High Accurate Counting of Steel Rebar with Defected Tips

Nazlı Sümeyra Dağılgan[1*], Murat Furat[2]

[1*] İskenderun Teknik Üniversitesi, Mühendislik Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Hatay, Türkiye, (ORCID: 0000-0003-4443-4567), nazlidagilgan.mfbe18@iste.edu.tr

[2] İskenderun Teknik Üniversitesi, Mühendislik Fakültesi, Elektrik Elektronik Mühendisliği Bölümü, Hatay, Türkiye (ORCID: 0000-0003-3179-5099), murat.furat@iste.edu.tr

Abstract

The product quality in the iron and steel industry is highly important. From the casting process to bundling, a large amount of energy is used at each step of the production. In the present study, the counting of steel rebar bundles located in the storage area has been taken into account. When it is necessary to recount the rebar in a bundle, depending on the number of rebar in the bundle, either a staff is assigned to count or the bundle is moved for weighting again. Both of them are time and energy-consuming solutions. In the present study, an algorithm is developed to count the rebar in a bundle by taking a photograph of rebar tips. Although the existence of defects such as deformed cutting, steel rib features, lack of painting, and also insufficient lighting of the storage area, the proposed algorithm is able to give highly accurate results.

Keywords: Image Processing, Iron and Steel Industry, Steel Rebar Counting, Hough Transform, Canny Edge Detection.

Hatalı Uçlu İnşaat Demirlerinin Yüksek Doğruluklu Sayımı

Öz

Demir çelik sektöründe ürün kalitesi son derece önemlidir. Döküm sürecinden paketlemeye kadar üretimin her aşamasında büyük miktarda enerji harcanılır. Bu çalışmada, depolama alanında bulunan çelik inşaat demiri sayımı dikkate alınmıştır. Bir paketteki demetin yeniden sayılması gerektiğinde, paketteki demet sayısına bağlı olarak ya saymak için bir personel atanır ya da tekrar tartılmak üzere götürülür. Her ikisi de zaman ve enerji tüketen çözümlerdir. Bu çalışmada, inşaat demiri uçlarının depolama alanlarında fotoğrafı çekilerek bir paket içerisindeki demet sayımı için bir algoritma geliştirilmiştir. Deforme kesme, çelik nervür özellikleri, boyama eksikliği ve ayrıca depolama alanının yetersiz aydınlatılması gibi kusurların varlığına rağmen, geliştirilmiş algoritma yüksek doğrulukta sonuçlar verebilmektedir.

Anahtar Kelimeler: Görüntü İşleme, Demir çelik Endüstrisi, Demir Demet Sayımı, Hough transform, Canny Kenar Bulma..

* Corresponding Author: nazlidagilgan.mfbe18@iste.edu.tr

1. Introduction

The aim of image processing in the industrial processes is to obtain meaningful data. The image in digital form is computed in computers using variety of algorithms. In the few decades, image processing methods has been applied in many areas of industry such as health, food processing, agriculture, iron and steel production. Depending on the advances in imaging sensors, image processing applications provide great advantages in the quality control processes and in the environment where physical conditions are not suitable.

In the present study, a problem from iron and steel industry is taken into account. In this industry, massive products have been produced which are billets, slabs, blooms, ingot and steel rebar. The products are whether final products or semi-finished products for other industries. Thus, the quality of the quantity of the products are highly important [1].

One of the important products of iron and steel industry is steel rebar used in buildings. Several image processing applications can be performed in the iron and steel industry such as steel rebar grade, flaw detection on steel strip surface, the correct number of rebar in a package [2]. In the present study, we focused on rebar counting in a bundle. Since it is massive and long product, accurate number of rebar in the packages are highly important while using in buildings.

As its nature, the quality control of steel products are difficult. When it comes to the packing stage, such as steel rebar bundle, the automatic counting system plays an important role in making the bundling. Traditionally, there are two ways to count rebar. One is performed by a staff just before the bundling. Another is to be weighted the rebar package and then dividing the result by a unit weight of a rebar. Currently, technological developments allow to count automatically using the pattern recognition techniques of image processing.

