Efficient Image Processing Technique for Solid Waste Bin Detection

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Abstract. The main challenge in the technology of image processing is designing of efficient technique for a suitable application area, because the technology is application dependent. Therefore, great attention must be given to designing of the efficient technique and utilizing of the efficient one for the right application. The main aim of this paper is proposed to design image processing techniques by applying Canny edge detection method for extraction of edges. Next, Hough Transform (HT) for getting strong and thin lines from extracted edges. Eventually, orthogonality checking for corner detection and cropped corner parts of image for similarity matching to detect solid waste bin (SWB). To detect corner of the image correctly, two orthogonal lines whose length and coordinate points are thoroughly considered. These orthogonal lines are extracted from detected corners. A 20-by-20pixel width of the detected corner part is cropped. Similarity matching of template image with original image by using cross correlation is done for the correctly detected corner part of the images. Eventually, performance evaluation of the designed technique with existing techniques is done which shows the proposed technique is efficient in detection of SWB.

Keywords: Canny · Hough transform · Orthogonality checking · Corner detection · Cross correlation · Solid waste bin

1 Introduction

Image processing is a way of performing operations such as preprocessing, segmentation, feature extractions and classifications of digital images on digital computer using computer vision algorithms. Image processing technique is a method or an algorithm used to perform these operations. The digital image processing technology has been widely used in many scopes such as solid waste management, food engineering, environment and medical care and so on [1].

The secret of selecting image processing in this work rather than another related technology like machine learning, deep learning is since the input image, SWB, should not be labeled and no need of layering the image. This is because it is possible to identify the image having captured it correctly from its dumping area.

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In digital image processing, image preprocessing, edge detection, feature extraction and classification are particularly the major stages [2, 3]. Techniques for each phase are different even if the whole phases are applied to one specific application. Researches are also undertaken separately for these stages as well. Image preprocessing is a way of removing unwanted information from the image before submitting it to the next image processing stages. It is the method used to prepare images for the further analysis like segmentation and feature extraction [3].

Image segmentation is the most important and challenging task in image processing. It is a process of partitioning an image into meaningful parts which have similar properties and features [4].

The main reason [4] for segmentation in image processing is to extract some features from the image for further analysis. One type of this segmentation is edge detection which is the way of extracting available edges from the images.

One of the most important application areas of the image processing technology is SWB detection. The SWB is a container that contains rubbish until it is collected and disposed. The solid waste is daily outcome of human activities, which can never stop [1]. There are various sources of solid waste which generates large and diverse nature of waste in urban cities. The SWB detection using image processing is a way of detecting the bin by using different image processing techniques [1, 5].

In here, author designed efficient method for SWB detection using image processing techniques such as edge detection, line detection, corner detection and similarity matching. The SWB image data is used by capturing the bin directly from the waste dumping area in Addis Ababa city.

2 Related Work

2.1 Edge Detection Technique

An edge is the most significant feature in the image to analyze the image. And edge detection is the most important and hot research field in the computer vision. There are many edge detection techniques in the image processing.

The works in [6, 7] surveyed the common and classical edge detection algorithms under image segmentation in image processing. The author of this paper concluded that Canny edge detection algorithm is an optimal algorithm among the recommended edge detection algorithms like Sobel, Laplacian of Gaussian and Prewitt edge detectors. Other than Canny edge detection technique, these three techniques have performance problems. Some of these problems are resulting in high error rate which means there are a response for non-edge during edge extraction, high distance of edge pixels in actual and testing images, and there is also a probability of occurrence of noisy pixels in extracted edges [6, 7]. The main secret of famousness of this algorithm is it has three special good characteristics. As authors [6–8] illustrated three good criteria of this algorithm

are: first-low error rate this means that edge occurring in the image should not be missed and there should be no response for non-edge. Second-good localization this means the distance between the edge pixels as found by the detector and the actual edge is to be minimum and the third criteria is single response this means that to have one response for a single edge. These three criteria made the Canny edge detection algorithm the leading-edge detection algorithm in the field of image processing.

