A STUDY ON PERCEPTION METHOD OF THE MARKING LOCATION FOR AN AUTOMATION OF BILLET MARKING PROCESSES

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Abstract: The machine vision has been applied to a number of industrial applications for quality control and automations to improve the manufacturing processes. In this paper, the automation system using the machine vision is developed, which is applicable to the marking process in a steel production process line. The working environment is very harsh to workers so that the automatic system in the steel industry is required increasingly. The developed automatic marking system consists of several mechanical and electrical elements such as the laser position detecting sensor system for a structured laser beam which is projected to the billet in order to detect the geometry of the billet. An image processing algorithm has been developed to percept the two center positions of a camera and a billet, respectively, and to align two centers. A series of experiments has been conducted to investigate the performance of the proposed algorithm. The results show that two centers of the camera and the billet could be detected very well and differences between two center positions could be also decreased via the proposed tracking algorithm.

Keywords: Machine Vision, Vision Sensor, Automatic Marking System, Structured Light

1. INTRODUCTION

The machine vision has been applied to a number of industrial applications for quality control and automations to improve the manufacturing processes. In this paper, the automation system using the machine vision is developed, which is applicable to the marking process in a steel production process line. The working environment is very harsh to workers so that the automatic system in the steel industry is required increasingly. Steel is one of the world's most widely used materials. The production process of steel can be classified four sequential processes such as iron making, steel making, continuous casting and rolling processes. After iron and steel making processes, the crude steel is poured into a continuous caster equipped with a water-cooled mold that solidifies the outer surface of the steel and give it its basic form. The slowly solidifying steel is then drawn through a series of rollers that shape it into one of three major semi-finished products such as slabs, blooms, or billets. They are the basic forms from which all finished steel products are made. Among these, the billets are rolled into long products such as beams, bars, rails. A side of cutting plane is from 60 to 160 mm and the length ranges from 1m to 9m. After finishing continuous casting process for the billet, the marking on the side cutting plane is needed for representing manufacturing information. Marking on the billet is done with marking machine. Most of them can be categorized into two groups. One is mechanical guidance method and the other one is machine vision method.

However, because most of marking machines work through mechanical guidance, there are several troubles in marking process. One of them is a misalignment which could take place between a marking machine and a billet. This misalignment can make failure goods and induces a decrease of productivity.

This work has developed an automatic marking system that can detect the amount of the misalignment above mentioned and can correct it. For sensing the misalignment, the structured laser images are adapted and the design of a structured light source system is considered as well. The detecting system and the tracking algorithm are so simple that the proposed automatic marking system can be applicable to industry easily.

2. BILLET AUTOMATIC MARKING SYSTEM

2.1 Configuration of Automatic Marking System

The developed automatic marking system consist of several mechanical and electrical elements such as the laser position detecting sensor system for structured laser beams, a frame grabber for image capturing, a computer system for calculation, a manipulator for moving a marking machine, controller and power supply. The configuration of the marking system is explained schematically in fig. 1. The laser position detecting sensor system is the most important element which can implement our idea for detecting the position error between a marking machine and a billet.

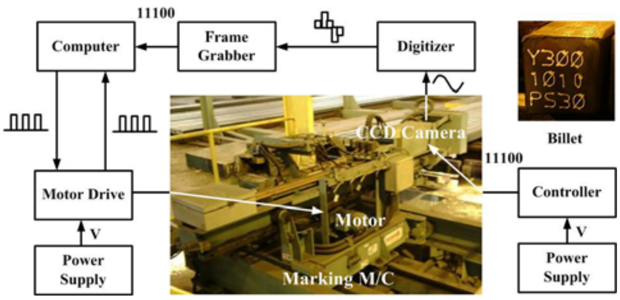


Fig. 1 Billet Automatic Marking System

2.2 Laser Position Detection Sensor System

The proposed sensor system consists of a CCD camera and four line type structured light sources. As being shown in fig. 2, each laser light stripe source is installed perpendicularly. The proposed simple light pattern is projected to the billet, and the pattern reveals the geometry of the billet such as the rotation angle and the center position. Especially, the turn on/off of each light source can be controlled separately. In case all light sources is turned on, the image will be what is shown in fig. 3. It is important to note that the geometrical configuration and the separate turn on/off of light source are main idea of the proposed laser position detecting sensor system. The CCD camera is a Sony XC-711 with digitizer configuration NTSC. The lens is used with 12.5mm-75mm Zoom Lens.

