Journal of Computer Engineering
ISSN 10003428

Original Research Article
Vol 12, Issue 3, 2023 | ISSN: 1000-3428

Enhancing Image Analysis: Illumination and Shadow Filtering for Object Detection in Unconventional Digital Images

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Abstract—In recent years, object detection has gained much attention and very encouraging research area in the field of computer vision. The robust object boundaries detection in an image is demanded in numerous applications of human computer interaction and automated surveillance systems. Many methods and approaches have been developed for automatic object detection in various fields, such as automotive, quality control management and environmental services. Inappropriately, to the best of our knowledge, object detection under illumination with shadow consideration has not been well solved yet. Furthermore, this problem is also one of the major hurdles to keeping an object detection method from the practical applications. This paper presents an approach to automatic object detection in images under non-standardized environmental conditions. A key challenge is how to detect the object, particularly under uneven illumination conditions. Image capturing conditions the algorithms need to consider a variety of possible environmental factors as the colour information, lightening and shadows varies from image to image. Existing methods mostly failed to produce the appropriate result due to variation in colour information, lightening effects, threshold specifications, histogram dependencies and colour ranges. To overcome these limitations we propose an object detection algorithm, with pre-processing methods, to reduce the interference caused by shadow and illumination effects without fixed parameters. We use the *Y CrCb* colour model without any specific colour ranges and predefined threshold values. The segmented object regions are further classified using morphological operations (Erosion and Dilation) and contours. Proposed approach applied on a large image data set acquired under various environmental conditions for wood stack detection. Experiments show the promising result of the proposed approach in comparison with existing methods.
Keywords—Image processing, Illumination equalization, Shadow filtering, Object detection, Colour models, Image segmentation

I. Introduction

COMPUTER vision is a rapidly expanding area and is encouraging attention in many fields of image processing such as object recognition, surveillance and classification of plant types, based on multispectral satellite images, biometric security by using images of faces and images of fingerprints and intelligent robots [1], [2]. A massive amount of research in object detection, localization and tracking can classify into four main groups. (1) Feature invariant approaches: Invariant features, (passive to brightness, and position) are utilized in this approach to detect the object. (2) Template matching method: This technique involves comparison of portions of images against one another. Examples of this method are active Shape Model and shape template [3], [4]. (3) Knowledge-based method: In this method, the position of the object is localized by finding the invariant feature of the object. (4) Appearance-based method: In this method, a series of desire object images are trained that establish a object model for object detection. Feature detection may be achieved by image segmentation in which an image is split in different regions for analysis. Object detection in images is an essential step for many image processing application and accuracy rates of all these applications are combined with the object/feature detection described [5]. In this paper we will concentrate on automatic object detection of wood stacks obtained in the different environmental conditions occurring in the forestry fields. The principal task in object detection is to handle a wide variety of variations in the image such as scale, object orientation, lighting, shadows and colour. External factors such as occlusion, complex backgrounds, inconsistent illumination conditions, same colour objects within the image and quality of the image may increase the complexity of the problems in object detection [6].

Most up to date techniques use pixel-based detection methods which classify all the pixels as object- or background-pixels individually and independent from the neighbouring pixels [7]. Back Projection is a way of recording how well the pixels of a given image fit the distribution of pixels in a histogram model. We need to calculate the histogram model of colour channels and define the histogram bin values for the desire feature and then use it to find this feature in an image [8]. Colour is known to be a useful cue to extract object areas in the images, this allows easy object localisation of likely regions without any consideration of its texture and geometrical properties. The red, green and blue (*RGB*) colour space has been around for a number of years and is widely used throughout computer graphics because colour displays use red, green and blue as they are three primary additive colours that can produce any desired colour. However, *RGB* is not very efficient in real world images. All three RGB components need to be of equal bandwidth to generate any colour within the *RGB* colour cube, also this colour space failed to control the intensity of given pixel. The *Y CbCr* colour space was developed as part of ITU-R

How to cite: Amir Khan, Evelyn Rodriguez, Julian Styles (2023). Enhancing Image Analysis: Illumination and Shadow Filtering for Object Detection in Unconventional Digital Images. Journal of Computer Engineering, 12(3), 14–26. DOI: https://doi.org/10.5281/zenodo.19347987

BT.601 during the development of a world-wide digital components video slandered. *Y CbCr*, used widely in video and image compression schemes such as MPEG and JPEG. *Y* is the luma component, which is luminance, meaning that light intensity is nonlinearly encoded based on gamma corrected RGB primaries and *Cb* and *Cr* are the blue-difference and red-difference chroma components. The HSV (Hue, Saturation and Value) model, also called *HSB* (Hue, Saturation, and Brightness), defines a colour space in terms of three components: Hue (*H*), the colour type (such as red, green). It ranges from 0 to 360 degree, with red at 0 degree, green at 120 degree, blue at 240 degree and so on. Saturation (*S*) of the colour ranges from 0 to 100 %, also sometimes it called the "purity". The lower the saturation of a colour, the more "greyness" is present and the more faded the colour will appear. Value (*V*), the Brightness (B) of the colour ranges from 0 to 100%. It is a nonlinear transformation of the RGB colour space.

