A New Arithmetic for Dividing Packed Bar Steel

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ABSTRACT: *Automatic Counting of the packed bar steel is unsolved. A new segmentation method based on quasi-circular assumption and a new object recognition method based on scanning are present. Owing to the simple addition, subtraction and logic operation, these two methods have real time property. The total CPU time is less than 1 second for an 640*480 pixels image, The experiments show that the new method can segment the aggregated bars effectively, and it can be used to improve the accuracy and the speed of recognizing and countering of irregular and aggregated objects.*

Keywords: Bar Steel, Image Segmentation, Concave Point, Auto Counting

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1. Introduction

Image processing has been applied in automatic counting field successfully, especially in cell counting and granulometry analysis, but it is still unresolved in counting packed steel bar. Zhou had used model covering method to count these barÿtheir result is much dependent on the quality of bar' binary image processed. To solve the problem, we provide an segmentation and recognition method based on circular assumption, it takes full advantage of the particular information of the steel bar' end image. The test show that the new arithmetic has been worked correctly and effectively, particularly, it can segment steel from very aggregated bars.

Mathematical morphology can segment objects by erosion operation. It is difficult to select a good structure element and to validate a new object segmented for this method, and it cost much computing time.

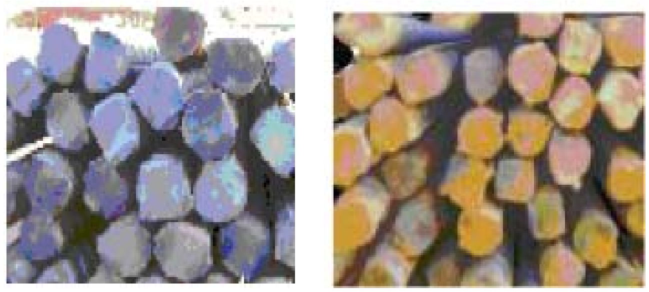
Hough transform can be used in object recognition. This method can work effectively in noise image, but it will cost huge computation and memory, especially, it is very difficult to use this method when object is irregular or unknown.

Making use of concave point can segment objects[1],generally, they find out all concave points, then, select segment points from these concave points by some rules. The key is to find out concave point and to verify segment points. Decomposition based on circular assumption and polygonal approximation can split the objects touched each other in some case[4], while thelongest path of two local edge points do not always cross inner part of the objects, in this case, the error result will be given out.

Segmentation method based on pattern recognition can give a good results for irregular quasi-circular objects[2], while the test slow that it take long time to find object center point in the beginning, and it can not be used in on line counting.

There will be a local shade transition area[3],this can be used to split objects touched, but it is limited in objects in same color or gray level.

When cuting, wire bar(such as steel bar) is packed (about one hundred bars per pack), then carried market to sale. Now, factory almost count these bars by manual work or weighting method, these two ways has much error, and the former take much labor, so it is necessary to count them automatically. The end image of bundled steel bar is asymmetry in shape, color and lightness. Figure 1 is two typical photo, in this figure, left(a) is not rusted, right(b), rusted. And these bars aggregated very much, in addition to the influence of side, it is much difficult to recognize and count the single bar.



(a) (b)

Figure 1. End image of steel bars bundled : a non-rusted, brusted

2. Definition and Segmentation Principle

2.1 Some Definition

The left and right concave points, the up, and down concave points: in a local objects on the adhesive image, supposing that the scan direction is vertical, to detect the thickness of objects in vertical direction. When scanning from left to right, the thickness of the objects will be changing. If in a points, the thickness more reduced than that of its right points, the points is defined as left concave points (Figure 2-b the c points). instead, if in a points, the thickness is more increased than that of its right points, the point is defined as concave points (Figure 2-b the d points) . The up points and down point is the point that the thickness is changed in horizontally direction abnormally, its nature is similar to that of left and right concave points. In the figure 2 point a is an up concave point, the point b is down concave point. The left, right, up and down concave point represent the depression towards basically.