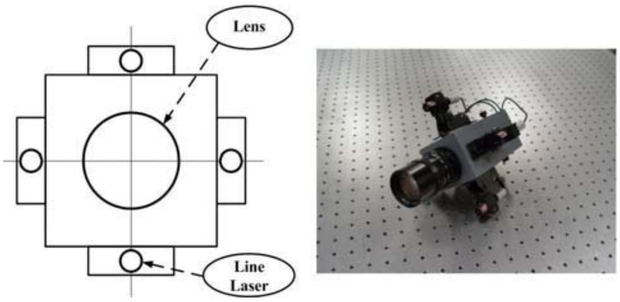


Fig. 2 Laser Position Detecting Sensor System

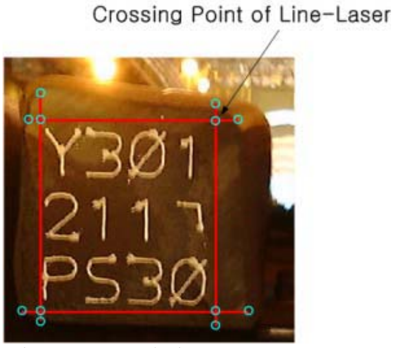


Fig. 3 Image of Line-Laser

2.3 Pre-Processing

Through the pre-processing, five low level images are acquired sequentially. The pre-processing is explained schematically in fig. 4. In first step of the pre-processing the basic image is acquired without any laser stripe pattern on the billet. After that, 4 different line laser images are acquired as just only one light source turn on sequentially. Therefore each line laser images contains only one vertical or horizontal line pattern. The examples of the basic image and the line laser image are shown in fig. 5 respectively.

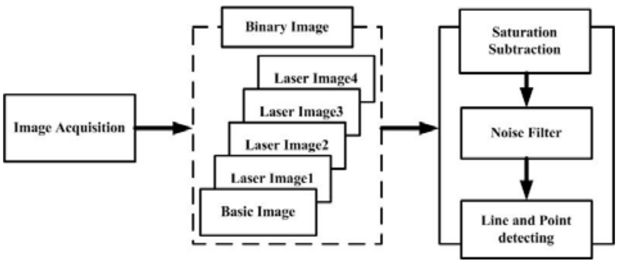


Fig. 4 Schematic Diagram of Pre-Processing

We create five threshold binary images $I_{binary}(x,y,j)$ by defining. [3]

$$I_{binary}(x,y,j)=\begin{cases}1, & if\ I(x,y)>thresholding\\ 0, & otherwise\end{cases}, \quad (1)$$

where j=basic, 1, 2, 3, 4

By applying equation (2), the four subtracted images $I_{new}(x,y,k)$ are resulted in. [3]

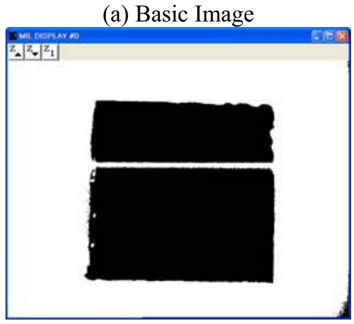
$$I_{new}(x,y,k)=\{I_{binary}(x,y,basic)-I_{binary}(x,y,k)\}, \quad (2)$$

where k=1, 2, 3, 4

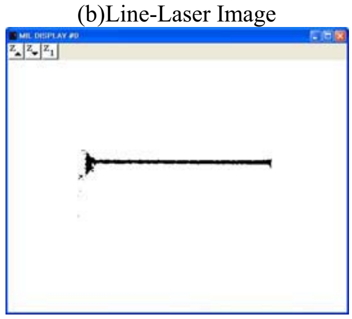
The basic image means the background image of the other images. However the background images are not exactly same because there exist the time delay of each image acquisition and environmental noises. In order to eliminate wide meaning noises in the binary image, the algorithm of morphology is used. [4]

After pre-processing of images, the resultant image is shown in fig. 5.