A set of rules is constructed in [8] to describe object cluster in *RGB*, *Y CbCr* and *HSV* space classifies desired regions of object by setting bounding rules on channel values. These approaches are strongly dependent on colour channels ranges and histograms bins. The data are split into intervals, called bins, to construct a histogram. Each individual bin contains the number of occurrences of scores in the data set contained within that bin. The proposed solution should not require any user preparation such as predefined colour ranges. During the last decade, considerably development in object detection has been achieved and showed that visual information helps to improve the accuracy and precision of a object detection systems. Image segmentation is a problematical task, because of small contrast between objects, uneven illumination and shadows are important factors which reduced the reliability of image processing algorithms including image segmentation and object detection. Shadow detection and three removal methods, model-based shadow removal, additive shadow removal and combined shadow removal are usually used [9]. Another method *CLAHE* (Contrast Limited Adaptive Histogram Equalization) is used to enhance the contrast of the image in [10]. The drawback of *CLAHE* algorithm is the fact that it is not automatic and needs two input parameters; N size of the sub window and *CL* the clip limit for the method to work. Unfortunately none of the researchers have done the automatic selection of N and *CL* to make the algorithm suitable for any autonomous system [11]. One main reason is that the shadows will be generated when the object illumination comes from the different directions, i.e. parts of desire object will be covered by shadows. Under this situation, it is non-trivial to detect the object precisely from image. To overcome these problems, we propose two pre-processing methods for shadows removal and illumination equalization that could automatically detect shadow regions and then remove them from image.

The key component of the proposed approach is to detect objects (wood stack) automatically in digital images without any user interaction, such as the use of track bar, predefined ranges of colour channels and thresholds. In the first part of the methodology section, the characteristics of the applied colour images and its key factors of the image capturing process and collection of datasets are described. Secondly, we analyse image pre-processing steps (illumination equalization, shadow filtering) in addition with morphology (Erosion and Dilation) to modify the image characteristics for improving the final segmentation result. After that, we describe the experimental results for three different approaches. Polygon and contour approaches are applied on the detected objects discussed in results and discussion part. The processing chain has been developed using Visual Studio 2013 and OpenCV Library [12].

II. Material and Methods

Image is a central part of the computer vision and provide the representation of visual appearance that we obtain from the imaging sensor to process for a particular image task. An image is considered as a continuous bi-dimensional area of two coordinates in the image plane expressed as (*i,j*) or (*column,row*). The spectral characteristics of a two-dimensional image vary according to the number of 'colour' channels, the specific location and band width of the colour channel within the electromagnetic spectrum. The images used in this study are collected by a frame sensor sensitive in the red, green and blue region of the electromagnetic spectrum. Hence they represent both luminance and chrominance (colour information) within the scene.

1) Colour Models: The visual appearance of the object in image holds a lot of information and spatial unit of a digital colour image is a pixel. The spectral information of each pixel is retrieved from the pixel specific spectral channel combination of primary colours. A channel in the context of digital imagery is the mono dimensional (gray scale) image of the same spatial size as a colour image, for instance, an image from a standard digital camera will have *RGB* a red, a green and a blue channel. On the other hand there is one channel in gray scale image. There are many colour models used in image processing. *RGB* is the most common model as the human visual system uses the same spectral components. Many approaches are available in the literature to do this task whereas an image is often segmented by the means of transforming *RGB* colour space into *CIE − LUV* (colour space adopted by the International Commission on Illumination CIE), *HSV* (Hue Saturation Value), *Y CbCr* (Y is the luma component and Cb and Cr are the blue and red-difference chroma components) or a similar space [13], [5], [7]. *Y CbCr* is used by the popular *JPEG* image format and designed it for digital images. Some colour spaces have their luminance component separated from the chromatic component, and check discriminately between pixels over various illumination conditions. Colour models that operate only on chrominance subspaces such as the *Cb–Cr* have been found to be effective in characterising various object colours [14], [15]. We will also use the *Y CbCr* in our proposed method. Object colour classification can be accomplished by explicitly modelling the distribution on certain colour spaces using parametric decision rules [16].