During the continuous production of steel rebar, it is sometimes needed to recount of rebar in the bundles located in the storage area. In this case, there are two possible solutions to determine the number of rebar. One is same with traditional case: assigning a staff for counting [3]. Depending on the number of rebar to be counted, workforce is wasted. Another solution is to move the bundle by a crane to weigh again. Since the bundle is massive, the cost of energy spent for remeasuring of its weight will be large.

Therefore, recounting of rebar package is negatively affect the cost of the production. We need to mention about three barriers before applying the image processing methods for the solution of the problem.

1.1. Plant Environment

Iron and steel plants are industrial environments with high noise and pollution. Also, the high temperature of the final product, as well as steel rebar, makes it difficult for a staff to count. Therefore, the production is performed under hard conditions. Thanks to image processing methods, there is no need for much time and energy loss for counting of steel rebar.

Fig. 1. A view of steel production line [1]

1.2. Insufficient Lighting of Storage Area

Another barrier in front of image processing is the dark environment of storage area. In order to get appropriate digital image using a camera, it is required to illuminate the tips of steel rebar. However, in reality, it is not possible for most of rebar storage areas.

1.3. Non-circular Shape of Rebar Tips

While steel rebar are produced, shapes called steel ribs are formed on steel bars as shown in Fig.2. These ribs can distort the circular shape of the iron rebar. In addition, while the tips of the steel rebar are cut, the tips deteriorate. Defects such as steel rib features, damaged cutting and lack of painting negatively can affect counting of steel rebar.

Fig. 2. A view of steel rebar tips with ribs

The studies in the literature on the counting of steel rebar can be classified as counting on production line [4-7] and counting rebar in storage area [8,9].

In [7], the proposed algorithm is based on image counters. High accuracy has been obtained with the image of steel rebar tips. Although the image used in [7] is very realistic, the high contrast between the background and the tips of the rebar makes it easier to separate the rebar tips between each other. A software application has been implemented for the proposed algorithm in [8]. The proposed algorithm was based on K-means algorithm and Hough transform.

In order to overcome missing detection of the rebar such as obscured rebar, oxidation dark rebar and bent rebar, two cameras were used simultaneously to capture top and front view of the rebar [10]. It was proposed as efficient way to to recognize missing rebar having the above features.

The rebar counting is important not only in the production phase but also in the inspection of building constructions. For this purpose, a deep learning-based rebar counting is proposed in a new study to increase the efficiency of building inspection [11].

Remaining of the present study are organized as follows. In the next section, the proposed algorithm is explained in detail. Experimental results are given in the third section. Finally, the results and future studies are concluded in the last section.

2. Proposed Algorithm

At the end of the production, the steel rebar which is cut in certain lengths is tied in bundles. Then the bundles are moved to storage area. The tip surface of cut steel rebar may be deformed or misshapen. Generally, the illumination in the plant environment is not sufficient and staff may not use a high resolution camera. In addition, the dust density of the environment also affects the images negatively. Under the conditions, the images of steel rebar in a storage area were obtained using a camera of a smart phone approximately 1m away from the rebar tips.

The images were preprocessed to clarify the sight of the steel rebar. Gaussian Blur filter is selected for the purposes of reducing noise. The proposed algorithm has five variable parameters for canny edge detection, threshold value and Hough transform.

The proposed algorithm is applied to count 8mm and 12mm steel rebar packages and the most suitable value range is determined for accurate counting of steel rebar. The steps are illustrated in Fig. 3.

2.1. Preprocessing and Blurring Filter

OpenCV is a utility for reading and processing various types of image files from video and photos. This utility, which contains hundreds of functions related to image processing, is an open source library. Factors such as background light, pollution of the environment, and the difference between day and night light sources needs filtering of the image. Because of noise and interference in the image, Gaussian Blur filter was preferred in counting of steel rebar. Blurring is a basic and often preferred image processing step. There are many reasons for using smoothing, but it is usually done to reduce noise or camera defects in the image. Smoothing is an important process to adjust the image resolution [12].