In-phase concave point and out-phase concave point: When scanning horizontally or vertically, the concave points that is in the same direction as concave direction (such as all the up concave points) are defined as In-phase concave point. With in the opposite direction, the concave point (such as up concave point and down concave points) is defined as out-phase concave point.

Local quasi-circle: the circle that has the diameter by two points e and f , these two point is on the outer contour lines of the image and has the longest distance. The line ef is also known as the long axis of the image.

Pairing concave point: in the local image, the out-phaseconcave points is two endpoints of the line for objects segmentation, they are also known as pairing pits.

The length of dividing line: the length of the pairing concave point. That of c, d point recorded as Len (c,d). The length of divider chord: the extended line of pairing concave point, which intersect the quasi-circle. That of c,d point recorded as Chord (c,d).

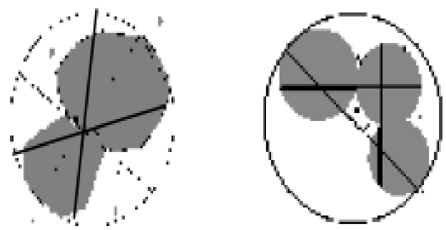
The segmentation area: each regional area after local images are split.

2.2 Segmentation based on circular assumption

Figure 2-a illustrates the segmentation arithmetic based on circular assumption and polygonal approximation. The outer contour

line of the image is divided into two parts by the longest axis ab, one is area A, the other is B.

There exists two concave points s and e in the two phase respectively, when Len(s,e)<Chord(s,e)×FSS, the line between s and e is a true split line, thus the original region is decomposed into two area by straight line segment se. Where , Len(s,e) is the length of se, Chord(s,e) is the chord length of the circle passing points s and e, FSS is the factor according to the object shape closing to circle and the roughness of the edge. Because the object being processed has a least size, the area must be discarded when its area is less than the minimum value. To avoid over splitting, the decomposition can not e done when the region' area of two segments are less than the least reasonable value A_T. Therefore, for a real split line, we have $A_X>A_T$ or $A_Y>A_T$. The last rule is that we should select the shortest line among the all possible segment line first. This segmentation method has been used successfully in multi cell aggregated to split them, but it is strongly dependant on the longest axis location, and it implies that the longest axis must cross the inner region of the object, in some case, this is not true. See figure 2-b, the longest axis is partly out the object region, thus the two shortest distance between the circle center and the edge points in two parts are not the true concave points, and nor the real split points also. In this case, the true split points a, b, c, d can not be found.



(a) (b)

Figure 2. the illustrate of the arithmetic a) Qi arithmetic b) New arithmetic

3. New Arithmetic

The new arithmetic is based on the following assumptions. First, the end image of whorl steel is in quasi-round shape, second, the two points of split line must locate at two sides of one vertical or horizontal line, and the length in local object region of this vertical or horizontal line will increase or decrease remarkably when moving along the split line. The vertical or horizontal thickness spectrum curve of figure 3 explains this abrupt length change. Note that an isolated noise point can provide two concave points, this will affect the segmentation, even cause an err segmentation. By using extra limitation, this error can be avoided, but this paper does not consider this case, it means that we assume there is not hole in the image and all dark pixel are edge points, this will simplify the arithmetic.

3.1 Determining and classifying concave points

When scanning the binary image vertically or horizontally, we label the length of the adjacent scan line in one object region as lastL and newL. The adjacent scan line means two lines' start points is contiguous and has the same scan direction. When

$$lastL\text{-}newL>L_T \text{ or } newL\text{-}lastL>L_T$$

it means a possible concave point has been founded. The L_T is the threshold. The concave point found by the former condition is classified into same-phase concave point, otherwise it is classified into anti-phase concave point. Thus we get a set of same-phase concave points and anti-phase concave points respectively.