2) Data Set: The study presented here was conducted using an experimental data set consisting of 46 images achieved during field campaigns in 2013-2016 in Germany. The images were achieved at several wood stack locations directly in the forest. Therefore, the data set provides real operational characteristics. The image quality varies on its radiometric characteristics and the object characteristic itself. The object variations are mainly presented by: Wood colour, background objects like standing trees, front covering objects e.g. grass, shadows. The images are collected using different digital camera with different resolutions. The image data are stored as *JPEG* compression level 99 which represents the lowest possible compression rate supported. The image series were acquired with same parameter settings of the camera to avoid the effects of changes in image brightness, contrast level, angle, distance and overlapping of wood stacks.

A. Pre-Processing

Smoothing is often used to reduce noise within an image or to produce a less pixelated image. Most smoothing methods are based on low pass filters that provide flexible and robust analyses, as mentioned in [17]. So far, we reviewed three image filters: Gaussian, median and bilateral. One of the most advanced filters is bilateral. The drawback of these type of filters is that it takes longer time to analyse the input image and define the kernal sizes. However, in some cases these filters can enhance the edges of objects but on the other side it also analyses the noisy pixels around the object. Gaussian smoothingis also used as a pre-processing stage in computer vision algorithms in order to enhance image structures at different scales [18]. In our research, we have high quality and large size of images with considerable computation time so we proposed two filters to overwhelm the lightening and shadows problems.

1) Illumination Equalization: Images are captured in different environmental conditions where, sometimes lightening is very strong and irregular. This irregularity is the cause of a variety of disorders that can lead to erroneous object detection, and makes it difficult to estimate actual volume of object. In the past, various methods have been proposed for the enhancement of image, Histogram equalization and equalization of the lighting [17]. The method in [19] works exclusively on the luminance value of the individual pixel. Although, it has few flaws such as: The effects of irregular lighting are attenuated only along the single direction vertical and fixed scaling size of image (71×144) and mask size (3×3). We decided to improve the model presented in [19] making it more robust with respect to light, multiple direction horizontal and vertical, working no more than on the single pixels but also on local regions as well within the image. The extended algorithm can adapt to the multiple directions of the lighting as shown in Fig. 1.

The original image size $m \times n$ provided to the input of the function is initially converted in *HSV* colour space; let $L(i,j)$ is the $L'(i,j)$ representing respectively the luminance of each pixel before and after the operation of equalization. To simplify the process, assume that the non-uniform illumination is instead linear along the direction of its application. As mentioned earlier, the innovation brought to method implemented in this elaborate consists of manipulating not the luminance value of the individual pixels, but working on a local region of size $(2p + 1) \times (2q + 1)$. Each pixel of the original image assumes the value obtained from the calculation of the average of the luminance values of all the pixels included in the mask that flows throughout the image along the two main directions identified. The calculation of the luminance value of the pixels obtained by the application formulated (Horizontal and Vertical) directions is as shown in
(1).

$$L'(i,j) = \begin{cases} L(i,j) + \frac{(n-2j+1)*(r(p)-l(p))}{2(n-1)}, & i \in [1,p] \\ L(i,j) + \frac{(n-2j+1)*(r(m-p)-l(m-p))}{2(n-1)}, & i \in [p, m-p] \\ L(i,j) + \frac{(n-2j+1)*(r(i)-l(i))}{2(n-1)}, & i \in [m-p, m] \end{cases} \tag{1}$$

$$L'(i,j) = \begin{cases} L(i,j) + \frac{(m-2i+1)*(b(q)-t(q))}{2(m-1)}, & i \in [1,q] \\ L(i,j) + \frac{(m-2i+1)*(b(j)-t(j))}{2(m-1)}, & i \in [q, n-q] \\ L(i,j) + \frac{(m-2i+1)*(b(n-q)-t(n-q))}{2(m-1)}, & i \in [n-q, n] \end{cases} \tag{2}$$

where l_i and r_i denote the average intensity of respectively left and right edges of the local region of size $(2p+1) \times (2q+1)$, to the i_{th} row of the mask. Similarly, t_j and b_j denote the average intensity of the upper and lower edges of the local region at the j_{th} column of the mask as shown in Fig. 1.

