Development of character recognition system for the mixed font style in the steel processing material

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Abstract: In the steel production line, the molten metal of a furnace is transformed into billet and then moves to the heating furnace of the hot rolling mill. This paper describes about the development of recognition system for the characters, which was marked at the billet material by use template-marking plate and hand written method, in the steel plant. For the recognition of template-marked characters, we propose PSVM algorithm. And for the recognition of hand written character, we propose combination methods of CCD algorithm and PSVM algorithm. The PSVM algorithm need some more time than the conventional KLT or SVM algorithm. The CCD algorithm makes shorter classification time than the PSVM algorithm and good for the classification of closed curve characters from Arabic numerals. For the confirmation of algorithm, we have compared our algorithm with conventional methods such as KLT classifier and one-to-one SVM. The recognition rate of experimented billet characters shows that the proposing PSVM algorithm is 97 % for the template-marked characters and combinational algorithm of CCD & PSVM is 95.5 % for the hand written characters. The experimental results show that our proposing method has higher recognition rate than that of the conventional methods for the template-marked characters and hand written characters. By using our algorithm, we have installed real time character recognition system at the billet processing line of the steel-iron plant.

Keywords: Character recognition, KLT, SVM, CCD, PSVM

1. INTRODUCTION

Nowadays, humans are being replaced by automated systems in many fields of applications, such as robotics [1], control system, system manufacturing, machine diagnosis and maintenances analysis, aircraft autopilot, and autopilot enhancement. The automated systems can save time, reduce cost, increase efficiency, performance, and reliability. This improvement has been reached in many systems, but it is far from being reached in other fields. One of the challenging fields that are still an open area of research is pattern recognition. So far, many approaches had been used and still a lot of research is needed to automate this problem. The character recognition technique is a part of the pattern recognition. In the field application, such as steel and iron plant, a circumference environment has a serious effect in the character recognition. In the steel production line, the molten metal of a furnace is transformed into continuous casting slab or bloom via continuous casting processes and then move to the heating furnace of the hot rolling mill. A billet is extracted from bloom through the hot rolling processing. For the classification of the quality and uses of these slab or billet, material management numbers are marked in their front area. A small error in their classification causes serious results. Therefore, it is very important to recognize exactly this management numbers. This paper describes about the real time billet number recognition system in the steel production line. Normally, the billets are mixed at yard so that their identifications are hardly tractable. The characters of billet image can be marked by use three kinds of methods such as auto marking machine, template-marking plate and hand written method. The conventional classification algorithm such as Karhunen-Löeve transformer (KLT) classifier is good for the recognition of printer letter, which is marked by use auto marking machine.[1][2] But it is not good for the template-marked character or hand written character. This paper describes about the development of recognition system for the characters, which was marked at the billet material by use template-marking plate and hand written method, in the steel plant. For the recognition of template-marked characters, we propose potential one-to-one support vector machine(SVM) classification algorithm. And for the recognition of hand written character, we propose combination methods of closed curve detection (CCD) algorithm and potential one-to-one SVM (PSVM) algorithm. The PSVM algorithm need some more time than the conventional KLT or SVM algorithm.[3][4][5] The CCD algorithm makes shorter classification time than the PSVM algorithm and good for the classification of closed curve characters such as 0, 4, 6, 8, and 9 from Arabic numerals, 0 ~ 9. For the testing of algorithm, we used 100 billet images, which were captured by CCD camera in the steel processing line. The characters of billet image are composed with template-marked characters and hand written characters. We have compared our algorithm with conventional methods such as KLT classifier and one-to-one SVM. The recognition rate of experimented billet characters shows that the proposing PSVM algorithm is 97 % for the template-marked characters and combinational algorithm of CCD & PSVM is 95.5 % for the hand written characters. The experimental results show that our proposing method has higher recognition rate than that of the conventional methods for the template-marked characters and hand written characters. By using our algorithm, we have installed real time character recognition system at the billet processing line of the steel-iron plant, and we will continue testing for the improvement of reliability and durability.