(a) Basic Image



(b)Line-Laser Image



(c) Subtracted Image

Fig. 5 Resultant Images of Pre-Processing Processes

3. IMAGE PROCESSING ALGORITHM

The image processing algorithm in this work has two folds, which are the center position detecting algorithm and the location tracing algorithm. The center position detecting algorithm determines the center positions of the billet and that of the camera respectively. In order to calculate the coordinates of each center points, it is needed to determine the twelve points circled in fig.3 Based on four line-laser images, the crossing point could be acquired very quickly with comparing these four images. After that, the edge points of billet could be determined as well.

If we find the coordinates of above mentioned 12 points as shown in fig. 6, the four new points in fig. 7 could be calculated as following equation (3)

$$\overrightarrow{Q1}_{xy}=\frac{1}{2}(\overrightarrow{P1}_{xy}+\overrightarrow{P8}_{xy}),\ \overrightarrow{Q2}_{xy}=\frac{1}{2}(\overrightarrow{P2}_{xy}+\overrightarrow{P3}_{xy})$$
$$\overrightarrow{Q3}_{xy}=\frac{1}{2}(\overrightarrow{P4}_{xy}+\overrightarrow{P5}_{xy}),\ \overrightarrow{Q4}_{xy}=\frac{1}{2}(\overrightarrow{P6}_{xy}+\overrightarrow{P7}_{xy}), \quad (3)$$

From the coordinates of the new points, the coordinates of the camera center position can be calculated by equation (4) and the coordinates of the billet center position by equation (5).

$$\vec{O}_{cx} = \frac{1}{2}(\overrightarrow{P13}_x + \overrightarrow{P10}_x)$$
$$\vec{O}_{cy} = \frac{1}{2}(\overrightarrow{P10}_y + \overrightarrow{P11}_y) \quad , \qquad (4)$$

where $\vec{O}_{cx}$, $\vec{O}_{cy}$ are the coordinates of camera center position in X and Y direction

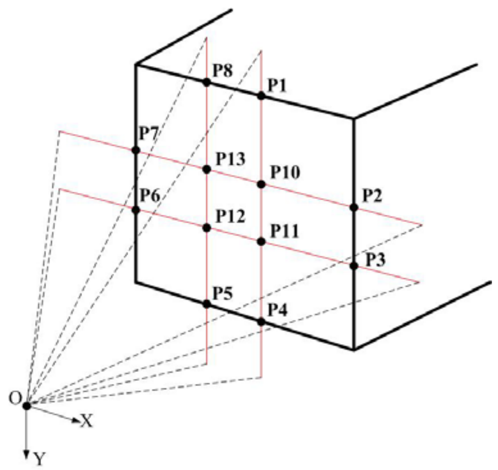


Fig. 6 Coordinate of the Line-laser Image and The Billet (Coordinate of 12 points)

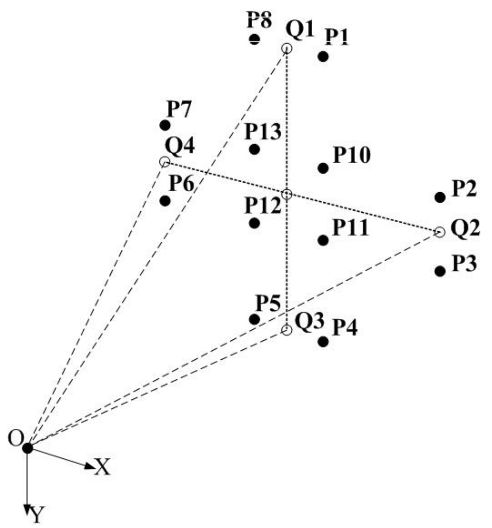


Fig. 7 The Coordinates of New Points for determining the center

$$\vec{O}_{ox} = \frac{1}{2}(\overrightarrow{Q4}_x + \overrightarrow{Q2}_x)$$
$$\vec{O}_{oy} = \frac{1}{2}(\overrightarrow{Q1}_y + \overrightarrow{Q3}_y) , \qquad (5)$$

where $\vec{O}_{ox}$, $\vec{O}_{oy}$ are the coordinates of billet center position in X and Y direction