2) Shadow Filtering: The presence of shadow in real image is responsible for reducing the reliability of computer vision algorithms, including image segmentation and object detection. Therefore, shadow detection and removal is an important pre-processing step to improve the object detection methods. Shadow detection and three removal methods, model-based shadow removal, additive shadow removal and combined shadow removal are usually used [20]. The pre-processing phase of the frames concludes with the application of a mean filter designed to reduce noise caused by the presence of shadow in the images described [22]. These kinds of disturbances are once again because of different lighting conditions e.g. sourcing of light angles and some sort of shades nearer objects, such as grass and trees. Unfortunately, up to no,w algorithms of automated object detection have not effectively solved the problem of locating the objects in uneven lighting with shadows conditions. Illumination equalized image used to reduce the interference brought by shadow. To implement shadow detection method, we used these steps: i) Convert the illumination equalized image into grayscale. ii) Consider the image as a matrix in which the rows are characterized by the index i and columns from the index j. iii) Calculate the accumulation of the grey-level value for each column of the image, and obtain column index corresponding to the mean value of the accumulation curve as the boundary of shadow. It is used to divide the grayscale image into in two sub images left I_{sl} and right I_{sr} to enhance the contrast between desire object and surrounding objects with (3).

$$I_e = \frac{255(I - I_{min})}{(I_{max} - I_{min})} \qquad (3)$$

where, I_{min} is the minimum grey-level value in the image, and I_{max} is the maximum value. The boundary shadow eliminated by applying a mask (3 × 3) in the image by matrix M. M

Fig. 2 (a) Original image (b) Greyscale (c) left image (I_{sl}) convoluted (d) right image (I_{sr}) convoluted (e) Merged Image, (f) output result after shadow filtering

is used to perform a mean filter to smoothing contrast filter on both images, where I^i is the result of the i_{th} time filter, which applied on both sub images by (4).

$$\delta_i = dist((I^{i+1}),(I^i)) \qquad (4)$$

Euclidean distance δ_i is determined by calculating the distance between (I^i) and (I^{i+1}). δ_i is determined by calculating the distance between (I^i) and (I^{i+1}). If ($\delta^{(i+1)}$ is greater than or equal to Euclidean distance then process will stop and (I^i) is marked as final image I_f. Convolution process ends when the Euclidean distance decreases by less than two units between two subsequent iterations. In the proposed function, we determined I_f to each sub image and get the whole image and output image I_{sl} extracted by subtraction of the initial image I^0 and final image I_f. The middle line in Fig. 2 (e) is obtained between I_{sl} and I_{sr} by curve, having information about boundaries of the object and the minimum value of the row position is considered the corner points of the object. The shadow detection ends by making new image by merging two images left I_{sl} and right I_{sr} as shown in Figs. 2 (c) and 5 (e), improvement between the original and image is obtained after smoothing the contrast under the shadow displayed as more highlighted.

III. Experiments and Overview of Previous Methods

Various works have been made for the object detection in the last decade. In this section, two typical approaches will be reviewed. Colour regions are extracted by using set of bounding rules based on the colour distribution obtained from data set of images [8]. In our first two experiments we followed these rules to detect the desired object.

A. Experiment 1

In our first experiment, we used the back projection method to detect and draw the contour line. Process chain diagram of method is described in Fig. 3.

The main steps taken in this method are as follows:

- Read the *RGB* image and apply smoothing filters (bilateral).
- Split the Image channels RGB and define the ranges, *R*(90 – 255),*G*(70–250),*B*(30–215)
- Covert *RGB* to *HSV* and select the$'H'$ $H < 45$, calculate histogram with HistSize = 16 and *range*(20,180)
- Apply Back Projection and Binary Thresholding in range(60–255).
- Apply morphological ellipse erosion and dilation (opening), Dilation size= image image/50,Erosion size = dilation size /3.
- Find largest contours and store in mask Image.

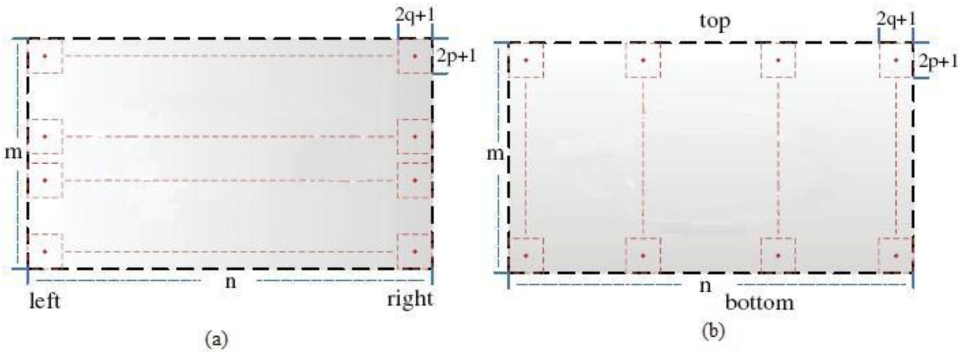

Fig. 1 Illumination Equalization in (a) Horizontal Direction and in (b) Vertical direction [19].

