Development of character recognition system for the billet images in the steel plant

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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 realtime billet characters recognition system in the steel production line. Normally, the billets are mixed at yard so that their identifications are very difficult and very important processing. The character recognition algorithm used in this paper is base on the subspace method by K-L transformation. With this method, we need no special feature extraction steps, which are usually error prone. So the gray character images are directly used as input vectors of the classifier. To train the classifier, we have extracted eigen vectors of each character used in the billet numbers, which consists of 10 arabia numbers and 26 alphabet aharacters, which are gathered from billet-images of the production line. We have developed billet characters recognition system using this algorithm and tested this system in the steel production line during the 8-days. The recognition rate of our system in the field test has turned out to be 94.1% (98.6% if the corrupted characters are excluded). In the results, we confirmed that our recognition system has a good performance in the poor environments and ill-conditioned marking system like as steel production plant.

Keywords: billet, character recognition, KLT

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 have 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 realtime billet number recognition system in the steel production line. Normally, the billets are mixed at yard so that their identifications are hardly tractable. The character recognition algorithm used in this paper is base on the subspace method by KLT(Karhunen-Loeve Transformation) [2]. With this method, we need no special feature-extraction steps, which are usually error-prone. So the gray character images are directly used as input vectors of the classifier. To train the classifier, we have extracted eigen vectors of each character used in the billet numbers, which consists of 10 arabia numbers and 26 alphabet aharacters, which are gathered from billet-images of the production line. We have developed billet characters recognition system using this algorithm and tested this system in the steel production line during the 8-days. The recognition rate of the classifier in the field test has turned out to be 94.1% and could be more improved to 98.6% if the corrupted characters are excluded. By through the field test, we confirmed that our recognition system has a good performance in the poor environments and ill-conditioned marking system. In some cases, wrong qualities of billets are injected into heating furnace, which result in bad quality products. To prevent miss-injection, the billets are monitored by CCTV, which is installed in front of heating furnace. To build billet-tracking control, the automatic billet identification is necessary condition.

2. Karhunen-Loeve transformation

The Karhunen-Loeve(K-L) decomposition [3][4], named after Karhunen [5] and Loeve [6], is used in many different applications that deal with large data sets. In the literature, K-L decomposition is known by several different names. It is known as empirical othogonal functions, quasiharmoic modes, singular value decomposition, Hotteling transform, proper othogonal decomposition and principal component analysis. In these approaches, K-L decomposition was used as either a compression tool or as a feature identifier. In the last few years, K-L decomposition has been used extensively by Smaoui *et al*., in fluid flow in porous media, in the analysis of sand stones, and in the study of flames. In face recognition, K-L decomposition was used by Smaoui

and Matar [7]. In this paper, recognition method by K-L transformation is use secondary variance of input data. If we define that input pattern $x = [x_1, x_2, \ldots, x_N]^T$ is random vector in the vector space of N-th order and c_x , m_x are covariance matrix, mean vector, respectively. Then we can denote as follows,

$$m_x = \mathrm{E}[x] \quad (1)$$
$$c_x = \mathrm{E}[(x-m_x)(x-m_x)^T] \quad (2)$$

Because c_x has a real number value and symmetry matrix form. There are exist eigen value, which has a positive value of N numbers, and eigen vector of each eigen values. Eigen vectors of each different eigen values are mutually orthonormal. Let assume that λ_i , φ_i are the eigen value, eigen vector of c_x , respectively and λ_i is arranged in order of $\lambda_i \geq \lambda_{i+1}$ ($i = 1, 2, \ldots, N-1$). Then, eigen vector matrix, Φ is represented as follow,

$$\Phi = [\varphi_1 \ \varphi_2 \ \ldots \ \varphi_N] \quad (3)$$

First column of matrix Φ has a eigen vector, which has a maximum eigen value and last column of matrix Φ has a eigen vector, which has a minimum eigen value. If we define Φ^T as a transform matrix, which has transform x into y. Then, we obtain following equation that

$$y = \Phi^T (x - m_x) \quad (4)$$

In Eq. (4), we designate y as a Karhunen-Loeve transformation and Φ^T as a Karhunen-Loeve transformation matrix. In this case, transformed new random vector has following properties.

$$m_y = \mathrm{E}[y] = \Phi^T(\mathrm{E}[x] - m_x) = 0 \quad (5)$$

$$\begin{aligned} c_y &= \mathrm{E}[(y - m_y)(y - m_y)^T] \\ &= \mathrm{E}^T c_x \mathrm{E} \\ &= [a_{ij}] \end{aligned} \quad (6)$$

here, $i, j = 1, 2, \ldots, N$

$$a_{ij} = \begin{pmatrix} \lambda_i & for \quad i = j \\ 0 & otherwise \end{pmatrix}$$

Therefore, each components of vector y, which was transformed by KLT, is mutually uncorrelated. In generally, the size of eigen vector of K-L transformed vector, y is N when the size of input vector is N. Most of transformed energy is concentrated in the M-dimensional space (M≤N).