2. MULTI-CLASS SUPPORT VECTOR MACHINE

2.1 Support Vector Machine (SVM)

SVM is a new promising binary classification technique proposed by Vapnik et al. In this algorithm, an input vector is mapped into a high-dimensional space using a non-linear function, and a linear discriminate function is then searched in the high dimensional feature space. Solving the following quadratic programming optimization problem does the

learning based on the margin maximization:

$$\text{maximize} \quad \sum_{i=1}^{l}\alpha_i - \frac{1}{2}\sum_{i=1}^{l}\sum_{j=1}^{l}\alpha_i\alpha_j k(x_j, x_j)y_i y_j \tag{1}$$

$$\text{subject to} \quad \sum_{i=1}^{l}\alpha_i y_j = 0, \qquad 0 \le \alpha_i \le C \tag{2}$$

Where x denotes the learning data, l denotes the number of the learning data, α denotes a Lagrange multiplier for data i and y_i denotes the label of data i (-1 *or* + 1). The support vectors satisfy the conditions $\alpha_i \ge 0$. C is a parameter, which penalizes the learning errors. If the data are separable, we may set $C = \infty$. The decision function for an input vector z is defined as

$$f(z) = \sum_{i \in SV}\alpha_i y_j k(z, x_i) - b \tag{3}$$

Where $x_i \ \ i \in SV$ denotes a learning vector and SV denotes the set of the support vectors. $k(a, b)$ is the kernel function. The class is determined by the sign of the function $f(z)$. From several kernel functions, we adopted the Gaussian kernel:

$$k(x, y) = \exp\left(-\frac{\| x - y \|^2}{\delta^2}\right) \tag{4}$$

In the real life, most of complicated status is non-linear. But SVM is not good for the non-linear problem. Therefore, it is necessary to convert non-linear problem into linear problem by use mapping into new plane. Figure 1 shows mapping of input plane into the linear feature plane. The SVM has been utilized in handwritten numeral recognition successfully and achieved very good generalization ability. The basic SVM is for two-class problem; thus it must be extended to multi-class when recognizing numerals.

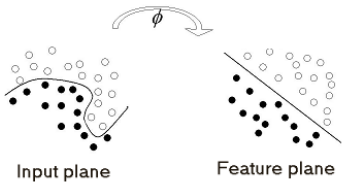

Fig. 1 mapping of input plane into linear feature plane

2.2 One-to-one SVM

The so-called one-to-one classification is constructed by selecting any two training classes to form one SVM, thus there are $n(n\text{-}1)/2$ SVMs for n-class problem. All these SVM classifiers must be used for classifying the testing samples and the synthesizing result is gotten. Figure 2 shows the structure of general one-to-one SVM. Supposed the SVM_{ij} is constructed with the ith class and jth class, and the d_{ij} is defined below:

$$d_{ij}(x) \equiv \begin{cases} +1 & x \in class \quad i \\ -1 & x \in class \quad j \end{cases} \tag{5}$$

and $d_{ij}(x) = -d_{ji}(x)$. Let $s_i(x)$ denote the reliability of the sample x, which belongs to i th class, and

$$s_i(x) = \sum_{j=1\sim n, j\ne i} d_{ij}(x) \tag{6}$$

The input sample belong to j-th class if there exists

$$s_i(x) = \max_{1\sim n} s_i(x) \tag{7}$$

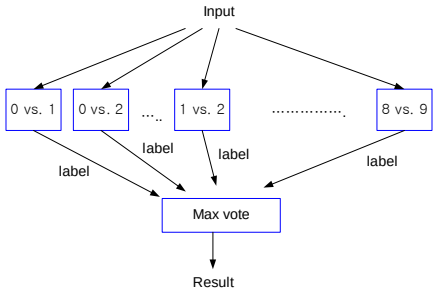

Fig. 2 The structure of one-to-one SVM algorithm

3. Character recognition of the mixed font style

3.1 Potential one-to-one SVM

A conventional one-to-one SVM usually uses the maximum voting to decide the final class. The maximum voting method has a risk that causes the wrong classification when some classes have similar votes. It is necessary to revaluate potential classes with many votes. Various algorithms as well as the one-to-one SVM can select these classes. The grouping algorithms such as k-means algorithm can be used too. However, these algorithms are not suited to template-marked digits with partially erased parts, since these parts cause the wrong classification in algorithms using euclidian distances.