- Subtract mask image with original image and save as sub image.
- Final out put image, Draw contour / Polygon or Convex Hull . This method showed some good results of polygon contour line but failed in many cases to find a closed boundary line, In this method under limited conditions such as fixed colour channels ($RGBandH$), binary thresholding and histogram bins values in addition to Bilateral smoothing filter with back projection are applied. We calculate the execution time as well. The red channel value$'R'$ value must be bigger than Blue $'B'$and Green$'G'$ value.

B. Experiment 2

In this experiment, we followed the RGB and H channel bounding rules, but without using the YCrCb rules defined in [8], [15]. These rules are constructed based on the object colour distribution obtained from the data set images.

The main steps taken in this method are as follows:

- Read the *RGB* image and apply smoothing filter.
- Set the ranges for *RGB* Channels $(R > 95) \wedge (G > 40) \wedge (B > 20)$,

$(R > 220) \wedge (G > 210) \wedge (B > 170)$

- *H* channel value from 0-180 and $(H < 45)$
- Equalized Histogram of *V* channel
- Each pixel that fulfils Rule *RGB* and *H* is classified as an object colour pixel and stored in new *RGB* image
- Convert Mask new *RGB* object into grey scale and use thresholding 0 255 of Otsu

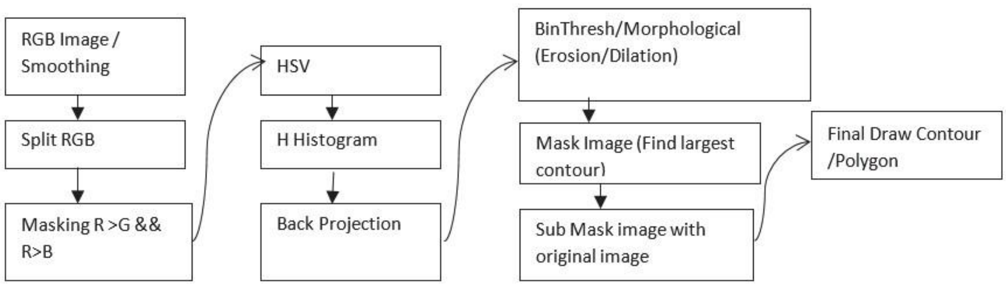

Fig. 3 Process chain diagram with RGB and H channel rules with Back projection

- Apply morphological (opening), Dilation size= image image/50, Erosion size = dilation size /3.
- Find contours, largest one (Mask Image).
- Subtract mask image with original image. • Draw contour / Polygon (Convex Hull).

In this method we used the Median blur filtering for smoothing and apply otsu thresholding default values (0-255) and colour channel values of *RGB* and *H*. Results showed that we have good results as compared to previous method 1 as well as less processing time.

C. Proposed Method

Keeping in view the main objectives of our research and the limitations of previous methods, there is a strong need to develop the algorithm without specifying the colour ranges and thresholding values, lightening effects and shadows to retrieve more robust object detection result. In some cases, images have shades on the wood stacks and bad lightening produced by surroundings trees or objects. It gives bad detection result. To avoid these problem, we used Illumination equalization method and shadow filtering methods. An effective method to reduce the effects of uneven illumination is proposed that is more robust with respect to light, multiple directions (horizontal and vertical), and working on both the single pixels and on local regions within the image. In the past, some shadow detection methods been proposed, but these techniques are applicable only in indoor environments, and have not been studied for natural environmental conditions. Therefore, we proposed a function for shadow removal as described in shadow filtering section. The illumination equalized image convert into grey scale and finds the vertical axis where the shadow started. The image divided into two sub images (left and right sub images). For each sub image, the stretch contrast of the grey pixel value is applied and both images merged. We obtain a convolved image. The vertical axis represents the index where the shadow started. The effectiveness of the proposed pre-processing steps as shown in Fig. 2. It can be clearly observe that there is no uniform illumination in images (e.g. in horizontal direction). There are some darker parts on the left or right side, and the same in vertical directions where darker parts are on the top or bottom. By applying illumination equalization to both directions in the image and shadow filtering, the result was quite impressive. Uniform illumination could be obtain and the dark part of the right region significantly reduced as shown in Fig. 2.