2.2 Applications of Image Processing in SWB Detection

As the application areas of image processing is not limited to specific discipline, there are many more contributions of the technology to many domains. One of the applications which is selected by respective researcher of this work is SWB detection and monitoring. Then, the respective author focused on designing an efficient image processing and detection technique for the SWB. Contribution of image processing to effective SWB detection is that, firstly, data acquisition is done, then the color image is converted to grayscale image. Then the grayscale image is resized accordingly and given to edge detection method.

Having detected available edges from the SWB, an edge connection and line formation method is applied. After extracting strong straight lines, the target area should be identified. Eventually, similarity matching is computed to identify true images and match a template image with image in database images [9, 10].

Shafiqul et al. [5] developed the system for SWB detection and classification using image processing. The work tried to bring good solution for SWB detection having used embedded system. However, the system used inefficient image processing techniques such as Dynamic Time Warping (DTW) which detects the bin of solid waste. The drawback of this work is that the work did not consider what will happen if there is noise in the image which means there is no image smoothing method used. The work is also computationally too expensive during calculating whole parts of template with original image for similarity matching.

Hannan et al. [11] developed the system to extract features from the SWB to detect and classify the SWB level using image processing. The work solves the urgent problem by extracting features which is easy and fast to decide the waste level. However, the work did not use efficient image processing technique to extract features and computationally expensive because it considers whole image pixels during matching for true images. There is no described technique for corner detection of the bin as well. The work extracts features using HT only which is not the right way in image processing. Because firstly, the image should be detected correctly having done the right edge detection techniques, then line should have been detected using HT. And also, mechanism to detect the corner of the SWB should be clearly done then, suitable similarity matching techniques should be used. The work missed these main techniques.

3 Proposed Solution

3.1 Introduction

The main objective of this paper is to design efficient image processing technique which effectively detects the SWB. The new technique results:

- effective in edge detection
- effective in line detection
- effective in corner detection
- effective in similarity matching

3.2 Edge Detection Method

In this paper, author selected Canny edge detection to extract and detect the edges from the grayscale image of SWB effectively. The reason for the selection of this technique is already said by previous researchers that the method is effective in resulting in response to single edge, low error rate and good localization.

Therefore, based on this evidence the method is chosen for this paper and details of working principle for this Canny edge detection technique is clearly depicted in the methodology part in the following Fig. 1.

3.3 Line Detection Technique

In this paper HT technique is used and which is an efficient method for detecting lines in binary images. The idea of the Hough algorithm is to transform the shape of interest into its parameter space. For instance, a line in a Cartesian coordinate system (x, y) can be represented as [12],

$$y = mx + b \tag{1}$$

where m is slope of the line and b is interception with y. Each line is characterized uniquely by pair of constants m and b. Consequently, any line can be represented by a point in a coordinate system m and b. In another word, any point (x, y) is associated with a set of values for m and b which satisfy Eq. 1, and can be rewritten as [12],

$$m = \frac{y}{x} - \frac{1}{x}b \tag{2}$$

Therefore, each point (x, y) is represented by a line in a (m, n) space. Algorithmic steps for slope-intercept parametrization of HT looks like the following ones [12, 13]:

- Build a parameter space with suitable quantization level for line slope m and intercept b,
- Create an accumulator array A (m, b),
- Set A (m, b) = 0 ∀ (m, b),
- Extract image edge using Canny edge detector,
- For each pixel on image edges (xi, yi) ∀ (mk, bl), verify equation: $b = x_i mk + y_j$, Increment A (mk, bl) = A (mk, bl) + 1,
- Find the local maxima in the A (mk, bl) which indicates the lines in the parameter space.

Moreover, the slope intercept parameterization is quite acceptable. But there is a problem when vertical lines are close to vertical. In this situation, the slope approaches to infinity. To avoid this problem [13], polar coordinates should be used, which are expressed as:

$$\rho = x\cos\theta + y\sin\theta \tag{3}$$

Where ρ is the minimum distance to the origin and θ is the angle of the line with the horizontal axis, both are related to m and b through

$$m = -\frac{\cos\theta}{\sin\theta} \tag{4}$$

$$b = \frac{\rho}{\sin\theta} \tag{5}$$

3.4 Designing of Corner Detection Technique

Having detected strong lines from HT technique, it is needed to detect corners of the SWB correctly and efficiently. Corner detection is a method of detecting intersecting of two orthogonal lines for the SWB [14, 15]. In here, the main thing to extract lines which could be corners are identified by using orthogonality of two lines.