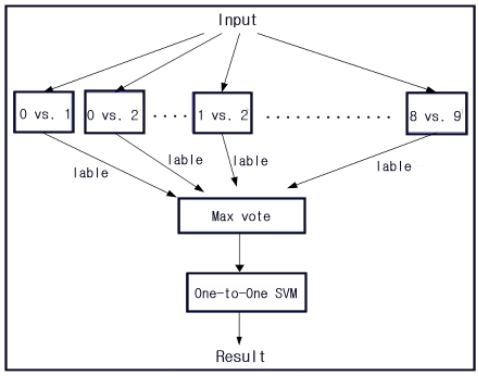

Fig. 3. Structure of potential one-to-one SVM algorithm

One-to-one algorithm for selecting potential classes is used in the recognition system. Figure 3 shows the structure of PSVM using the one-to-one structure. This algorithm selects potential classes exactly using examining all possible matches. The classes scoring more than six votes are regarded as potential classes in our system. Since the potential classes are

revaluated using different kernel SVM, this system can recognize the final class more exactly. This structure needs many calculations, and takes some long time. If n_2 are selected as potential classes, $n(n-1)/2 + n_2(n_2-1)/2$ svm classifiers are required. It's not good for a fast recognition application.

3.2 Closed curve detection (CCD) algorithm

This algorithm use closed curve, which is exist Arabic numbers, for the recognition of characters. This algorithm use binary image instead of gray image. We make labeling closed curve within numbers into any numbers except that 0, 1. And then, we extract center points of these numbers . Finally, we recognize that number by use location and number of center points. For example, we suppose that there are exist 0, 4, 6, 8 and 9 of printed- font styles. In the first, we recognize into 8 about numbers, which have two closed curve. Next, we make process about other numbers, which has one closed curve. By use value P(= closed-curve area/number area), each numbers have following relation. That is, P(0) > P(4) > P(6) = P(9). Here, numbers 0 and 4 can be recognized by use value P. Other numbers 6 and 9 can be recognized by use location of center point. For example, number 9 exist its center point at the upper side of center line and number 6 exist at the other side. But this method is not good about hand written numbers because this numbers has not any fixed pattern. Specially in the case of hand written numbers, recognition error are happened usually about numbers 0, 4, 6 and 9, which is exist one closed curve. Therefore, in the case of 0, 4, 6, and 9, other classification algorithm are required to improve recognition rate.

3.3 CCD & PSVM algorithm

The PSVM algorithm need some more time than the conventional KLT or SVM algorithm. The CCD algorithm makes shorter classification time than the PSVM algorithm. In this paper, we propose combination of CCD and PSVM classification algorithm. PSVM algorithm makes higher recognition rate and CCD algorithm make shorter classification time. We make use advantages of these two algorithms for the recognition of handwritten characters. Figure 4 shows structure of CCD & PSVM algorithm.

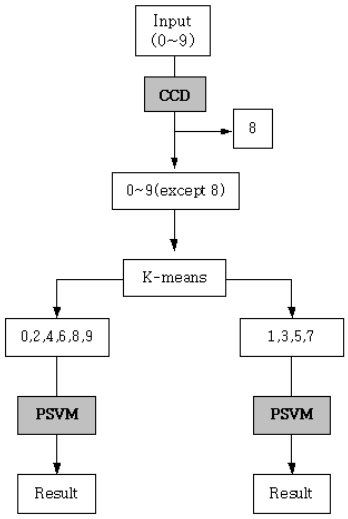

Fig. 4. Structure of CCD & PSVM algorithm

In the first step, extract number 8, which have two-closed curve, by use CCD algorithm. Next, use tree structure SVM of each different structure about 0~9, except 8. For this classification, K-means algorithm is used to classify numbers, which has a one closed curve, from the first step. By use CCD algorithm, Arabic numbers, 0~9(except 8) are classified into two classes, which have one closed curve (0,2,4,6,9) and others (1,3,5,7). Finally, characters of each class are recognized by use PSVM algorithm. This method compensate PSVM algorithm by use CCD algorithm.

4. EXPERIMENTAL RESULTS

For the experiment, we have used billet character image. Figure 5 shows two kinds of mixed font style in the billet image and figure 6 shows template-marking plate. The Arabic numbers in the template-marking font does not have closed curve.

