

Loading Condition Detection of Grain Transportation Vehicle Based on Visual Image

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Abstract. To solve problem of grain loading reliably and accurately during master-slave collaborative operation of harvester-grain transportation vehicle structure, the detection methods of loading status based on visual image are proposed in this paper. The original image of grain bin is acquired by in-vehicle. After noise is eliminated by Gaussian filter, edges of binary image are recognized with Sobel operator, and gradient map of grain and bin is obtained by non-maximal-suppression method. Straight segments of grain bin edge are acquired using line detection algorithm of randomized Hough transform, and then region of interest (ROI) is obtained through pairwise intersection points of four straight edges. Grain region is recognized through colour space conversion and threshold segmentation. Loading status of grain bin is identified by the distribution state of grain with the convex points of grain region. The system extracts clear and complete edges of grain bin and monitors grain loading status real-time and dynamically, which avoids grain scattering outside and improves master-slave collaborative operation efficiency and monitoring capability of harvester-grain transportation vehicle.

1. Introduction

With the development of agricultural automation, the collaborative operation of large-scale agricultural machineries is applied to the modern agriculture[1]. The collaborative operation of harvester-grain transportation vehicle structure is a more common mode in the agricultural machineries collaborative operation. The location and loading status of grain bin are two important problems for completing the task of harvesting efficiently. The real-time monitoring of grain loading status avoids the grains scattered to the grain bin and realized the grain loading evenly during the harvester unloads grains to grain transportation vehicle.

At present, the loading detection methods include mainly mechanical sensor, ultrasonic sensor, 3D laser scanning sensor and pressure sensor[2]. The above method exists the disadvantages, such as the high failure rate, the poor stability and resistance in harsh environment. In this paper, the loading state of grain bin in the transport vehicle is detected by visual image processing and recognition technology, which is combined with the image edge detection of grain bin and the status of grains region.

2. Boundary recognition of grain bin

The original image of grain bin is acquired by high definition color industrial camera installed in transportation vehicle, and image data is transmitted by video capturing and processing board to DSP



controller. After the random noise being eliminated by Gaussian filter, edges of binary image are recognized by extracting significant points between grain box edge and background interface with Sobel operator. The adaptive threshold segmentation method removes the interference area of grain bin gradient image. Through erosion and dilation processing, burrs and depressions of edge region are eliminated. Straight segments of grain bin edge are acquired using line detection algorithm of randomized Hough transform, and then a linear edge of grain bin is fitted with multiple collinear straight segments. The extraction process of image boundary of grain bin is shown in figure 1.

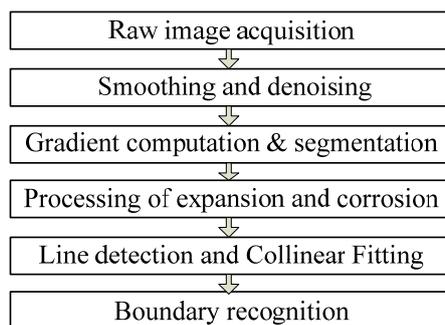


Figure 1. Block diagram of the boundary recognition.

2.1. Pre-processing of grain bin image

The original image of the grain bin is influenced by various factors such as illumination, environment, motion and vibration, so the image quality will be degraded and there is the interference noise, which is a disadvantage in extracting the boundary of grain bin. The disturbances of the original image include mainly pepper-salt noise and random noise. There are many smoothing image methods, such as neighborhood averaging, median filtering, Gaussian filtering, mean filtering of gray minimum variance. In this paper, the interference noise of image can be removed after 3×3 and 9×9 Gaussian filtering, but a larger template size will make the image more blurred. Therefore, when meeting Smoothness, system selects the smaller size template. Gaussian filtering removes the noise interference pixels generated by light. The effect of Grain image after denoising and smoothing is shown in Figure 2.



(a) Original image (b) 3×3 Gaussian filtering (c) 9×9 Gaussian filtering
Figure 2. Smoothing & denoising of grain box original image.

2.2. Boundary extraction of grain bin

The boundary of grain bin image is extracted mainly through the obvious point in gray-scale changes between grain bin and background. The boundary detecting operators include Roberts, Sobel, Prewitt, LOG (Laplacen of Gaussian) and Canny[3]. After the image is smoothed and denoised, the boundary is detected by several operators, and the results are analyzed in this paper. The edge detection results are shown in Figure 3.