In addition to this, lengths and angles of lines are also considered. However, to identify the two orthogonal lines, the author of this research work used intersection points for these two orthogonal lines.

To test that two lines are orthogonal, it is necessary to use the following equations [16].

$$\rho 1 = cos\,\theta 1x + sin\,\theta 1y \tag{6}$$

$$\rho 2 = cos\,\theta 2x + sin\,\theta 2y \tag{7}$$

$$(cos\,\theta 1 * cos\,\theta 2) + (sin\,\theta 1 * sin\,\theta 2) = 0 \tag{8}$$

$$x = ((\rho 1 \sin\theta 2) - (\rho 2 \sin\theta 1))\big/((\cos\theta 1 * \sin\theta 2) - (\cos\theta 2 * \sin\theta 1)) \tag{9}$$

$$y = ((\rho 1 \cos \theta 2) - (\rho 2 \cos \theta 1)) \Big/ ((\cos \theta 2 * \sin \theta 1) - (\cos \theta 1 * \sin \theta 2)) \quad (10)$$

If Eq. 8 is true, then the two lines are orthogonal unless two lines are not orthogonal. And Eqs. 9 and 10 show that the intersection coordinate for two orthogonal lines. If these equations satisfy, then it is possible to find corners by using intersection point for only two orthogonal lines. In this case, it must be noted that to get corners for SWB image, the above equations should be satisfied. Therefore, from top lines extracted from HT technique, lines which are orthogonal are considered to detect corners for SWB image. However, there are many lines may be orthogonal to each other, but to detect corners from these many orthogonal lines, the lengths and intersection points for those particular orthogonal lines are considered to efficiently detect true corners from those of unnecessary lines among top lines.

3.5 Similarity Matching Method

In this paper cross correlation is technique is used and which is a way of performing similarity matching between template and actual images. The equation for correlation coefficient to do similarity matching is as follows [4, 17]:

$$c(I,T) = \frac{\sum m \sum n (I_{mn} - \mu_I)(T - \mu_T)}{\sqrt{\left(\sum m \sum n (I_{mn} - \mu_I)^2\right)\left(\sum m \sum n (T_{mn} - \mu_T)^2\right)}} \quad (11)$$

Where I is the candidate corner area in the image, T is the SWB template, m and n are indices to each pixel in I and μI and μT are means of pixel values of I and T respectively. The location of the template superimposed on the actual image with the highest correlation value is considered as true image.

To do similarity matching, rather than checking whole part of image which will be computationally too cost, author used the following method to do it. First, the orthogonality of the two intersecting lines is checked, then the coordinate for these lines is computed and considered as corner of the image as well as it is checked with the coordinate of the template image. Then, 20-by-20pixel width of the detected corner is cropped. Finally, by using cross correlation, this cropped image is checked with all respective cropped images of original with the same pixel width as template image, 20-by-20. The correlation coefficient whose coefficient is highest is considered as true corner and in turn true image SWB.

3.6 Architecture of the Methodology

In this paper, author designed the efficient image processing technique by using the following methodology.