If there is the position error between the coordinates of camera center position and the coordinates of billet center position, the location tracing algorithm activates the controller for moving marking machine until the amount of the position error is less than ε. The ε is defined by

$$\| \vec{O}_{cxy} - \vec{O}_{oxy} \| \ \leq \ \varepsilon , \qquad (6)$$

4. EXPERIMENT

The set of experiments was designed to investigate the performance of the proposed automatic marking system. For experimental convenience, we carry out experiments with X-Y table in laboratory instead of a marking machine in industry. The picture of experimental apparatus and testing target billet are shown in fig. 8. The billet size is about 130×132mm and the camera is installed at position of 1m above X-Y table as shown in fig. 8.

(a) (b)

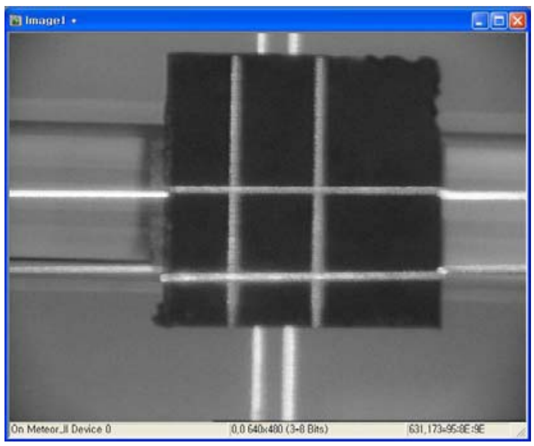
Fig. 8 Experimental Apparatus and Testing Target Billet

The experiments are carried out about two case as followings

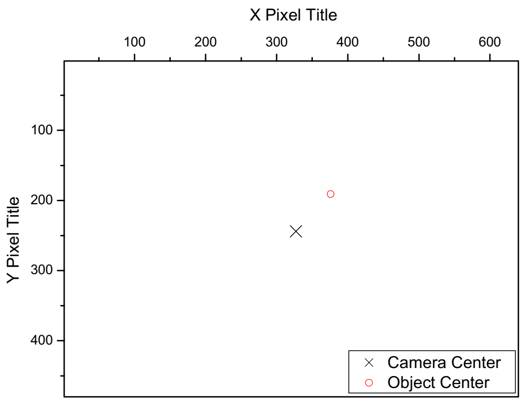
1) normal case: There is no orientation of billet
2) rotational case: There is some orientation of billet

4.1 Normal Cases of Billet Position

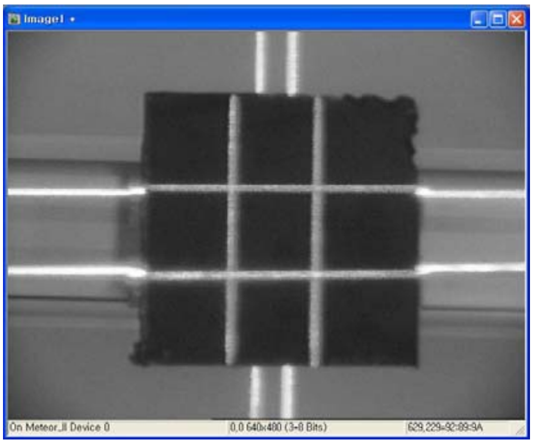
After moving the center of billet to 20mm in X and Y direction, the experiments are carried out and result is shown in fig. 9.