3. Billet characters recognition

We applied several image processing steps for the recognition of management characters from the billet image. Fig. 1 represents flowchart of our character recognition algorithm. In the processing line, billets can be rotated to the any directions, which are 0°, 90°, 180°, 270°. we should consider this rotation at the first step. In the case of rotation, 90°, 270°, it can be more easily distinguished than the rotation, 0°, 180° by the comparison of a format of character string and numbers of individual characters within a character string.

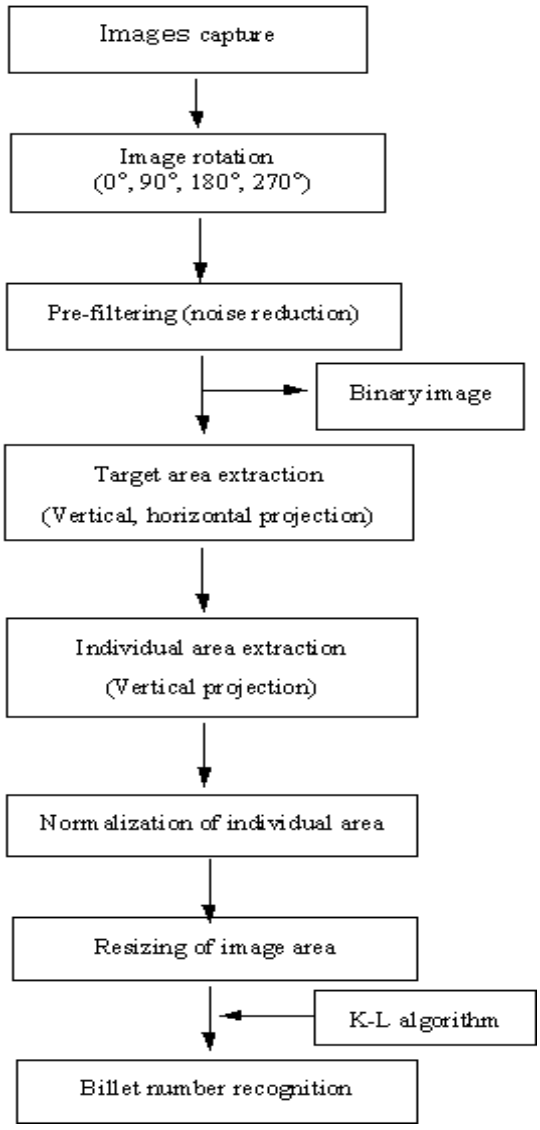

Figure 1. Flowchart for the recognition.

In the case of rotation, 0°, 180°, we have distinguished their rotation angle using the voting methods, which are based on recognition rate. In this paper, we compare their reconstruction error in the domain of KLT and inverse KLT between input character and candidate characters. Candidate characters, which are predefined, are alphabats 26 and arabia numbers 10. The character classification is need to find a final character, which has a minimum reconstruction error between input character and candidate character. The reconstruction error is calculated by a $\varepsilon = \|x - \hat{x}\|^2 = \|x - m_x\|^2 - \|\hat{y}\|^2$ Here, the parameters are as follows, x : input vector, $\hat{x}$: inverse transformed vector of

x , m_x : mean of x , $\hat{y}$:K-L transform about the subspace area. Horizontal or vertical projection methods were used for the extraction of a border. Fig. 2 represents the references for the projection. Low pass filter was applied in the pre-filtering and binary images were used for the better extraction of a border. The individual character areas, which have some different size, are normalized to the same size, 40×40 and then, image size of these individual characters are resized for the reduction of the computing time.

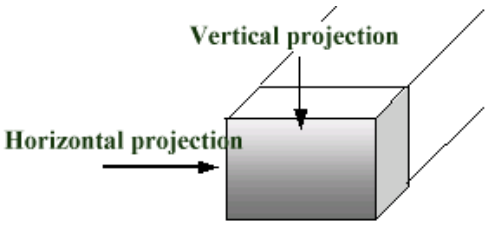

Figure 2. The references for the projection.

4. Experiments and results

In the steel production line, the molten metal of a furnace is transformed into 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 their processing steps of this billet, material management characters are marked in their front area. We designed image processing system for the acquisition of the billet images, which is marked material management characters. The CCD camera has located at the input side of heating furnace of the hot rolling mill. Therefore, billet images are acquired before it is transferred to the heating furnace. Fig. 3 represents system layout for the real time image acquisition of billet.