- Description for above Methodology

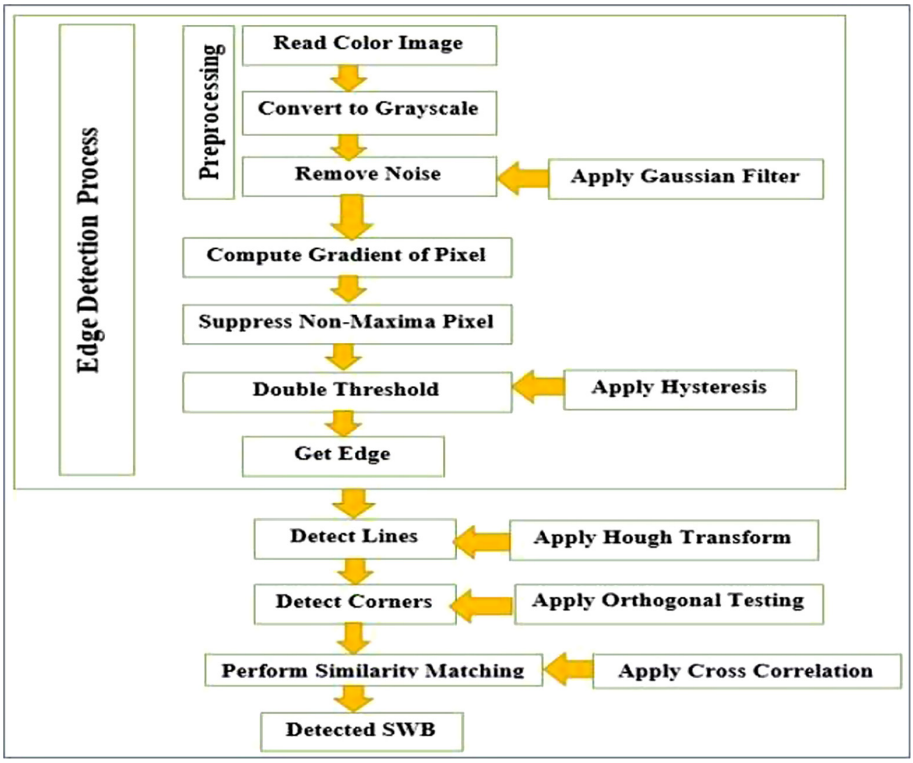

Fig. 1. Architecture of the proposed work

This above Fig. 1 shows firstly, the color image whose pixel value is around 2^{24} is given as input to the system, then the system converts it to grayscale image whose pixel value is around 256 to reduce the computation cost. The color image is captured from real waste dumping place from Addis Ababa city around sub-city of Akaki-Kality in area of Alembank, and Akaki.

The design methodology used here is probable simple sample method. The reason is because the shape of SWB is rectangular shape and it is the same in all cities of Addis Ababa. And the image is captured by smartphone of TECNO mobile with selfie camera stick. During capturing, the distance between the camera man and the bin is around 2 m away and from surface of the bin to top of camera selfie stick is 3-m-long. Because to effectively capture four corners of the bin, the distance should be thoroughly determined.

Then, an image preprocessing technique which is Gaussian filter is applied to smooth the image and remove random noise occurs during image capturing. Having removed the noise, computation of gradient for a pixel is done to extract the edges with its direction from the image. Next to this, Non-Maxima Suppression (NMS) which ignores weak edges and reserves strong edges based on fixed high and low threshold value T.

Then again, applying double threshold to finalize the edge extraction process. This is the process of removing thick edges and reserving thin and strong edges which could

be actual edges of the original image. Finally, the strong edges are extracted. These steps show the edge detection process as it has been depicted in the figure.

Next to edge extraction process, strong lines are extracted from the extracted edges using HT. Then, from extracted available lines, the system detects corner by considering the length and intersection point of these two orthogonal or intersecting lines. From detected corner, the system computes an angle from these orthogonal lines. Then after, 20-by-20pixel width from detected corner part is cropped to do effectively the similarity matching of template image with original image by using cross correlation.

For this paper, the image data is taken from real waste dumping place in Addis Ababa city by using selfie stick and smartphone to test that how well the new technique works. The reason is that since this work is part of research-project initiated by Addis Ababa Science and Technology University and handled by a team in the department of computer science and respective author of this paper.