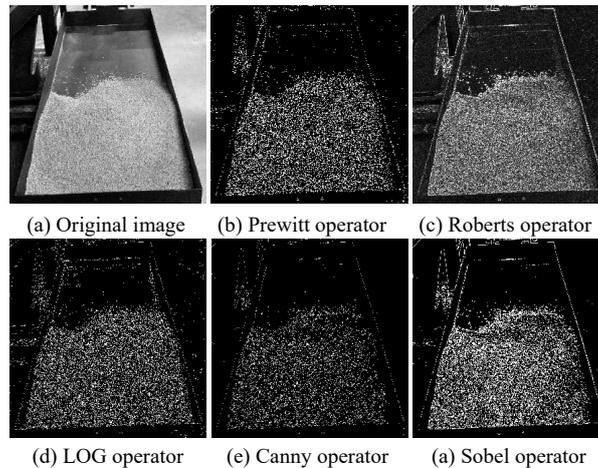


Figure 3. Comparison of several edge detection results.

Prewitt operator can effectively suppress noise, and the pixel average operation is equivalent to the low-pass filter; Roberts operator can locate more accurately, but it is more sensitive to noise since it isn't smoothing step in the edge detection process. The LOG operator can get the edge points by detecting the zero-crossing point of the second derivative, however there is a contradiction between the edge localization accuracy and the noise elimination; Canny operator has better edge representation and denoising ability during detecting step-type data in a first-order traditional differential. Sobel is the first-order traditional differential operator. Sobel operator weights pixel position, so the effect is better.

According to the gray-level difference characteristics of adjacent pixels, Sobel difference operator enhances the edge information and weakens non-edge information of image at the same time. The edge of the grain bin becomes prominent after the Sobel operator enhances, and then the gradient of the bin and grain is obtained by the non-maximal inhibition. Binarization processing reduces the amount of image information and improves the real-time processing. The interference regions of grain bin gradient image are removed by threshold segmentation method, and then the edge region of grain bin was acquired. The gray-level threshold will directly affect the selection of the image segmentation. The images of Grain bin and internal grains are affected by light, salient points, and environmental factors, so the adaptive threshold need to be selected.

2.3. Expansion and corrosion

There are burr regions of grain bin edge after boundary extraction. In order to reduce effect of the edge burrs on the straight line, the burr and the concave of the edge area are removed by the expansion and erosion algorithm of the regional morphology. The expansion adds pixels to the edges of objects in image; Corrosion removes pixels at the edges of the object. The number of pixels added or removed depends on the size and shape of the structural elements of the image. Expansion and erosion are favorable for the edge recognition of the calculation area. The images of expansion and corrosion are shown in Figure 4.

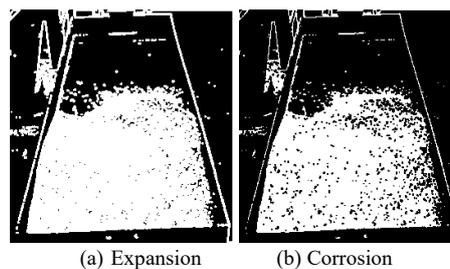


Figure 4. Expansion and corrosion.

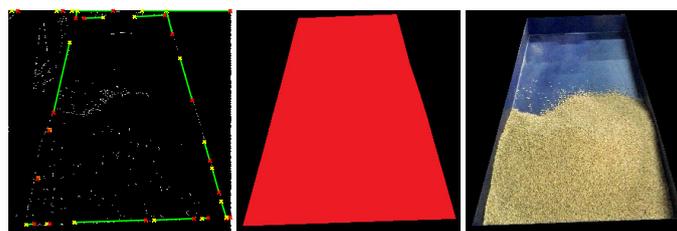
2.4. Boundary identification of grain bin

After the Sobel operator and binarization, the edge of the grain bin is not only enhanced, but also the contours of other objects are enhanced and causes to appear false boundary. Line segmentation method based on random Hough transform is used to obtain several segments of straight line, and the line length is selected by straight line length threshold to eliminate the useless interference straight segment. After a number of collinear line segments are fitted, four edge lines are obtained.

2.4.1. Randomized Hough transform. Hough transform is a shape matching technique proposed by Hough in 1962. It can condense the parameter curve in the image in the parameter space, and then the parameters of each curve in the image are obtained with the parameters of the corresponding curves[4,5]. The detection problem of straight line in the image space is converted to the detection of the points in the parameter space by Hough transform. The one-to-many mapping of the standard Hough transform will bring huge computational load, and the accumulator structure of the multi-parameter space will bring huge memory overhead. In order to overcome the shortcomings of the standard Hough transform, the probability theory is introduced into the Hough transform, and then the random Hough transform method generates. Random Hough transform adopts a multi-to-one mapping, that is, n pixels are randomly selected to determine n curve parameters[6].

