

An Online System for Detecting Bending in a Pallet Car

Ahmad Pouramini

Computer Engineering Department
Sirjan University of Technology, Iran

ABSTRACT

Image processing techniques are widely used to detect defects in industrial equipment. In this paper, an online system is presented to detect bending in pallet cars of a travelling grate conveyor used in sintering machines. If bending in several pallet cars exceeds a specified limit, it can stop the production line. Therefore, an early and precise diagnosis is required. The system consists of a camera in a specific position to monitor the pallet cars and provide an online video. A method is presented to detect and extract an appropriate image of a pallet car from this video. The image is then processed to detect bending of the pallet car's middle frame and measure the degree of bending. Particularly, edge detection methods and Hough transform are used to locate and measure the curvature. The experimental results show a precision of 98% and a recall of 100% for the detection method.

General Terms

Image Processing

Keywords

Defect Detection, Hough Transform

1. INTRODUCTION

Image processing is one of the mostly increasing areas in computer science. Digital image processing is used to extract various features from images [11]. This is done by computers automatically without or with little human intervention. One of the most important operations on digital image is to automatically identify and classify various kinds of defects in industrial equipment and products [10, 3]. In this paper an application of image processing is presented for detecting defects in a pallet car of a sintering machine used in pelletizing industry.

In pelletizing process, after preparing green pellets, they are transported on a special conveyor, called *traveling grate*, through a sintering machine where they are dried, burned and cooled. Traveling grate consists of a chain of pallet cars rolling on rails. The sinter is discharged at the tipping station, where the pallet cars are lowered from the upper strand to the return track by gear rims and curved rails. Then, they return to the charging station to be charged again with green pellets.

Figure 1 shows an isolated pallet car. It consists of four main parts namely two side walls, one steel cast middle frame and four traveling rollers. Bending can occur on the middle frame



Fig. 1. A typical isolated pallet car.

during operation due to the high temperature of the furnace and axial strain. Excessive bending can cause the pallet car to become engaged with the underlying structure, increasing the force required to rotate the conveyor. At the extreme, it can stop the conveyor's movement. The bending may be slight or severe; therefore, a precise method is required to detect a smooth curvature in the body of a pallet car. The first stage is to acquire a suitable image from the middle frame of each pallet car. In the next section, a method to accomplish this is proposed.

2. IMAGE ACQUISITION

The system consists of a camera for acquisition of an online video from the in-operation conveyor. The only place for capturing an image from the middle side of each pallet car is before the charging station, where the pallet cars are rotating on the curved rails. The rotation opens up a gap between two successive pallet cars where the middle side of the first pallet car is observable. Figure 2 shows two pictures taken from this view. The best time to acquire a suitable frame is when the pallet car is in horizontal position (left picture of Figure 2). This problem is a case of event detection and visual object tracking whose core is to robustly estimate the motion state (i.e., location, orientation, size, etc.) of a target object in each frame of an input image sequence [5, 7].

To track the pallet car movement and capture the desired frame, the color changes of three squared regions in consecutive frames are tracked (see Figure 2). First, the color image is converted to

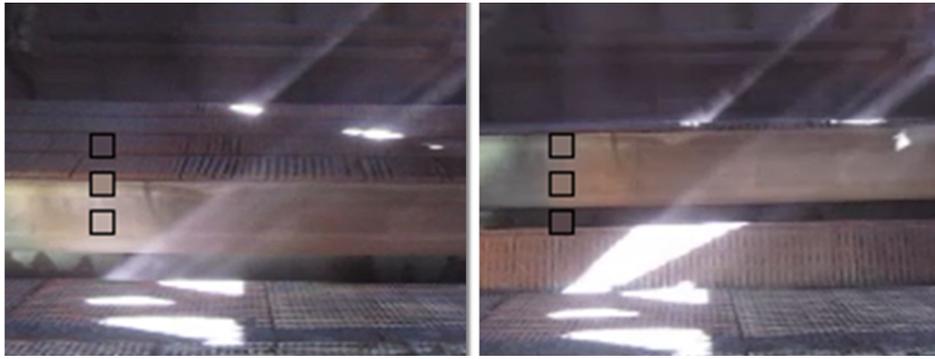


Fig. 2. The front view of pallet cars before charging station

a grayscale image. Then, for each square, its average gray value is calculated. As shown in Figure 2, when the pallet car is fully horizontal, the color of the first and second squares is very close to each other because they both belong to the same surface. At the same time, the third square is much darker than the other squares because it falls into the gap area before the pallet car. We employ two thresholds to detect this arrangement. Suppose that the average gray value of the n th square is specified by $MeanGray_n$. Then a video frame satisfying the following conditions is extracted:

$$TargetFrame = (MeanGray_2 - MeanGray_1 < T_1) \text{ and } (MeanGray_3 - MeanGray_2 > T_2)$$

The first condition states that the difference between the average gray value of the first and second squares must be less than a specified threshold. It means that their color is close enough to each other to be considered as one surface. The second condition states that the average gray value difference of the third and second squares must be greater than a specified threshold. It means that the third square is sufficiently darker than the second square. One may use the average value of the first and second squares instead of only the second square. When these conditions are met, the associated video frame is extracted and is passed to the next stage.