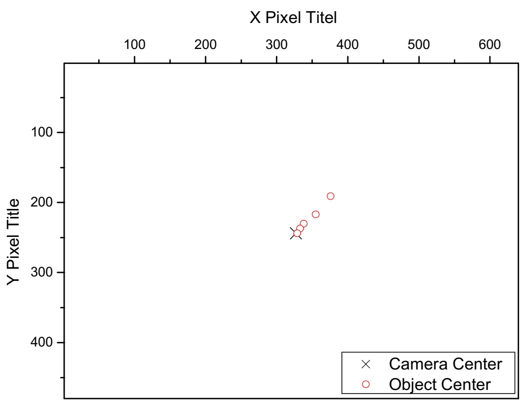
(a) Gray Level Image before the location tracing algorithm



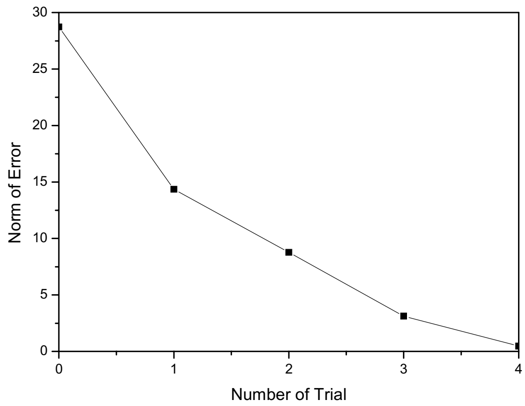
(b) The center position of the billet and the center position of the camera



(c) Gray Level Image after the location tracing algorithm



(d) The positions of camera center and billet center as the location tracing algorithm is running



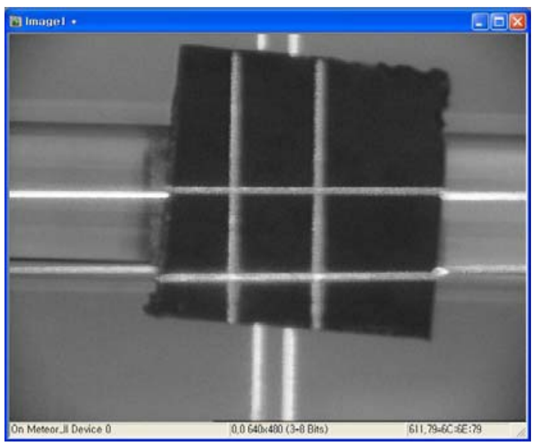
(e) The position error between two centers as the location tracing algorithm is running

Fig. 9 Experimental result of normal cases

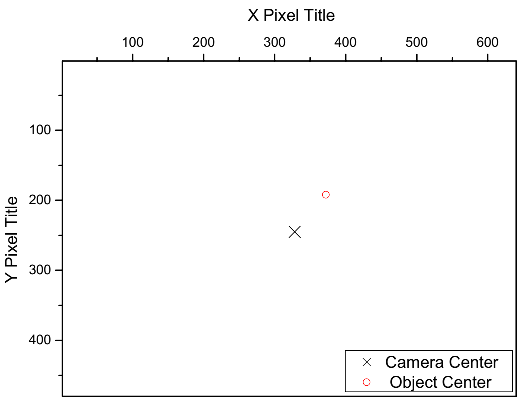
Fig. 9(a) shows an image of the structured light beams on the billet located at on initial position. A square of the structured light image can be shown at left and lower part on the billet. Thus, some mis-alignment between camera and billet center could be also detected so that the marking could not be done appropriately under this position. The difference between both center positions can be detected as shown in fig. 9(a) through the series of calculation as mentioned above in image processing algorithm. Then, the center tracing algorithm will be activated for the both center positions to be aligned as shown in fig. 9(b). Fig.9(c) shows the resulted gray level image of the billet after the location tracing algorithm. In this figure, we can see that the square of the structured light is located on the center part of the billet. In this algorithm, the marking processes could be performed successively. Fig. 9(e) shows that the position error norm between two centers is decreased gradually. Thus the final error between two centers is very small so that the camera center is located on the center of the billet.

4.2 Rotational Cases of Billet Position

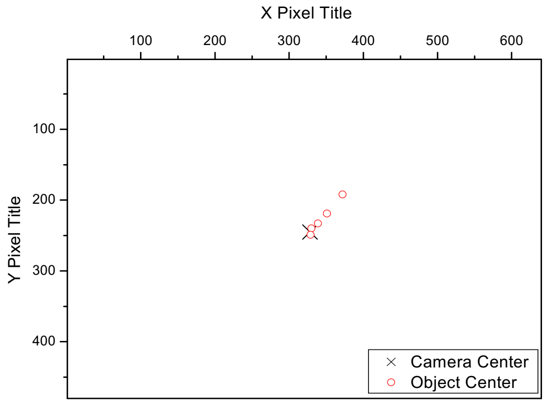
After moving the center of billet to 20mm in X and Y direction and rotating the billet some angle, the experiments are carried out and the result is shown in fig. 10.



