

*Corresponding author’s e-mail: 32864427@qq.com

Abstract. This paper focuses on the application and development of image recognition technology in glass defect detection industry, and studies the basic theory and implementation method of support vector machine. Aiming at the main shortcomings of incremental learning algorithm in current support vector machines, an improved symmetric incremental learning algorithm (S-ISVM) is designed. Support vector machines are selected as training tools and classification tools, and the training samples and test samples are used as prediction samples respectively. The feasibility of the algorithm and the correctness and validity of data processing methods are verified. The research results have broad prospects for development and practical value in the field of glass industry production.

1. Introduction

Traditional glass quality detection methods mainly adopt manual naked eye monitoring, but manual detection is slow, and human eye detection will be affected by external factors. Different people and even the same person have different inspection results under different conditions, which is very easy to cause missed or mistaken inspection of defects[1]. Therefore, in order to ensure the accuracy and stability of glass detection, an objective and effective detection method is needed.

In this paper, an on-line glass defect detection system based on digital image pattern recognition technology is studied. The system can effectively detect glass defects in production.

2. Architecture Design of Glass Defect Online Detection System

The structure of the glass defect detection system is shown in the following figure. The system is mainly composed of transmission belt, lighting system, CCD camera and on-line detection system. The main work flow of the system is as follows: First, the glass image on the production line is captured by CCD camera. The image is transformed into digital signal which can be recognized by computer through image acquisition card. Then, the image is sent to the on-line detection system. The on-line detection system is based on C/S mode. The glass image data on the production line is collected by the terminal and transmitted to the server. Then the server performs defect detection on the received glass image through three modules: image preprocessing, feature extraction and classification recognition[2]. Finally, the detection information is saved to the database and the processing results are displayed on the computer in real time. According to the detection results, the system sends out control signals to the defect marking circuit and the glass optimizing cutting mechanism, marks the defect and optimizes cutting, so as to obtain high-quality glass that meets the production standards.
3. Classification and Recognition of Glass Defect Image

In this paper, an improved support vector machine algorithm is used for defect classification. Aiming at the main shortcomings of incremental learning algorithm in current support vector machines, an improved symmetric incremental learning algorithm (S-ISVM) is designed and applied to glass defect recognition[3].

The core code of the pattern recognition module in the glass defect detection system is compiled and the experimental platform is built by using the mixed programming technology of VC and MATLAB. A large number of experimental data prove that the S-ISVM algorithm proposed in this paper can effectively shorten the training time on the basis of guaranteeing the recognition accuracy under the condition of the same recognition technology.

3.1 Principle of S-ISVM algorithm

Although support vector machine has the advantages of fast convergence and good generalization, it has the disadvantage that can not be ignored: it does not support incremental learning. An effective solution is to train the original sample set which may become the support vector and the new sample set, so as to gradually improve the learning accuracy with the accumulation of the sample set[4]. Based on the equal incremental training algorithm, a new incremental learning algorithm, Symmetry-ISVM (S-ISVM), is implemented by coding in this paper.

The basic idea of S-ISVM algorithm is as follows: Firstly, the initial sample set A is trained and the support vector set Asv is obtained. (Since a support vector set corresponds to a decision function, the support vector set Asv is used to represent the decision function at the same time.) Then, using Asv, the original sample A and the new sample B are tested respectively to see whether there are original samples and new samples that do not satisfy the KTT condition. If not, the training is over, and Asv is the learning result. If it exists, Bsv is obtained by training the new sample B, and then the samples A and B are detected separately. If there is no misclassification, the learning is over, and Bsv is the result of training[5]. If it still exists, all support vectors and samples that do not satisfy the KTT condition are trained to form a new training sample set, and the boundary vectors in A and B that satisfy the KTT condition and are close to the support vectors are used as the test sample set, which is iterated repeatedly until no samples are misclassified[6]. The flow chart of the algorithm is shown below.
3.2 Implementation steps of the S-ISVM algorithm

First, define the following variables:

- \( A \): initial sample set;
- \( B \): incremental sample set;
- \( A_{sv} \): support vector after initial sample set \( A \) training;
- \( B_{sv} \): support vector after incremental sample set \( B \) training;
- \( A_s^1 \): sample set that satisfies the KTT condition in \( A \) after prediction using \( A_{sv} \)'s corresponding decision function;
- \( A_s^2 \): sample set in \( A \) that does not satisfy the KTT condition after prediction with the \( B_{sv} \) corresponding decision function;
- \( B_s^1 \): sample set satisfying the KTT condition in \( B \) after prediction by the \( B_{sv} \) corresponding decision function;
- \( B_s^2 \): sample set in \( B \) that satisfies the KTT condition after being predicted by the \( A_{sv} \) corresponding decision function;
- \( X_s^1 \): sample set of \( A \) and \( B \) that satisfies the KTT condition and belongs to the boundary vector after prediction by the \( A_{sv} \) corresponding decision function;
- \( X_s^2 \): sample set of \( A \) and \( B \) that satisfies the KTT condition and belongs to the boundary vector after prediction with the \( B_{sv} \) corresponding decision function.