Figure 2-b illustrate the arithmetic scan line (only show the scan line of abrupt length change). When moving vertical scan line horizontally, the scan line length in white area(object) has changed evidently in point a and b, and the change direction is opposite, thus found out a possible up, down concave point, and no remarkable length change in point c and d present in this scan direction. But when, scan direction rotated 90 degree, the left, right possible concave point c, d can be found.

3.2 The rule to determine split line

The split line must be the line connecting the local same-phase and anti-phase concave point. But only those lines satisfy the

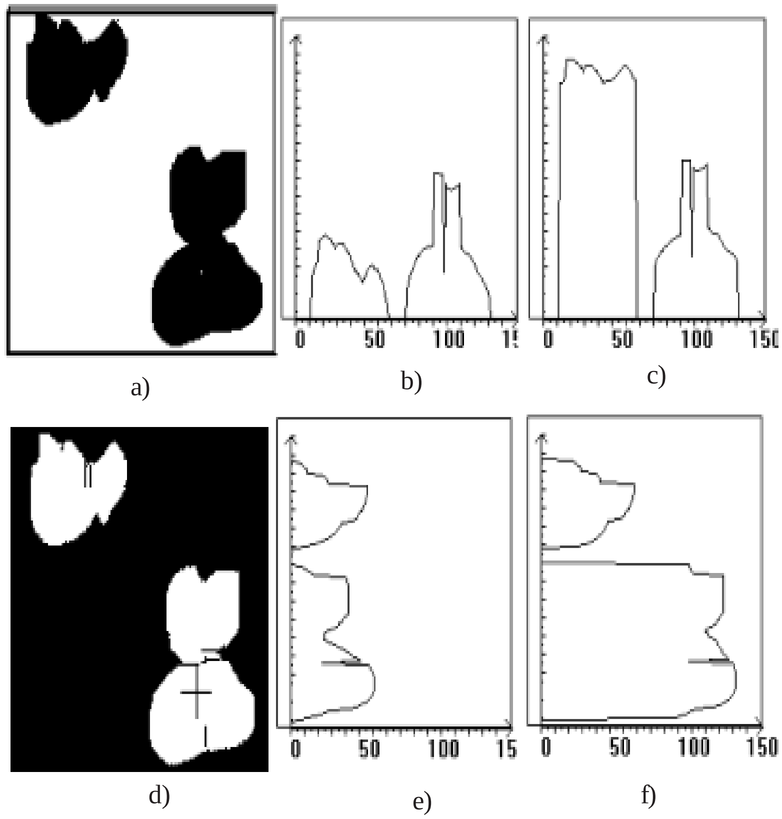


Figure 3. a) n simple image scan,a) original image,d split points,b) horizontal thickness spectrum curve,c) the end point of horizontal scan,e) vertical thickness spectrum curve f) the end point of vertical scan

following rules can be accepted the true split lines. Starting the two shortest distance points, then the second pair, the third pair, etc.

$$Rule\ 1: Len(s,e) \quad < max(Chord(s,s),\ Chord(e,e)) \times FSS$$

where Chord(s,s) is the length of scan line length passing point s. Len(s,e), FSS has the same meaning as above arithmetic. You can add the split line's middle vertical line length to max function. This rule means the split length must be much less than one of the two or the three line length assigned.

$$Rule\ 2: A_X > A_T \quad OR \quad A_y > A_T$$

where A_T is the minimum areaÿAXÿAy are the area of the two parts decomposed. It will avoid over-decomposition.

$$Rule\ 3: R_X > R_T\ AND\ R_y > R_T$$

where R_T is the threshold of roundness, R_X , R_y are the roundness of two parts. Because the object is irregular, some concave points may be classified into two different types, this cause an incorrect segmentation. By this rule, we can overcome this error. The roundness can be computed by the following ways:

a) finding the approximate center of the region(see the section 4 recognition).

b) computing the 8 distances between the center point and the edge points, the angle of the edge points is 45 degree step. When one distance is much longer than assigned radius, it should be deleted or limited by a possible maximum value.

c) computing the standard deviation of these distance, this can be one similarity of roundness.