4 Result and Discussion

4.1 Edge Detection

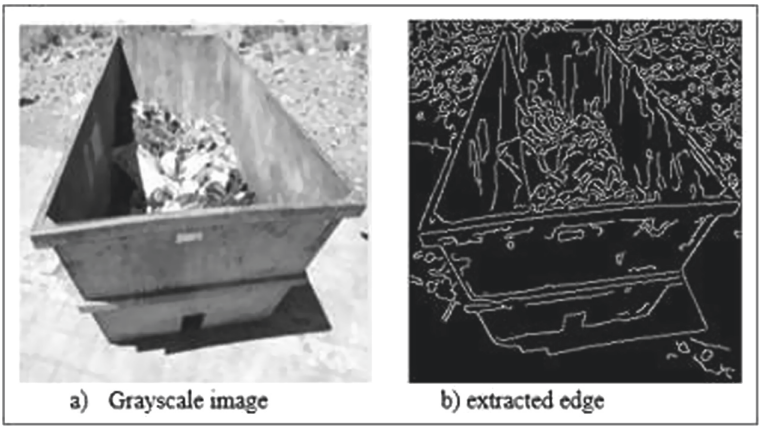

Fig. 2. Edge extraction process

Above Fig. 2 shows extraction of edges by using Canny edge technique. As it is said Canny technique is optimal edge techniques by previous researchers resulting in single edge, low error rate and good localization. Based on this information, author of this paper applied the technique to grayscale image because the technique is only applicable for grayscale image and the result is shown in Fig. 2 in b.

And the technique also smooths the random noise and results in preprocessed result by involving Gaussian filter with in it.

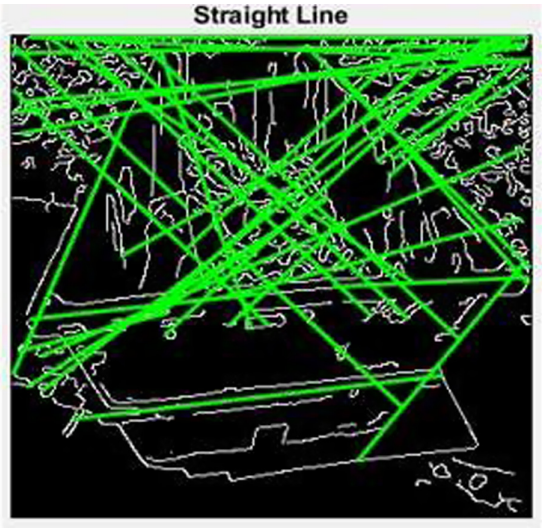

Fig. 3. Strong lines extracted from detected edges

4.2 Line Detection

Figure 3 shows that extracted strong lines by using HT from extracted edges of Fig. 2b. In this result there are 35 lines are extracted from the MATLAB tool by considering a line that when the length of a line is more than 81 and merging two-line segments when a gap between them is less than 31.

4.3 Corner Detection

In the above Fig. 4, corner is detected from strong extracted lines by orthogonality checking. As it has been proved that in order to detect corner in the SWB image, the orthogonality of two lines should be preserved. This means that two longest lines whose coordinates are checked and validated by the actual coordinates of image should be intersecting each other.

As it seen in Fig. 3, there are many lines at most 35 lines are extracted and among those lines there are again many lines which are intersecting one other. From these lines, lines which could be corner/s are validated particularly by their coordinate points. And in Fig. 4, the two lines are orthogonal and their coordinate as it is circled in the figure are validated to detect the corner correctly. The detected corner shows that since the author of this paper used camera stick to capture the SWB image, it was challenging to perfectly capture all four sides which create four respective corners for the SWB image. So, if the one corner which is intersecting of two longest is correctly detected, it is considered as true SWB image and in Fig. 4 shows that correct corner of the image.

4.4 Similarity Matching

As it said, to do similarity matching, checking whole part of image which will be computationally too cost. So, author used orthogonality of the two intersecting lines, then

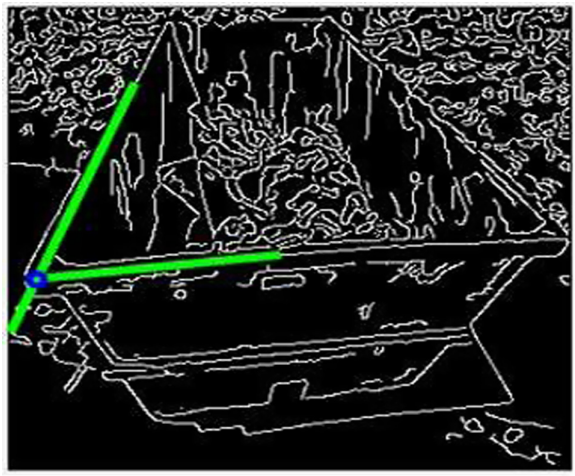

Fig. 4. Corner detection of corner

the coordinate for these lines is computed and considered as corner of the image. And then, it is checked with the coordinate of the template image. Eventually, 20-by-20pixel width of the detected corner is cropped.