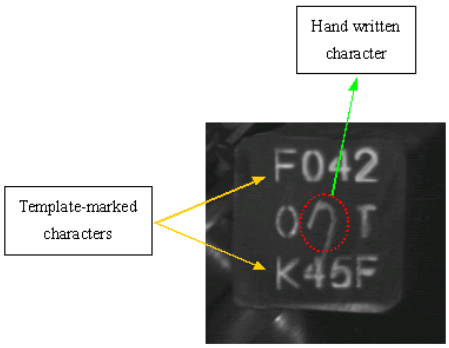

Fig. 5. Two kinds of characters for the billet image

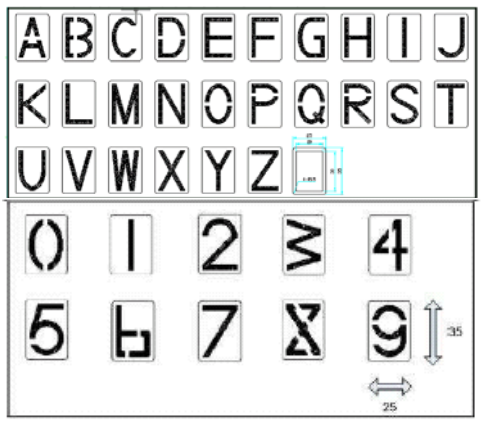

Fig. 6. Template-marking plates

For the testing of algorithm, we used 100 billet images, which were captured by CCD camera in the steel processing line. The characters of billet image are composed with template-marked characters and hand written characters. We have compared our algorithm with conventional methods such as KLT classifier and one-to-one SVM. Figure 7 shows experimental results about template-marked billet image and Figure 8 shows experimental results about handwritten character of template-marked billet image. As shown Figure 6, The Arabic numbers in the template-marking font does not

have closed curve. Therefore, These characters don't need CCD algorithm for the classification. The recognition rate of experimented billet characters shows that the proposing PSVM algorithm is 97 % for the template-marked characters and combinational algorithm of CCD & PSVM is 95.5 % for the hand written characters. Figure 9 show system configuration for the real time character recognition system for the steel processing line. In the steel plant, recognition rate are affected by the circumstance of processing line. Therefore, it's very important to overcome hazard circumstance of the steel plant.

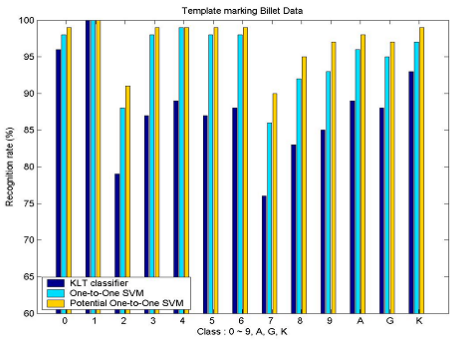

Figure 7 Experimental results about template-marked billet image.

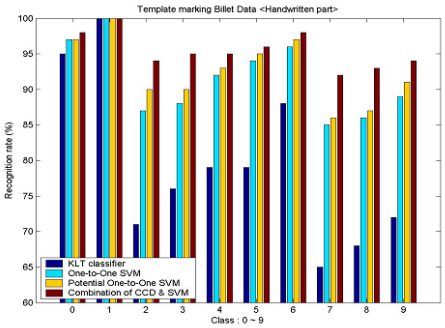

Figure 8 Experimental results about handwritten character of template-marked billet image.

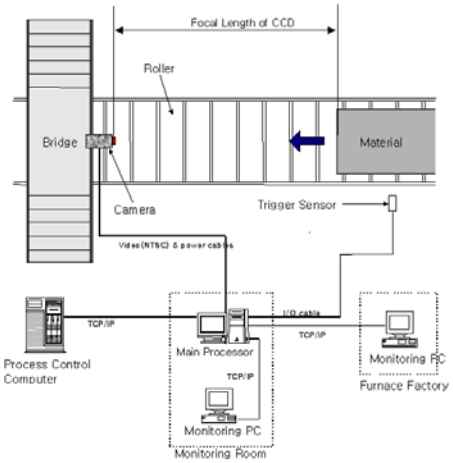

Figure 9 System configurations for the real time character recognition system for the steel processing line.

4. CONCLUSIONS

In this paper, we described about the development of real time billet characters recognition system for the mixed font style in the steel production line. The recognition rate of experimented billet characters shows that the proposing PSVM algorithm is 97 % for the template-marked characters and combinational algorithm of CCD & PSVM is 95.5 % for the hand written characters. The experimental results show that our proposing method has higher recognition rate than that of the conventional methods for the template-marked characters and hand written characters. By using our algorithm, we have installed real time character recognition system at the billet processing line of the steel-iron plant, and we will continue testing for the improvement of reliability and durability.

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