This rule can be modified as the rule 3':

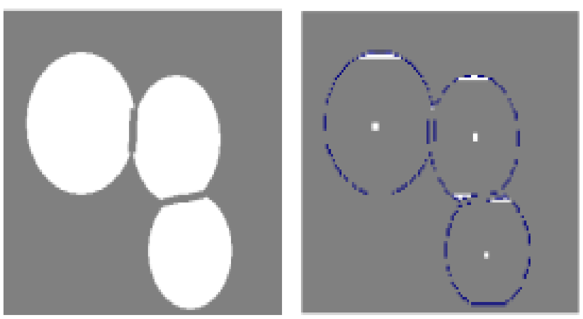
Rule 3' : $R_X > R_C$ or $R_y > R_C$;where R_C is the roundness of the original integrate region. It demonstrates the roundness should be increased by splitting.

Rule 4: $|k| \geq 1$ *for split line between up, down concave points;*
$|k| \leq 1$ *for split line between left, right concave points.*

Where, $|k|$ is the absolute value of split line's slope. In figure 2-b, there is only one up concave point b and one down concave point a, and line segment ab is fit for all above rules, so the line ab is a split line. The similar reason for left concave point c and right d, and draw an split line cd. See figure 3-a.

3.3 Quasi-circular center and object recognition

Scanning the image vertically and horizontally ,marks the middle point of each line segment .When one line length is much longer ,we should take its adjacent point as reference point .When all scan is completed ,checking the adjacent points of each middle point in its 3x3 contiguous area ,if there are three or four middle points ,the point may be one circle center .To verify the center ,computing the roundness according to the previous section .If the roundness is greater than the threshold value ,the center is valid and then compute the effective diameter .In this paper ,the diameter equals to the mean value of those distance computed . Filling the equivalent circle and marking the center using an small rectangle is the last step of the work . Figure 4-b illustrates the center and the object recognized by this method .



(a) (b)

Figure 4. The processing result of figure 2-b a) the splitting figure, b) the figure of recognition

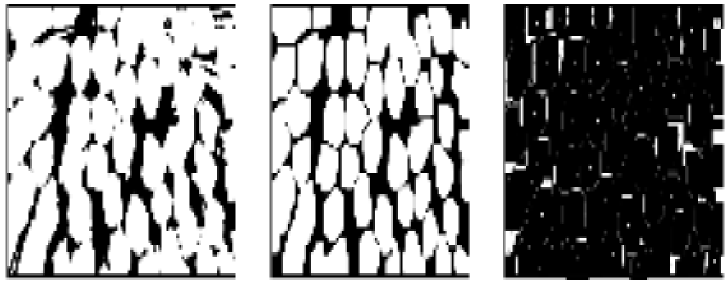
4. Experiments

The digital test images were from the construction scene.Figure 5 is the processing result of the figure 1-b.In the binary image, there are two distinct aggregated steel region, furthermore, the conglutination is very complex. Figure 5-b shows the split result, from the figure 5-a,the Result is ideal basically. The bottom-left aggregated objects is still touched, because there is no distinct hollow, and on the top-middle, the two objects is not splited, the reason may be a bigger threshold. The method suggested by reference[4] can split them, so we can integrate it with the new arithmetic. Assume that the packed steel bar are almost the same diameter, we can recognize the aggregated bars in the two situation, so we do not split them further.

The total result of nine image are up to 99 percent(Table 1), if the edge incomplete is not considering in the steel bar. The total time is from 3220 to 3780 millisecond when the image size is 1280 * 960, the time will decrease to 500 millisecond or so when the image is 640 * 480, while the error is increased correspondingly.

Now, let us analysis the statistical error.It is supposed that the error caused by the uncompleted edge is not take into account, that is, only the statistical error of the complete target is counted.