The main steps taken in this method are as follows:

- Read the RGB image
- apply Pre-Processing (Illumination and Shadow)
- Convert processed RGB image to YCrCb select Cr channel
- Thresholding 0 255 of Otsu on Cr Image
- Apply morphological ellipse erosion and dilation (opening) Dilation size= image image/50,Erosion size = dilation size /3
- Find Largest contours (Mask Image)
- Subtract mask image with original image (Sub Image)

- Draw contour / Polygon (Sub Image)

Fig. 4 shows the proposed methods with the experimental results of each step defined above. Firstly load the stitched colour image Fig. 4 (a) from data set and applied pre-processing steps to avoid the un-even illumination and shadows effects Fig. 4 (b), then converted into $Y\ CrCb$ colour space and split the three channels Y , Cr and Cb, select Cr channel Fig. 4 (c) and apply threshholding (otsu) to get a binary image as shown in Fig. 4 (d). To remove noisy pixels, we perform morphological operations with erosion size 10 and 15 for dilation in Figs. 4 (e) and (f). Find the largest contour on the dilated image and use as mask image and subtract mask image with original as shown in Fig. 4 (g). Finally, draw the contour line and polygon (convex hull) around the object, Figs. 4 (h) and (i). We can see the precise green colour boundary line around the wood stacks without losing any wood stack data. Furthermore with this, we can measure the area of wood stacks.

IV. Result and Discussion

A. Acceptance Criteria

We applied three different methods on a wood stack image data sets consisting of 46 images by using Visual Studio 2013 with Intel Open Source Computer Vision Library Opencv [12]. Fig. 4 (i) polygon and Fig. 4 (h) contour line showed good result without losing information of object and images are segmented correctly and were considered as reference with 100 % correct result for our acceptance criteria.

B. Experiments

The first method followed the predefined colour channels ranges RGB and H with ranges $R(90 - 255)$, $G(70 - 250)$ and $B(30 - 215)$. R value must be bigger than B and G value. Bilateral smoothing filter is applied and we calculated histogram of the H channel with HistSize (bins) = 16, ranges (20, 180), normalized it and applied Back Projection. Binary thresholding is applied with defined threshold values (60-255). Morphological operation applied ellipse erosion and dilation for finding and drawing the polygon contour (convex hull).

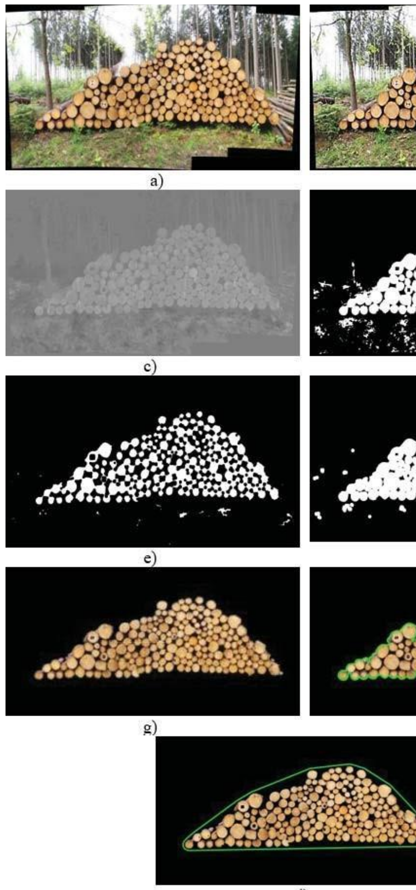

Fig. 4 Proposed method (a) Original Image (b) Smoothing filtering (c) cr Channle Image (d) Bi
image (h) contour result (i) conve

Fig. 5 is showing the overall result of method 1, where black trend line polygon/convex hull results are in range of 6878% and boundary line 5776%. Polygon contour having these conditions have some good result but failed in many cases (uneven illumination and shaded) to find closed boundary line. Secondly, we have to define the ranges of RGB, H channels, histogram bin, thresholding, erosion and high dilation size depending on the object size. In method 2, we applied the Median blur for smoothing and removed snow and sky colour pixels by setting ranges of RGB and H, if both conditions are true then pixels are considered to object colour pixels and remaining pixels are set to black and stored. The default Otsu thresholding with morphological operator, erode first and dilate are applied. Results showed that we have slightly good results in method 2 as compared to method 1 as shown in Fig. 7. Trend line of polygon shows that we have good polygon result between 75 and 80%, and the contour line is 68 to 79%. In this method, we lost the object data in the variation of colours, light and shadows where object is visible, also we have to set the ranges of desire object and as we early described that once we defined the colour ranges, it cannot be applicable for all the images.