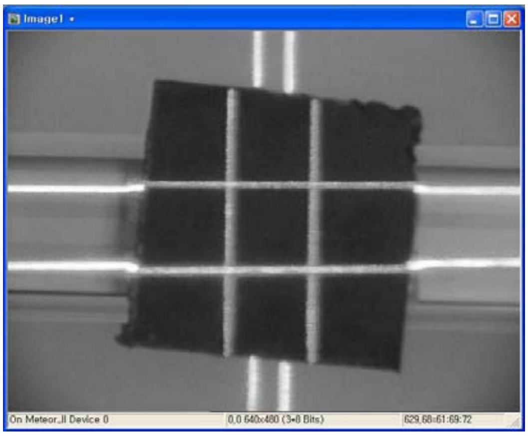
(a) Gray Level Image before the location tracing algorithm



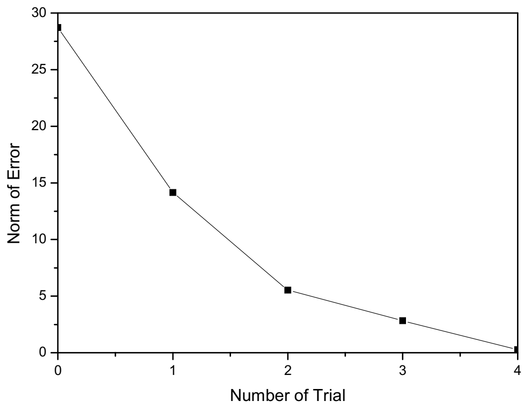
(b) The center position of the billet and the center position of the camera



(d) The positions of camera center and billet center as the location tracing algorithm is running



(c) Gray Level Image after the location tracing algorithm



(e) The position error between two centers as the location tracing algorithm is running

Fig. 10 Experimental result of rotational cases

Fig. 10(a) shows also an image of the structured light beams on the billet located and rotated at an initial step. In this figure, we can see that the square of the structured light is also located at left lower part on the billet. After the image processing and the center tracing algorithm are performed with similar processes as the above, the result image of the structured light on the billet is obtained as shown in fig. 10(c). We can conclude that the square of the structured light is also located on the center part of the billet even if the billet is slightly rotated. The error norm between two center positions is also decreased dramatically as shown in fig. 10(e).

5. CONCLUSIONS

This paper made effort to measure accurate the position and rotation information of the billet with the proposed simple vision sensor system and the simple algorithm. Especially this paper made effort to develop smart algorithm which is optimized in marking on the billet in the steel industry so that it could reduce computational time and could be robust against variations of environment. The experiments are carried out for evaluating the proposed algorithm and sensing system.

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REFERENCES

[1] D.Q. HUYNH, R.A. OWENS and P.E. HART MANN, "Calibrating a Structured Light Stripe System: A Novel Approach.," International Journal of Computer Vision 33(1), pp. 73-86, 1999.

[2] Scoutt. E. Umbaugh, "Computer Vision and Image Processing, Prentice Hall PTR," pp. 41-44, 1988.

[3] RANDY CRANE, "A Simplified Approach to Image Processing: (Classical and Modern Techniques in C), " Prentice-Hall, 1997.

[4] Chil-Woo Lee, Man-Jin Kim and Myung-Souk Ki, "A Visual Inspection System for Gravure Printing Using Perimetric Mask and Symmetry Transform Algorithm" Journal of Control Automation and System Engineering, pp. 984-994, 2003.

[5] K. E. Sung and S. H. Rhee, "High speed seam tracking using multi-line laser vision sensor," Journal of the Korean Society of Precision Engineering, pp. 584-587, 2002.