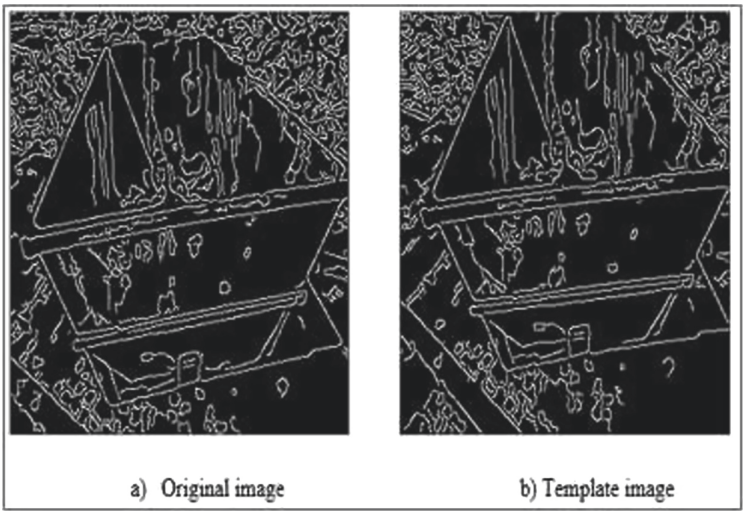

Fig. 5. Similarity matching

The above Fig. 5, shows that similarity matching using cross correlation for only detected corner part (Fig. 6).

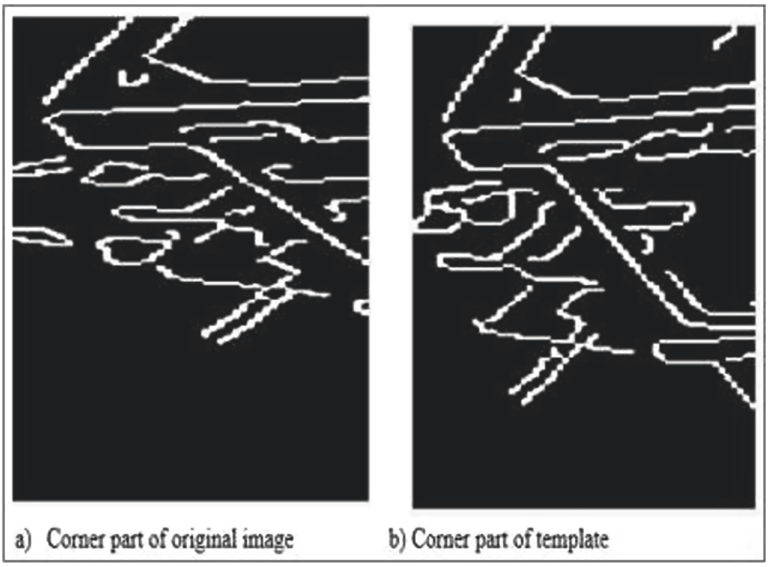

Fig. 6. Similarity matching using cropped parts of images

4.5 Performance Testing

To show that how far the technique is good, the author evaluated the performance testing based on edge detection and similarity matching technique. For edge detection techniques, Structural Similarity Index Metric (SSIM) and Signal to Noise Ratio (SNR) parameters are used for four different edge detection techniques. For similarity matching, cross correlation coefficient is used.

Table 1. Comparisons of different edge detection techniques

Parameter	Sobel	LoG	Prewitt	Canny
SSIM	0.0046	0.0047	0.0046	0.0048
SNR	−56.96	−54.17	−56.95	−52.38

The Table 1 shows that there are four different edge detection techniques like Sobel, Laplacian of Gaussian (LoG), Prewitt and Canny. Performance evaluation for these different edge detection techniques is based on detection of true edge, low error ratio and single response. These qualities are measured by SSIM which is used to measure the structural similarity between two images and Signal to Noise Ratio (SNR) measures that image quality based on the pixel difference between two images.