The algorithm steps are described as follows:

1. Training \( A \) to obtain \( A_{sv} \);
(2) A and B are detected by $A_{sv}$, and $A_{s1}$, $A_{ns1}$, $B_{s1}$, $B_{ns1}$ are respectively obtained;

(3) Judging conditions:

$$\frac{A_{ns1}+B_{ns1}}{A+B} < rate.$$ If the condition is true, return $A_{sv}$ and $A+B$, the program ends; if not, skip to the next step;

(4) Training B to obtain $B_{sv}$;

(5) A and B are detected by $B_{sv}$, and $A_{s}$, $A_{s}$, $B_{s}$, $B_{s}$ are respectively obtained;

(6) Judging conditions:

$$\frac{A_{s}+B_{s}}{A+B} < rate.$$ If the condition is true, return $B_{sv}$ and $A+B$, the program ends; if not, skip to the next step;

(7) Find the set $A_{s} \cup B_{s}$, $A_{s} \cup B_{s}$ respectively to meet the boundary vector sets $X_{s}$ and $X_{s}$, and let $B= X_{s} \cup X_{s}$, and return to step 1.

Compared with previous algorithms, S-ISVM algorithm has the following characteristics:

Firstly, the S-ISVM algorithm takes into account the fact that it is possible to misclassify the original sample by using the decision function generated by the training of the original sample to predict the original sample itself[7]. Thus, all samples with potential to become new support vectors are retained to the maximum extent, so that the final set of support vectors is as accurate as possible.

Secondly, the threshold rate is introduced to control the recognition rate of the whole sample, and the accuracy and efficiency of the training process can be balanced by changing the value.

In addition, it is impossible to use all the wrong samples and support vectors for retraining, while using all the boundary samples for prediction will not become support vectors, which greatly reduces the training and prediction time and saves memory space.

Finally, the algorithm returns two results, one is the final support vector set and its corresponding decision function, and the other is the original training sample relative to the next incremental training.

4. Experimental results and analysis of the effectiveness of S-ISVM algorithm

Considering that incremental training algorithm can reflect its efficiency advantage only when there are more training samples[8]. For this purpose, 210 glass images in the experiment are expanded appropriately by graphic methods such as translation, rotation, scaling and staggering, as shown in the following figure. The expanded experimental sample size is 2000.

![Figure 3. Some defective pictures used in the experiment](image)

Firstly, 1000 samples were selected as the original training sample set, then 600 of the remaining samples were selected and divided into four groups, 150 in each group, as an incremental sample for each time. Finally, the remaining 400 samples are used as predictive samples to test the recognition effect of incremental training. The threshold rate is set to 0.07.

Then, 600 incremental training samples are added to the original sample four times for incremental training, and the training time is output after the convergence of the training algorithm. Then, the same
steps are taken to train the incremental samples and the original samples with the non-incremental training method. The comparison of training time is shown in the following figure.

In addition, non-incremental training method, ISVM incremental training algorithm and three discriminant functions obtained by symmetric incremental training algorithm in this paper are used to test 400 prediction samples respectively. The recognition results are shown in the table below.

| Classification method | Bubble | Nodulation | Stone | Total recognition rate |
|-----------------------|--------|------------|-------|------------------------|
| Ordinary SVM          | 147/150| 149/150    | 86/100| 95.3%                  |
| ISVM                  | 145/150| 143/150    | 83/100| 92.8%                  |
| S-ISVM                | 147/150| 146/150    | 85/100| 94.5%                  |

Compared with the traditional non-incremental training, the incremental training algorithm can greatly shorten the training time. In addition, the S-ISVM proposed in this paper is used to classify glass samples. The recognition accuracy is much higher than that of the traditional incremental training algorithm, and even the recognition accuracy is almost the same as that of the non-incremental training method.

5. Conclusion
This paper focuses on the application and development of pattern recognition algorithm in image processing technology in glass defect detection industry. A new incremental training algorithm (S-ISVM) is designed and implemented by studying the related technology of pattern recognition. It is applied to the glass defect detection system in order to classify glass defects automatically.

The experimental results show that the recognition accuracy of this algorithm is higher than that of other feature extraction methods. At the same time, S-ISVM algorithm can greatly shorten the training time and improve the recognition efficiency on the basis of ensuring the recognition accuracy. It has great popularization value and application prospect in the field of glass industry production.

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