The advantage of this method is that it is independent of any specific color of the middle frame of the pallet cars. The color of the middle frame can vary depending on the light environment and the pallet cars' surface conditions, making the detection solely based on a specific color difficult.

3. BENDING MEASUREMENT

The next stage is to detect and measure the bending of a pallet car in the image resulting from the previous stage. Figure 3 shows an image extracted from the video. As shown, the pallet car is in horizontal position and its middle frame is completely visible. The pallet car shown in Figure 3 is slightly bent. This bending must be detected and its degree must be determined. For this purpose, first, a series of image processing transformations is applied to the image.

Since there is no useful color information in the image to distinguish visual features, it is first converted to a grayscale image. Then, an edge detection method is employed to distinguish the edges of the pallet car. There mainly exist several edge detection methods (Sobel, Prewitt, Roberts, Canny) [8, 14, 15]. These methods have been proposed for detecting transitions in images. For this work, the Canny edge detection algorithm, which is known as the optimal edge detector, was selected [1, 9]. In order to discard

small edges that may be due to noise and keep the strongest ones, a threshold of 0.25 was selected to be applied to the Canny method in Matlab (The range is from 0 (all edges) to 0.99... (only the strongest ones) [9]). The result of applying the Canny method to the image of Figure 3 is shown in Figure 4. As can be observed, the edges of the pallet car, which are represented by white pixels, are partially detected.

The next stage is to detect bending and to measure the degree of bending. For this purpose, a region in the image that includes the top edge is identified. Then, a curve is fitted through the edge pixels in this region. The coordinates of such a region cannot be fixed, because minor changes in the angle of the camera, or differences in the positions of different pallet cars require readjustment. Therefore, we detect the approximate location of the top edge in the image. For this purpose, we use the Hough transform. The Hough transform is widely used to detect straight lines in an image [6, 4, 2]. In our application, we first identify all the straight lines in the image. Then, the longest horizontal line in an approximate region around the top edge is selected as the top edge position. A rectangular area with equal distance from this line is selected as the region of interest. This region is later processed to detect the bending of the top edge.

In the following, we briefly describe how the Hough transform works and why it is suitable for our purpose. Hough transform is based on the fact that a line in the x - y Cartesian coordinate system can be mapped onto a point in the rho-theta space.

$$y = mx + b \text{ is mapped onto } r = x \cos \theta + y \sin \theta$$

where r is the distance from the origin to the closest point on the straight line, and θ (theta) is the angle between the x axis and the line connecting the origin with that closest point. Now when we have a point on the image, and we are not sure whether or not it belongs to a straight line in the image, we just go ahead and plot a point for all possible lines that can pass through that point. That would result in a sinusoidal curve in the rho-theta space. If the point actually does belong to a line, the actual rho-theta coordinate in the rho-theta plane will be reinforced by all points that belong to the line. If we plot an intensity curve of the reinforcement strength (number of curves that cross a point in the rho-theta space), we can see peaks at the values that correspond to possible lines. These points can be isolated and picked up by applying a threshold value.

As can be observed from Figure 3, white pixels that reside on a straight line along the pallet car's top edge are sufficient to

6. REFERENCES

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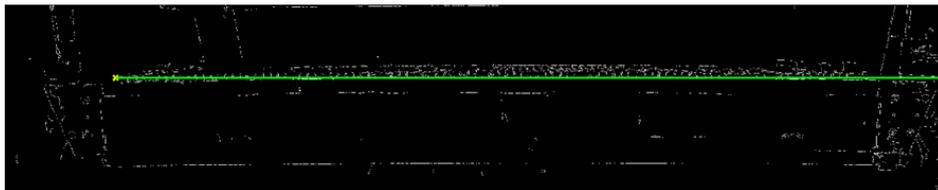


Fig. 5. The line located on the top edge detected by Hough transform.

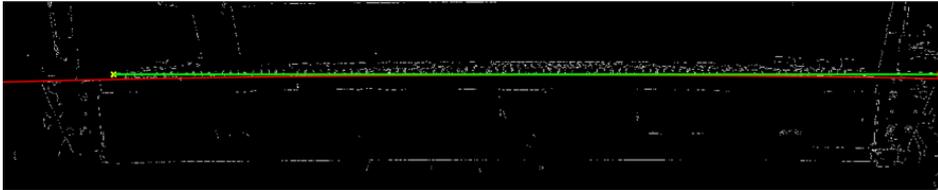


Fig. 6. The curve fitting the top boundary of the pallet car.