In Table 1, the Total Error(TE) is the error that caused by the total number of results subtracting the actual count. The Positive Error(PE) is the error that caused by addition counting. The Negative Error(NE) is error that caused by missing counting. The Total Error is an algebraic sum of positive error and negative error.



(a) (b) (c)

Figure 5. The result of the real steel bar packed, a) binary image of figure 1-b,b) splitting figure, c) the recognition figure(magnified related to a,b)

By look at the relative total error, we find that the error value is relatively small, the reasons maybe included follow factor. The first, when sampling the image, the camera angle is adjusted carefully, image quality is better. The second, the impact of the target edge is not considered, that is, if the uncompleted target is detected, it will removed from the total number, if it is not detected, the negative error is not changed. The third, the image resolution is 1280*960, and the image is processed in large sizes, so the processing accuracy is high. Furthermore, most of the image only has 50 bars or so, from the table we can seen that the more the bar is in the images, the bigger the total error is. In factor, with 640*480 image, and having actual 100 steel bars in a bunch, the error is bigger.

Image	Actual Number	Counting Number	PE	NE	TE	Error Rate
dcp-0009	24	24	0	0	0	0
dcp-0010	49	49	+1	-1	0	0
dcp-0011	39	39	0	0	0	0
dcp-0012	47	49	+2	0	2	4.2%
dcp-0013	93	86	0	-5	-5	7.5%
dcp-0014	31	30	0	-1	-1	3.2%
dcp-0017	60	58	+5	-7	-2	3.3%
dcp-0018	45	46	+1	0	1	2.2%
dcp-0019	51	52	+2	-1	1	1.9%
Total	439	433	11	-15	-4	1.0%

Table 1. Statistical Error

By look at the processed image, it can be found that the factors that impacting the results of image processing is show as follow:

(1) The quality of banding. When the face is more orderly, the error is small, and vice versa. This is due to that with the poor binding, the side image may result in positive counting, while in the shadow, the targets may be missed in account.

(2) The uniformity of the image. When the image brightness is more uniform, the error is small. The other hand, some of the darker values likely to be leakage into account in the binary processing. The more unify the target size is, the more smaller the error is. Especially in the zoom image, the different image size will increase the total errors significantly.

(3) The target size. Basically, the dimensions and the error is inversely proportional. The image size is increased when a single bar is bigger, and the processing time will increase significantly. Suggesting that 50 bar or so in a bundle, so that the speed and the error will have a relatively good balance.

(4) The difference between image and background. The greater the difference is, the smaller the error is. That is because that the more the difference is, the more completely the target is tested.

5) The degree of the target close to the circular: the more the target close to a circular, the smaller the error is.

5. Conclusion

The paper use computer vision methods to try to count the wire-line, the main research content is to find the efficiency methods, including image acquisition, preprocessing, segmentation and recognition of objects and counting. Depending on the actual image processing features, this paper proposes a new class-based segmentation method, to segment the adhesion target based on the statistical pattern recognition method, the objective is to identify the circle target and counting it. Because the algorithm is only the operation of addition, subtraction and logical operations, it is ensure the algorithm in real time. With a size of 640 * 480 image, the whole process takes less than 1 second, it can meet the actual production requirements. The algorithm use the image binary in higher efficiency. When the gap between tow objects is same as the background after binarized, the adhesion objects have significant depression after the binary, the recognition rate is high, the error is almost zero. On the contrary, the error will increase. The possible solution is to use the edge information of object to improve. The paper also attempts in this area, by the time constraints, only taking simple test. Although the introduction of the edge information can reduce the possibility of error, if the object gray is not uniform, the pseudo-edge information will impact the segmentation. While by using of the combination of edge information, the processing speed will be reduced.

The experiments show that the new method can segment the aggregated bars effectively, the accuracy rate can be 99.0%, when improved, the method can be used to recognize and count the steel bar real time.

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