In this method, a Gaussian kernel is used. The kernel must be positive and unique. The width and height of the kernel should be specified. The standard deviation in the x and y directions should be specified, with σ_x and σ_y. If only σ_x is defined, σ_y is defined the same as σ_x. Both are calculated from kernel size if given a value of zero. Gaussian blur plays a very important role in removing Gaussian noise from an image.

$$\left.\begin{array}{l} \sigma_x = \left(\frac{n_x}{2} - 1\right) \times 0.30 + 0.80 \\ \sigma_y = \left(\frac{n_y}{2} - 1\right) \times 0.30 + 0.80 \end{array}\right\} \tag{1}$$

An 8 mm or 12 mm steel rebar is indicated by the user.

The image is read and it is converted to gray image.

GaussianBlur filter and canny edge detection are applied.

The counting algorithm is created using the Hough transform.

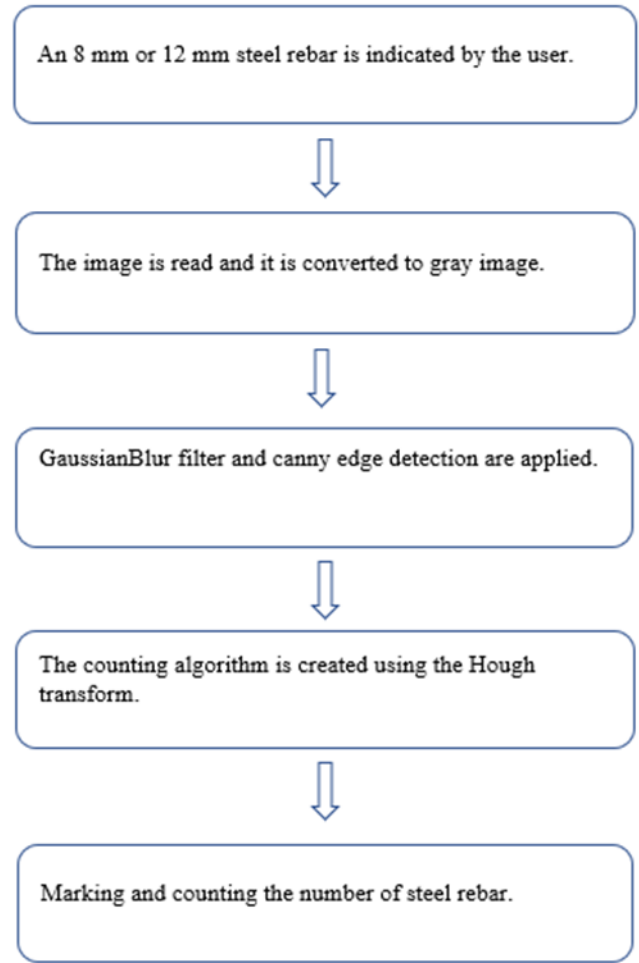Marking and counting the number of steel rebar.

Fig. 3. Proposed counting algorithm

2.2. Canny Edge Detection and Threshold Values

Interested objects may need to be distinguished from the background and some other objects on the image. Erosion and dilation are described as basic morphological processes. They occur in various situations such as providing the insulation of the elements and correcting the noise. Gradiends of an image and intensity holes or bumps can be found by morphological processes. It is generally used in processes such as the interpretation of pixels, analysis, thinning, image compression, corner analysis, distorted image repair (removing or adding missing or excess pixels), detection of textures in order to extract appropriate information on the image [13,14].

Edge detection among image processing algorithms is one of the most used methods. Edge detection algorithms are basically determined by the separation of the color values (0-255) of the pixels in the image. Roberts, Sobel, Prewitt, and Canny are commonly used edge detection methods. In this study, edge detection methods are tried and the most accurate results are obtained when using canny edge detection. It is a highly effective and useful algorithm in finding edges. First, the noise in the image is reduced by convolution with the Gaussian nucleus according to a σ value. Then, by driving the operator, the magnitude and direction of the edge gradient is calculated. Edges are thinned by applying non-maxima suppression. Finally,

the image is removed from the details by applying double thresholding. Thresholding is the most important part used for image segmentation. It is one of the best approaches. It is to separate the target shape in the image from the image background [14,15].