In the proposed method, we developed the two pre-processing methods to over come the lightening and shadow effects in the image, we used *Y crCb* colour space without setting the colour ranges as used in previous methods. According to our experiments, 90% of polygon results and 80% of the boundary lines around the wood stacks met our acceptance criteria and are represented in Fig. 4. Dotted line shows the percentage of attained polygon and boundary line contours. In some cases, we lost polygon and lines due to image quality and stitching problem.

Fig. 5 is showing a few more results where the wood stacks are in different conditions like soil (a), snow (b) and grassy areas (c).

C. Comparison

We compared the results by acceptance criteria. The method 1 used the back projection with setting the histogram bins and limited ranges of *RGB* and *H* colour channels of wood stack and binary thresholding (100-200) values as described in Table I. Average result of polygon is 73% and

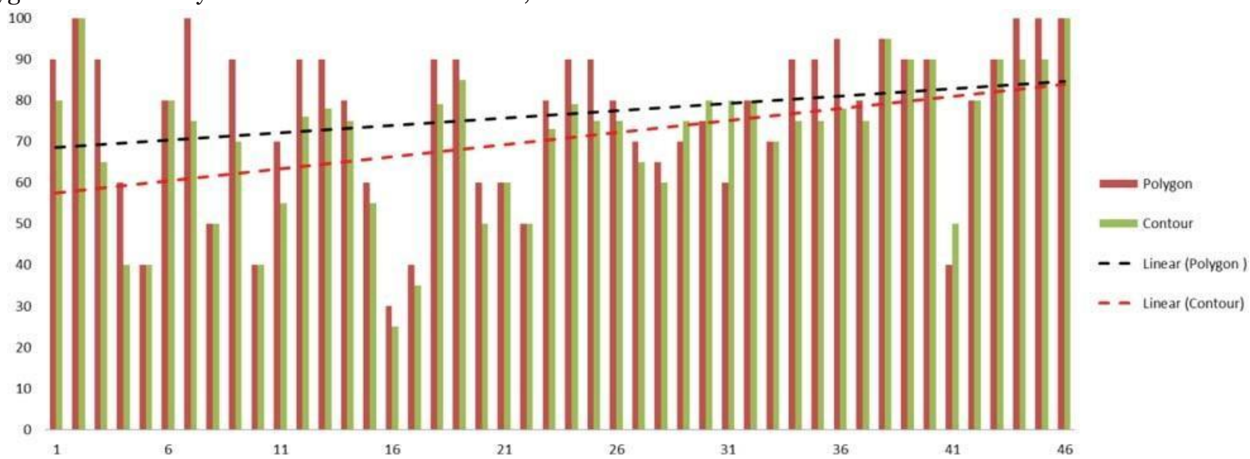

Fig. 5 Overall performance of method 1

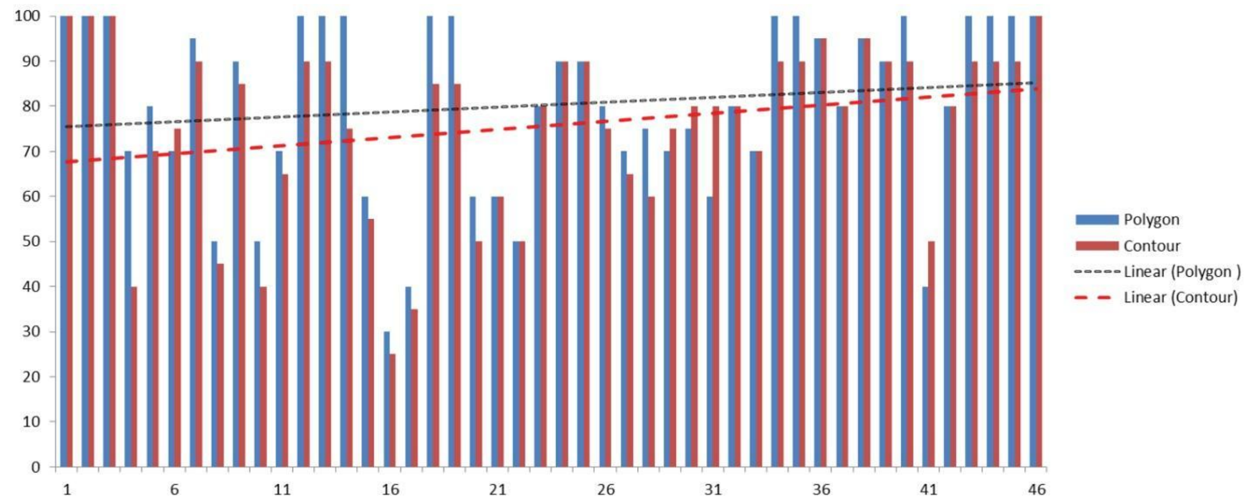

Fig. 6 Overall performance of method 2

TABLE I
COMPARISONS OF METHOD 1, 2 AND PROPOSED METHOD

Method	Polygon /covexhull %	Contour%	Threshold	Colour ranges	Back Projection	Smoothing / preprocessing
1	73.50	68	Binary (100-200)	Predefined	Yes	Bilateral
2	77.50	73.50	Otsu (default)	Predefined	NA	HE, Median