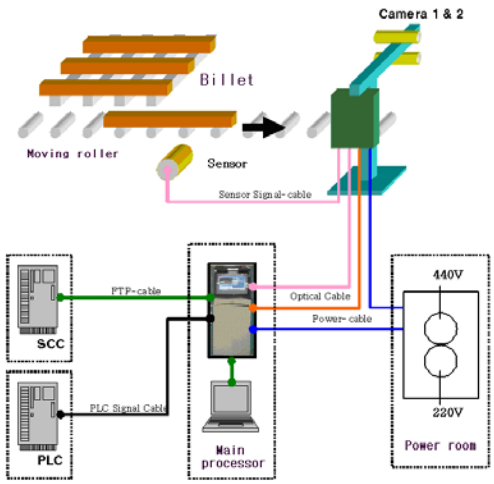

Figure 3. System layout for the image acquisition

Trigger sensor sends a trigger signal to the camera controller whenever the billet is arriving at the target zone. Frame grabber of a main processor captures these billet images by the synchronization with trigger signal. Main processor communicate with peripheral equipments by use of TCP/IP protocol. Fig. 4 represents signal interfacing of image processing system. The billets are located at the processing line and main processor are located at the monitoring room of branch factory. Distance between processing line and monitoring room is about 200~300 m. The image between these system are transmitted through optical cable. For the experiments, we used CCD camera of PLUNIX TM-6702, which has supporting 768 × 484 image size and 256 gray level. Frame grabber, Matrox Meteorl-II of PC is connected with CCD camera. Trigger sensor for the capturing of billet image are Simens-SRG6. For the stability of gray image in the billet processing line, we shined a halogen lamp on the cross section of a billet. Fig. 5 represents captured image of a billet. The font style of billet characters are various. Fig. 6 represents these fonts.

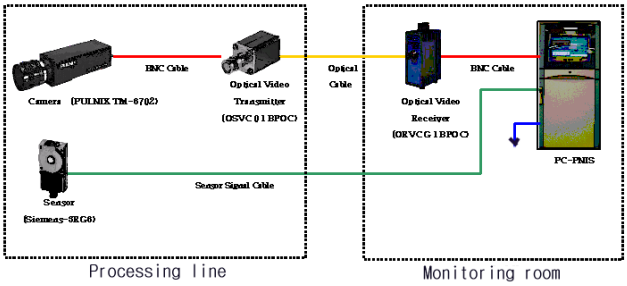

Figure 4. System interface for the image processing

Figure 5. Captured image of a billet

Figure 6. Font style of a billet images

For the application of K-L algorithm and training of the classifier in the character recognition. we constructed training set of each characters, which consists of 10 arabia numbers and 26 alphabet aharacters. The character images can be rotated to the 0°, 90°, 180° or 270°. The numbers of character image have two character string in the normal state. Therefore, in the case of rotated 90°, and 270°, two strings from the top side are selected for the character recognition. In the field test, we applied our system to the billets. Our system has located at the input side of heating furnace in the wire rod mill line. Test time was 8-days and 2503 billets were used for the test. The recognition rate of the system in the field test has turned out to be 94.1%. the cause of the recognition fail is classified into three types. Two types are cannot recognize by humaneyes as well as comuter system. These cases include 113 billets(4.5%). Only one type among the failed three cases could not recognized by our system despite the normal state. This case include 34 billets(1.4%). Therefore, the maximum recognition rate of our recognition system can be increased to the 98.6% if the corrupted characters are excluded.

Table 1. test results

test results	**state of billet**	**numbers of test billets**	**recognition rate**
successed	normal	2356	2356 (94.1%)
failed	different marking style	16	147 (5.9%)
	character damage	97	
	normal	34	
total	2503		2503(100%)

5. Conclusion

In this paper, we described about the development of realtime billet characters recognition system in the steel production line. The character recognition algorithm used in this paper needs gray image. So the gray character images are directly used as input vectors of the classifier. For the experiment, we have tested our system during few days in the steel production line. The maximum recognition rate of our recognition system could be increased to the 98.6% if the corrupted characters are excluded. In the results, we confirmed that our recognition system has a good performance in the poor environments and ill-conditioned marking system. In the future, we will continue out test at the wire rod mill of the steel production line.

References

[1] K. Fukunaga, Warren L.G. Koontz, “Application of the Karhunen-Loeve expansion to feature selection and ordering,” IEEE trans. on computers, Vol. C-19, No. 4, pp. 311-318, 1970.

[2] S. Watanabe, “Karhunen-Loeve expansion and factor analysis theoretical remarks and applications,” Proc. 4th Prague Conf. Inform. Theory, 1965.

[3] Karhunen K, “Uber lineare methoden in der Wahrsccheillichkeitsrechung,”annales academiae scientiarum fennicae, seried *AI*: mathematica-physica, pp. 3-79, 1947.

[4] G. Schweitzer, “Mechatronics for the design of human oriented machines,” IEEE/ASME Trans. on Mechatronics, Vol. 1, pp. 120-126, 1996.

[5] Jeong-Hoe Ku, “Design of freight train ID number recognition system based on Karhunen-Loeve transform ,” thesis of master degree of Pohang university of science and technology, 1994.