Pixels have two basic criteria: edge direction in radians and pixel density (0-255). Pixel density is expressed in double thresholds. These are high thresholds and low thresholds. High threshold defines strong pixels. It is used for pixels with higher density than high threshold. A low threshold identifies pixels that are not relevant. It is used for pixels with lower intensity than low threshold. 12 mm and 8 mm steel rebar images are binarized by appropriate threshold values (by trial and error) given in Table 1. Thresholding, which makes use of the gray dispersion histogram, is the stage of deciding that the areas of value above the threshold value determined from the pixels in the processed image obtained after the edge detection stages carry edge data and the remaining ones are unnecessary detail that cannot be noise or edges to be cleared [16]. Let's consider a T value determined according to the histogram to distinguish the objects from the background. This value is for pixel $f(x,y)$; for $f(x,y)>T$, the pixel will belong to the object. If $f(x,y)\leq T$ value, the pixel will belong to the background.

$$g(x, y) = \begin{cases} 1 & if \ f(x,y) > T \\ 0 & if \ f(x,y) \leq T \end{cases} \qquad (2)$$

2.3. Region of Interest (ROI)

In this study, region of interest (ROI) was used since the images of the steel rebar were not adjusted with the camera, the image was too noisy and the resolution value was not at the desired level. ROI means that is the cross-sectional area obtained by subtracting the image pixel to be processed from the value of all pixels in the image as illustrated in Fig. 4.
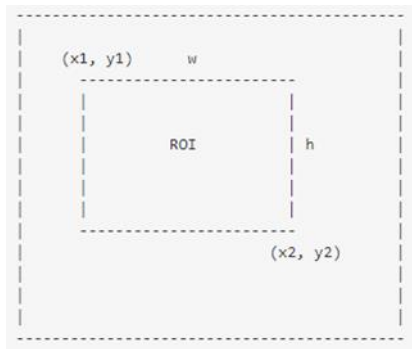

Fig. 4. A sample for ROI

The region of interest is drawn from the processed with boxes, circles, ellipses, irregular polygons, and so on [9]. In order to obtain most of the number of steel bars and count quickly, it is also convenient to further determine the relevant area, reduce the detection error in the relevant area. In this study, the part related to the steel rebars was extracted by ROI. Then the extracted image has been processed as our main picture.

2.4. Hough Circle Transform and Counting Algorithm

Hough circle transform is used to find the parameters related to the circle when the serial point falling around is known. Circular Hough Transform function detects multiple circles in an image. The image contains holes or circles or whose

centers can be in or out of the image [17]. A circle with r radius and center (a, b) can be explained with the parametric equations as follows:

$$(x-a)^2 + (y-b)^2 = r^2 \qquad (3)$$

The greater the number of parameters required to construct the shape, the larger the size of the R parameter space, the greater the complexity of the Hough transform. Thus, the parameter space for a circle will belong to R^3 the line only belonged to R^2.

With the Hough circle transform method, there is a circle whose radius which we predefine. It aims to obtain a circle-like shape by assigning points away from the center point at certain meters in Fig. 5. A circle finding algorithm can be created. We draw a circle with the radius we want at each edge point. This circle is drawn such as the value a on the x-axis b value on y-axis and the radius r on the z-axis in three-dimensional space.
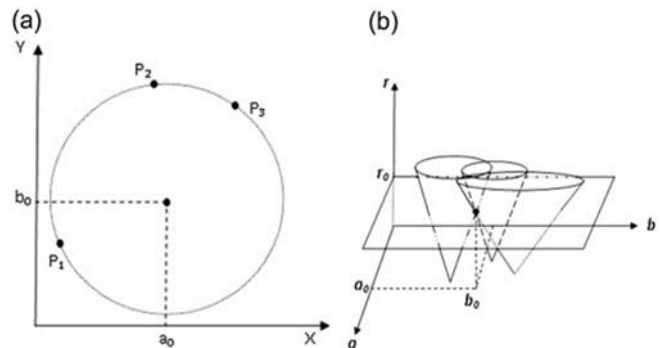

Fig. 5. Hough circle transform

Before applying Hough circle transform, the noisy images are cleared as much as possible. First, it is filtered with the appropriate filter and the edge detection algorithm is used to detect the edges of the image. In Table 1, appropriate treshold values for canny edge detection with respect to 8mm and 12mm diameter steel rebar.

