Computer Vision System for Defect Detection of Hot Rolling Products

Ahmet ÇELİK

Tavşanlı Vocational School, Dumlupınar University, Kütahya, Turkey

Abstract—Detecting defect is the most required and important step in the production process. Computer aided defect detection can provide precise and fast solution. Detecting the defective products during production process is both cost-effective and prevents time-loss. In this study, a system is developed to detect defects during hot rolling operation using image processing methods. The rail and profile images are obtained by CMOS camera when they are rolled. By analyzing these images, different types of defects could be identified by using the different gray values for defective and non-defective regions. Defective areas cannot be seen clearly on the images with gray values. Therefore, image processing algorithms have to be used on the obtained images. Defective regions can be indicated by using colored segmentation. This study is applied in rolling mill of Karabük Inc and is shown on feature identification for rail and profile surface’s defects.

Index Terms—Defect detection systems, Computer aided manufacturing, Image processing, Hot rolling systems.

I. INTRODUCTION

Automatic defect detection systems are used in several different fields. Nganet. al used such a system for detecting fabric defects [1]. In industrial processes, computer vision has been widely used to introduce solutions to encountered problems [2].

Many image processing algorithm used for object detection or region detection[3]. Defect detection on rail and profile surface could be done by image processing. In order to enhance defect determination performance results on rail surfaces, segmentation could be done on the image. Feature identification methods are not adequate alone for this detection. There has been some studies on detecting defects on flat products. Luo and He suggested an automatic detection system for flat steel[4]. Defect types of rail and profiles produced in hot rolling mill are similar to those of flat steel. Fig. 1 is showing defective region of real rail image.

Defect determining system consists of five stages (Fig. 2). Use of all the operation stages affects the performance significantly. Image obtaining stage is the recording images with CMOS camera. In the “Pre-treatments on the Image” stage, the gray image is turned into colored. The color values generated with the pixel segmentation operation help to identify defective area as pit or bump depending on the features of the defect. This stage is the most important stage of defect determining. Different colored regions then could be determined as defects or not. If there are any defective areas, they will be marked.

![Defect Image](image)

Fig. 1 Real defective rail image

II. IMAGE PROCESSING

Processing large amount of gray images with computer system can be fast and yield high performance [5]. The images of CMOS camera are gray in color. Processing these images and introducing color segmentation on these can help us in image analysis. Different kinds of defects then must be realized on the images. In this respect, standard deviation method can be considered [6].

A. Image Acquisition System

High quality images required for image acquisition of hot rolling production to achieve best performance. The camera used in the system has high resolution...
feature. CMOS Camera takes images according to reflected laser light source (Fig. 3).

![CMOS Camera and laser source](image)

The rails could be produced in different lengths, 32 meter to 72 meter, in rolling mill of Karabuk Inc. Rail or profile rolling speed can reach up to 7 meter per second.

Image gathering system is established in rolling mill before cooling section (Fig. 4).

![Image obtaining system](image)

An example of real profile image is illustrated in Fig. 5. At this stage, rail or profile’s temperature could reach to 1,000°C. Hence, it could be difficult to get the images.

![Newly produced profil image](image)

**B. Gray and Colored Image**

Both gray image and colored image acquired through analysis of the gray image give information about rail surfaces (Fig. 6). The gray image is the directly obtained from the capturing system. The colored image is the segmented image as a result of colored-segmentation [7, 8].

![Gray image and segmented colored image](image)

Rail and profile shapes differ from one to another. CMOS camera shows these differences through gray color distribution. Because the camera takes the image in gray, the differences among the gray values show us the surface distribution.

![Gray pixel values on the rail surface](image)

**C. Forming Colored-defective Area out of Gray Image**

Changes in gray image values are important in distinguishing defects [9]. High gray values show bump type of defect whereas low gray values show pit defect [10]. Fig. 7 shows gray value change in rail surface. The important factor here is to prevent perception of the pit area of the rail as defect. Therefore, the gray images of rail surface should be analyzed in column-based.

![Gray pixel values on the profile surface](image)

The gray value change on profile surfaces is different than those on the rail surfaces (Fig. 8). The gray value of the pit area of the profile is low but that of the edges is high. The defect determining system is supposed to mark only the defective areas by taking gray value changes due to rail structure into consideration.