When there is high numerical value for both SSIM [18] and SNR [19], the method is better to detect available edges on the image. Therefore, from above Table 1, Canny edge detection has high values in both metrics so that the method is optimal method to

detect edges. Based on this evidence, it makes the technique efficient in edge detection from SWB image.

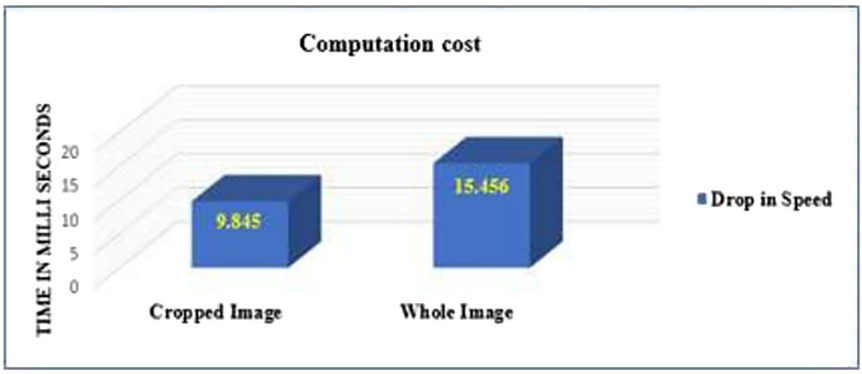

Fig. 7. Computation time for similarity matching for specific and cropped corner

Computing similarity matching for whole image of template with actual image is not cost effective. Therefore, it is necessary to do the computation only for correctly detected part of corner of the images. If the template of corner is detected effectively by using corner detection method, then it is possible to detect whole image of template correctly as well. Because corners are the main target area of the rectangular SWB image. Then, 20-20pixels width of edges of template image along the intersecting lines in the corner is cropped and superimposed on actual image to do similarity matching efficiently.

This is cost effective in reducing computation time than superimposing on whole part of the image and also detects shifted image within domain of the detected corner part. The comparative testing for running time of both whole image and cropped corner part is shown in the above Fig. 7. This is also another parameter which makes the designed new method is efficient in performing similarity matching only for specific part of images.

5 Contribution to New Knowledge

The efficiencies of the method are consideration of length and coordinating point of two intersecting lines from detected lines during corner detection, cropping of specific part for corner and finally, performing similarity matching of template image with original image by using only both cropped part of the images as well.

The technique has shown its better performance in edge detection technique by comparing with common existing edge detection techniques. And it is applied to SWB image to extract strong and weak edges of the image. It also has shown that similarity matching is efficient in performing for only detected and cropped part of the image rather than considering whole image. This results in reducing computation cost. Eventually, the designed method is not only applicable to SWB detection but also, to other application areas based on the structure and type of the application.

6 Conclusion

Designing of efficient image processing technique for SWB has been achieved successfully with the following components. These are edge extraction using optimal technique, Canny. Performance of the evidence of confidence for this optimality of the Canny technique has been tested and verified with quality assessment parameters such as SSIM and SNR. Having effectively extracted, next step is extracting lines by connecting extracted strong and thin edges using HT. Then, to detect the SWB image correctly and effectively, corner detection using orthogonal lines are detected.

During corner detection, length and coordinating point of these two intersecting lines are particularly considered. Then after, the specific part of detected corner part is cropped. Eventually, similarity matching of template image with original image is performed by using only both cropped part of the images. This is particularly to reduce running time during similarity matching of template with original image. This similarity matching is done by using cross correlation and the coefficient whose value is the largest considered as similar image.

The performance testing for used techniques is done with existing techniques in edge detection and cross correlation in order to show that the designed technique by respective author is efficient in detecting the SWB effectively. Therefore, our proposed technique is robust in identifying true position of SWB from other objects by using corner detection and orthogonality checking. It is also computationally cost effective in performing similarity matching by considering only cropped corner part which is correctly detected corner part as well.

The future work which should extended from this work is since the work here is part of the research-project already initiated and under construction by sponsor of Addis Ababa Science and Technology, it should include feature extraction and classification for the detected image to show the status of SWB like empty, medium and full.

After completion of the work, it will be good input for municipals of the city, Addis Ababa, to effectively monitor and manage solid wastes.

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