The threshold value is determined for the lowest value and the highest value of the radius in detecting the circles on the image. The results are summed up in a 3D accumulator array to form circles of different diameter and center. Five important parameters are required for proper image detection as follows:

- **python command:** cv2.HOUGH_GRADIENT command is used in python for entering parameters.
- **dp:** is the ratio of image resolution with accumulator. This ratio is inversely proportional. If dp = 1, the image and the accumulator have the same resolution.
- **minDist:** It is the measure of the closest distance of a circle to another circle. When this value is too large, it may not detect the circles which is exist. When this value is too small, it can detect more circles than are present in its surroundings.
- Two parameters called **param1** and **param2** necessary for circle detection are given and then the **minimum radius** and the **maximum radius** are calculated. After that counting algorithm is created.

These parameter values are changed according to the circle diameters on the image and the value is given.

Table 1. Selected threshold values

Steel rebar diameter	Edge detection algorithm	Low threshold (0-255)	High threshold (0-255)
12 mm	Canny	130	130
8 mm	Canny	125	125

3. Results and Discussion

It is obvious that, the most accurate result can be obtained when using an image of steel rebar without any defect as shown in Fig. 6 [18]. Since there is no defect on the rebar tips and the edges are so clear, 100% success is obtained with the proposed algorithm.
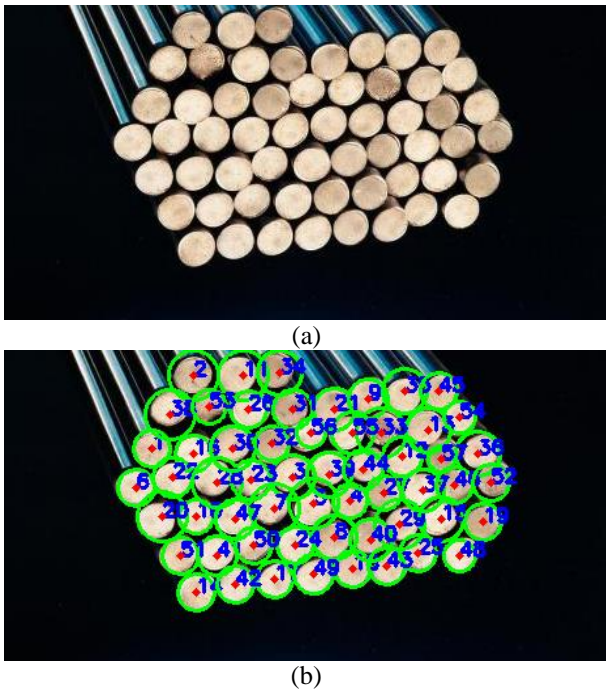

(a)

(b)

Fig. 6. a) Image of 57 steel rebar with no defect, b) counting rebars.

In our study, we selected steel rebar images having different number of rebar tips. The images are obtained by using the camera of a smart phone. The resulting images of each steps of the proposed algorithm are shown Fig. 7 and 8. Although adverse conditions such as insufficient lighting of environment, deforming cutting, rib feature of steel, lack of painting, the accuracy of the counting is very high as shown in Table 2.

Table 2. Results of counting steel rebars

Diameter of steel rebar	Real number of rebars	Counting result	Accuracy
12 mm	135	127	94.0%
8 mm	1983	2029	97.6%

In Fig. 7, the image includes dark and bright areas around rebar. Also, it is very clear that the tips of the rebar has been defected. The accuracy of counting for 12mm steel rebar is measured as 94% under these conditions.