![Gray pixel values on the profile surface](image)

In the gray image, different point values are seen in the color scale [11]. Fig. 9 shows the values on the
gray rail image taken by CMOS camera. Color value is defined by RGB (Red, Green and Blue) values.

Red, Green and Blue values exist in every pixel. Average of these values gives the gray value. For image processing, OpenCV library provides useful means to obtain pixel values [12]. Calculating gray value is given below:

\[
gray\_value = \frac{red + green + blue}{3}
\]  

(1)

Fig. 9. Gray values in different areas

III. COLMSTD ALGORITHM

COLMSTD (Standard Deviation of Column) image processing algorithm is based on mean of column and standard deviation of column. It classifies pixels having gray values greater than specified threshold level. On hot rolling production images, column operations are used because of rail structure [13]. Fig. 10 shows image processing method of rail image.

Defected images are need to be separated from other images. Separation process is last step of COLMSTD algorithm. Accordingly:

\[
I_{n,m} \neq 0
\]

\[
\text{if} \left| I_{n,m} - C_m \right| \leq S_m D_m
\]

\[
\text{Not \ defect} \rightarrow (O_{n,m} = 0)
\]

\[
\text{else if} \left| I_{n,m} - C_m \right| > 2
\]

\[
\text{Class \ 1 \ defects} \rightarrow (O_{n,m} = 255)
\]

\[
\text{else} \left| I_{n,m} - C_m \right| > 1.5
\]

\[
\text{Class \ 2 \ defects} \rightarrow (O_{n,m} = 150)
\]

(2)

Where \( I_{n,m} \) is the gray value of each pixel of image, \( C_m \) is the mean of column and \( S_m D_m \) is the standard deviation of column pixel values. \((O_{n,m} = 0)\), \((O_{n,m} = 255)\) and \((O_{n,m} = 150)\) are results of COLMSTD algorithm [14].

\[
C_m = \frac{1}{H} \sum_{n=0}^{H} I_{n,m}
\]

(3)

Where \( H \) is the height of image. Standard Deviation is important parameter for detecting defects and shown below [14].

\[
S_m D_m = \sqrt{\frac{1}{H} \sum_{n=0}^{H} (I_{n,m} - C_m)^2}
\]

(4)

In generally defect regions are indicated in white color. The performance of COLMSTD algorithm is shown in Fig. 11.

Fig. 11. Defect detection using COLMSTD algorithm
In this study, one of the most important parts of production process is defect determining stage composed withal those other algorithms, the best performance rate was obtained by using COLMSTD algorithm. Table I is showing performance values of all these three algorithms. COLMSTD algorithm has 85% success rate and the best performance [14].

### TABLE I SUCCESS RATE OF THE ALGORITHMS ON DEFECT DETECTION [14].

<table>
<thead>
<tr>
<th>Algorithm Names</th>
<th>Performance of the Defect Detection (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximally Stable Extremal Regions</td>
<td>60</td>
</tr>
<tr>
<td>Regions Algorithm (MSER)</td>
<td></td>
</tr>
<tr>
<td>BLOB Detection Algorithm</td>
<td>35</td>
</tr>
<tr>
<td>COLMSTD Algorithm</td>
<td>85</td>
</tr>
</tbody>
</table>

### IV. CONCLUSION

In this study, it is aimed to find out the most suitable algorithm for determining defects on rail and profile surfaces. Defect determining stage composes one of the most important parts in production process. In this study, image processing methods were analysed and results were interpreted.

Colour segmentation of rail and profile is useful mean to identify defective regions but it is not sufficient for detection of the defects and their type. This is achieved by COLMSTD algorithm. Using only colour segmentation can be inadequate or incorrect results because rail and profile structure is not flat.

In this study, colour segmentation and COLMSTD algorithms are applied. It has been shown to be worked on gray images. According to obtained results; comparisons with other well-known algorithms are conducted. Standard deviation-based COLMSTD algorithm could be used to detect defect in the rail and profile surfaces with more accuracy.

### REFERENCES