Proposed	92	81.50	Otsu (default)	NA	NA	Shadows , Illumination

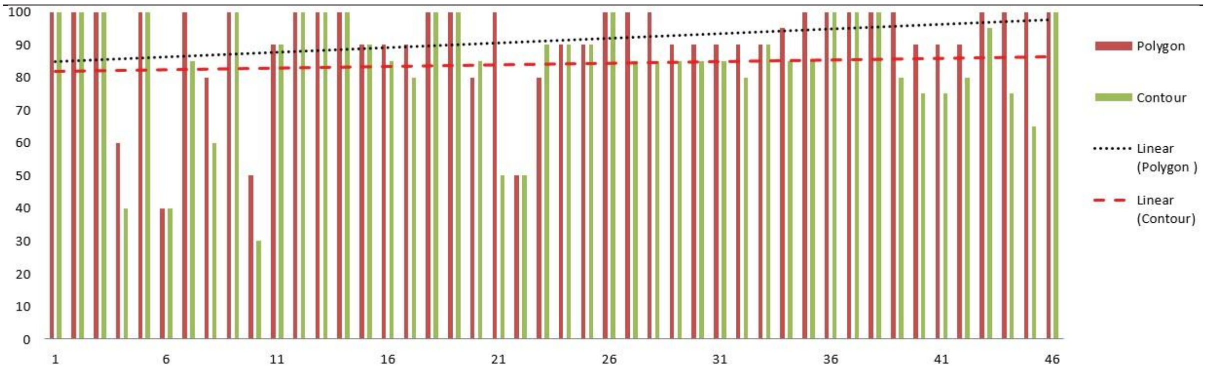

Fig. 7 Overall performance of proposed method

TABLE II

Image Size	Method 1 Bilateral(S)	Method 2 Median Blur (S)	Proposed (S)
3298 x 994	8.436	7.654	3.282
4268 x 1304	14.543	8.932	5.941
4517 x 1480	15.832	10.162	6.061
2973 x 1044	7.876	4.671	3.094
2747 x 1389	8.654	6.553	3.109
7970 x 1111	13.124	11.094	9.51
4695 x 926	9.451	4.671	4.349
2287 x 919	5.701	2.532	1.678
3189 x 930	4.325	2.541	4.315
3110 x 1077	6.367	3.922	2.232
4387 x 932	6.980	4.913	3.56
4233 x 1141	12.713	9.947	4.819
13100 x 1382	46.987	27.781	10.685
3872 x 715	5.943	3.595	3.507
4496 x 938	5.954	3.814	2.541

COMPARISON OF COMPUTATIONAL TIME IN (SECONDS)

Fig. 9 Overall performance of methods

used high quality digital images for experiments and observed that the computational time for proposed algorithm is less compared to other two methods. During the experimental stage, it is observed that applying bilateral or median blur we need more computational time, but in the proposed method with illumination and shadow filtering, it took less processing time. The time taken for some images is shown in Table II. The proposed algorithm is less computationally extensive as compare to other two methods

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results. It can be seen in Table II that the processing time is very high by using Bilateral smoothing filter in Method 1 and slightly less processing time required in method 2 by using median blur filter. Both of these methods are also limited to colour ranges and used Histogram equalization and *CLAHE* (Contrast Limited Adaptive Histogram Equalization) used to enhance the contrast of the image, which is not automatic and needs input parameters for the method to work. On the other hand, the proposed method applied pre-processing methods with setting colour ranges reached 92% robust results as

described in Table I. It has extracted the Polygon quite well. Actually, the proposed method is more tolerant to the uneven illumination and shadows. Furthermore, we have also examined those unsatisfactory results and found that the images in these cases all have either the very poor contrast between the object and the surrounding regions.

As the image quality is the driving factor of the success of any object detection method, we tried to combine the image capturing and the object detection in a very early stage of the image taking. As the environmental conditions vary a lot it would be efficient to control the camera parameters depending on the object detection success.

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