The randomized Hough transform has the ability to observe the entire parameter space, so there is no problem that the parameter space needs to be defined. It preserves the information of the parameter points and does not require any discretization, so it has a very high resolution and its resolution can be adjusted. Since the randomized Hough transform is continually re-zeroed to the parameter space, the memory size is always kept at a small level. In each step of the cumulative calculation, only one unit needs to be updated, so that greatly reduces the accumulation processing time[7].

2.4.2. Straight-line detection and collinear fitting. The segments of straight line at the edge of grain bin are obtained by the straight-line detection algorithm based on random Hough transform, as shown in Fig.5(a). Since there are gaps between the segments of line extracted from the image, in order to accurately extracting the four straight line segments representing the edge of the grain bin, it is necessary to connect these collinear adjacent line segments satisfying the following constraint statuses. A complete quadrilateral area is obtained by the intersection of the four edges, as shown in Fig. 5(b). This region is regarded as the region of interest (ROI) of the original image, which is facilitate the extraction of the grain area, as shown in Fig. 5 (c).



(a) Hough line detection (b) edge region of grain box (c) ROI of grain box
Figure 5. RHT linear detection and ROI region of grain box.

3. Loading status detection

To identify loading status of grain bin, a new method of grain in bin based on grain yellow characteristics is proposed. Through color space conversion and threshold segmentation of color grain image, grain region is recognized. The distribution state of grains in bin is detected by measuring the distance of the salient points of the grain area to the line edge, and it is not necessary to measure the overall external surface morphology of the grain inside bin. This method simplifies the computational work greatly and detects the grain loading status quickly and flexibly. The salient points of the grain region are obtained by using a two-dimensional point set convex hull algorithm. A convex hull of a

point set refers to a minimum convex polygon that the points in the point set are on or in the polygon edge. The loading statuses of grain bin are judged by comparing between the preset threshold value and the distances from salient points to the four edge lines.

First of all, the grain bin is divided into several parts as grain distribution area, as shown in Figure 6 (b) (five distribution areas shown in dotted line). According to the distance measured in real time, the grains distribution states in grain bin are determined by preset threshold: 1) When the distance is larger than the preset threshold (as a shown in in Fig.6); 2) When the distance is less than the preset threshold and greater than zero (as b shown in in Figure 6), the grains distribution area of the point is located is "not filled"; 3) When the distance is equal to zero (as c shown in Figure 6), the grains distribution area of the point is located is "has been filled".

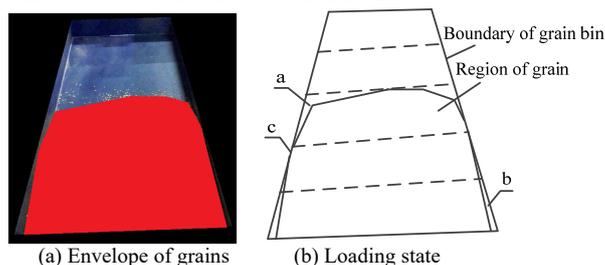


Figure 6. Envelope of grains in bin and Loading state.

4. System functions

The loading status identification system of grain transportation vehicle based on the vision image includes the colour digital camera wide-angle lens, detection terminal (DSP board, intelligent node and display screen) and so on. The high-definition colour industrial camera VS-250D and the wide-angle lens AFT-0420MP are installed on the narrow side of the food grain bin with the fixed bracket, which collects the grain image and transmits to DSPSEED-DEC643 video processing board by the video line. DSPTMS320DM643 CPU processes the image data and monitors the grains loading status, and the results are sent to the field computer and video terminal display.

5. Conclusion

The detection method based on vision image can effectively realize monitoring the grain bin loading status. The Sobel edge detection operator is used to identify the grain bin edges. Corrosion and dilation are introduced to correlate adjacent segment edges. Edge detection algorithm based on randomized Hough transform has better edge recognition ability and the feature of preserving image edge structure, which is suitable for the grain edge detection. The method of grain loading status based on the vision detection realizes the automatic recognition and measurement of grain loading condition during combine harvester-grain transport truck operation, which has good real-time detection performance and high detection precision.

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