In the literature, small number of rebar are counted using image processing. On the other hand, it is more necessary to count large number of rebar. Such type of example is shown in Fig. 8a. The accuracy of counting for 8mm steel rebar is measured as 97.6%.
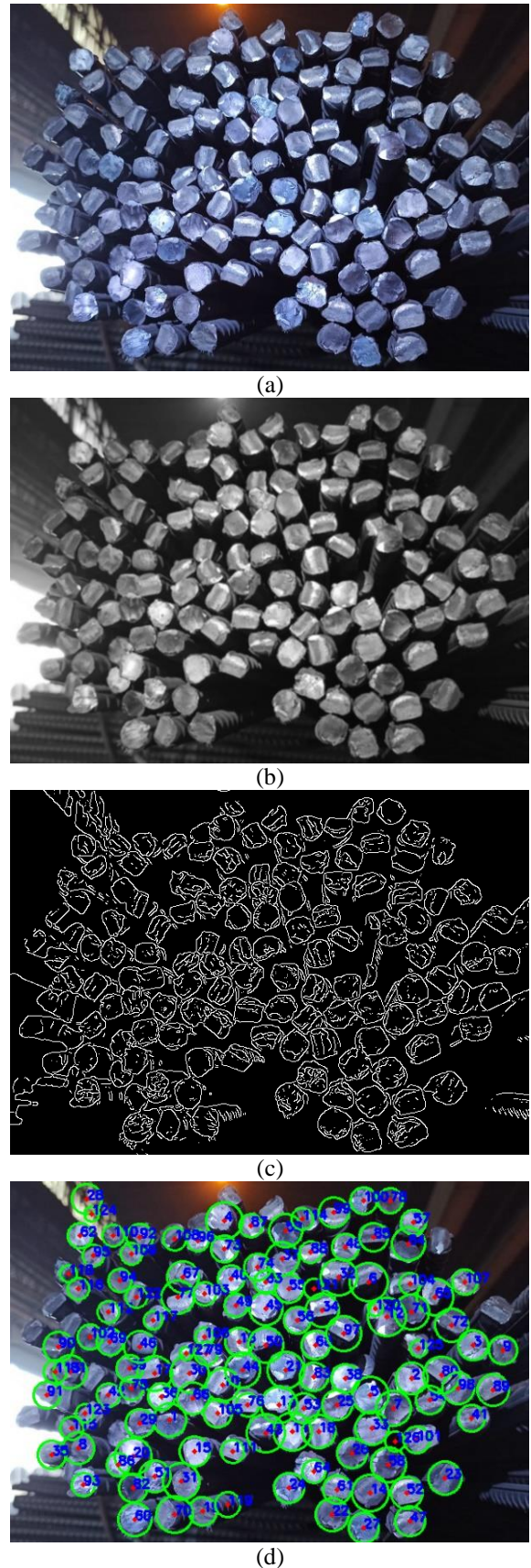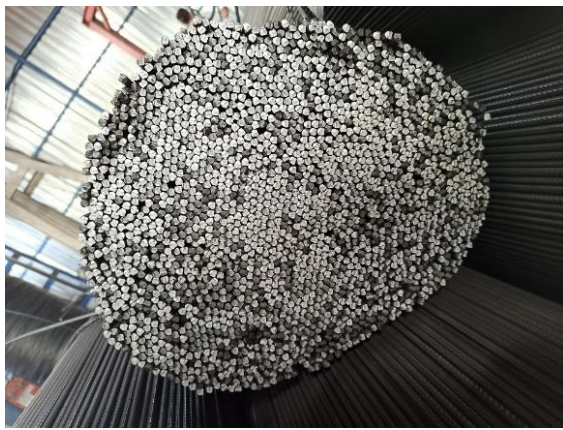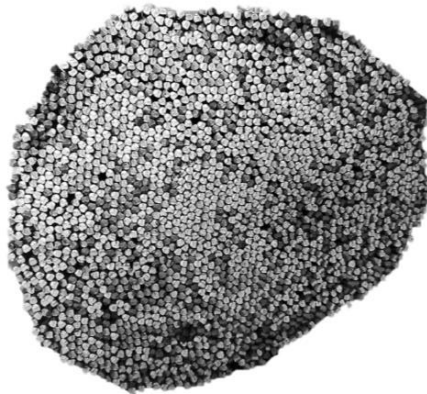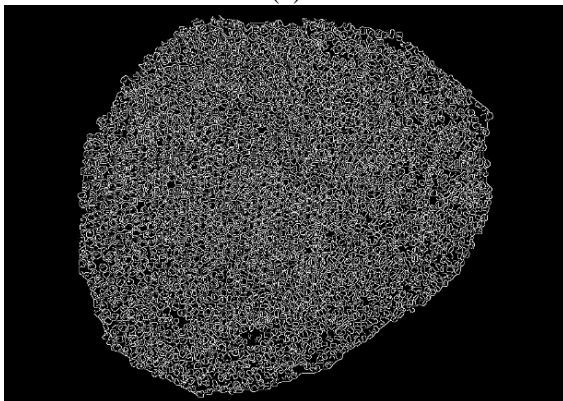

(a)

(b)

(c)

(d)

Fig. 7. Results of 12mm diameter rebar bundle: a) Original image, b) Gaussian blur filter, c) Canny edge detection, d) Counting
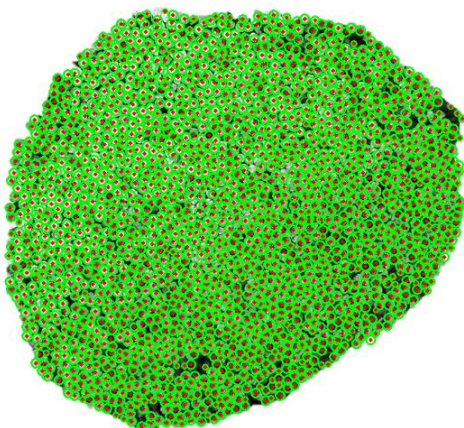
(a)

(b)

(c)

(d)

Fig. 8. Results of 8mm diameter rebar bundle: a) Original image, b) Gaussian Blur Filter in ROI, c) Canny Edge Detection, d) Counting

4. Conclusions and Future Work

In the present study, images of steel rebar which is taken from iron and steel plants and has different diameters were taken with a mobile phone camera. Counting of steel rebar was performed without any hardware enhancement such as light source adjustment and dark environment. The image of the steel rebar which are counted has been cut from the whole image in order to make a more accurate count. Median filter, Gaussian filter, Gaussian blur filter were tested and it was decided that the most effective filter was Gaussian blur. Two threshold values were determined by applying canny edge detection. Then, the circles were determined by applying Hough circle transform.

Environmental factors such as the density of the rebar, insufficient lighting and the matt rebar tips cause incomplete or overcounting. In addition, since the rebar are not aligned, the gap among them causes the rebar to be overcounted. Therefore, the counting results, less or above the real, are effected by all environmental factors.

Furthermore, the proposed algorithm results in high counting accuracy rate despite the defects that negatively affect the counting such as steel rib features, distorted cut, and lack of staining. With this study, it is aimed to save workforce and energy.

In the future study, it is aimed to continue development for a computer and mobile application. A graphical user interface (GUI) has been started to be designed for the convenience of the user. Tkinter is a GUI tool that comes with the Python programming language. Tkinter which is a python module will be used for this interface design. The necessary parameters for the proposed algorithms can be selected by the user with the GUI as shown in Fig. 9. It is targeted to adapt the interface which is developed to the algorithm.
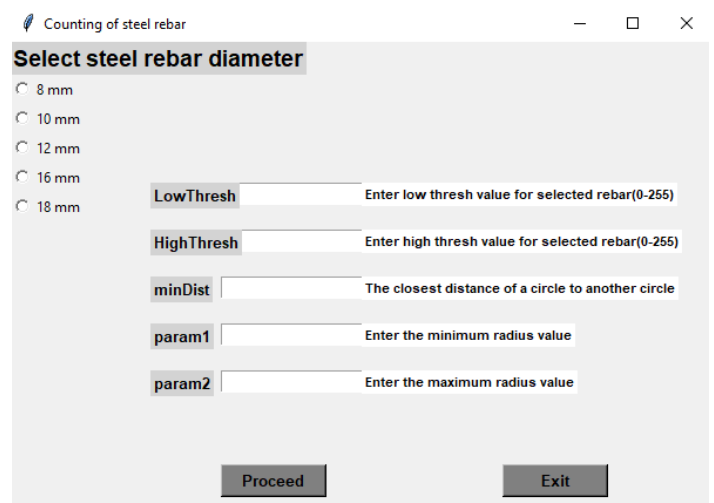

Fig. 9. GUI for the user of the proposed algorithm.

5. Acknowledge

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