"Investigate Edge Distortion Within C*aptured Image Under Low Lighting"*

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Abstract

Study and analysis image processing that deals with low lightness and low contrast has major importance in many applications and fields. Images captured in low-light environment companied always with noise and distortion. This considered a big problem in digital image processing. So, a focused study in this paper achieving at low lightness condition effect for captured images using two types of camera (Samsung and Sony). Lighting is controlled by self-proposed lighting system. This system has three florescent lights with different size and power to control light environment. Test image (black and white) used to study distortions that formed at edges image as a result of low lightness due to noise. This study focused on edge contrast, number of edge points and comparison between edge points for the best image picture lighting (80) Lux and group image under low lightness (1) Lux to see number of edges that added or removed as a function of light intensity. It shown that Sony is better than Samsung camera depending on edge contrast and common edge points under low lightness condition. These methods are good indicators to estimate the quality of images and cameras.
Keywords: Edge Detection, Images Lightness, Edge Point's Number, Noise.

الخلاصة:

تعد دراسة وتحليل الصور الرقمية قليلة الاضاءة والتباين ذات أهمية كبرى في العديد من التطبيقات في مجالات عدة. إذ ترافق الصور ذات الاضاءة المنخفضة نسبة عاليه من الضوضاءالضربية

والتشوهات وهذه تعتبر مشكلة كبيرة للصور الرقمية في تلك المجالات. لذا توجهنا في هذا البحث دراسة تأثيرالاضاءة الخافتة على الصور الملتقطة باستخدام نوعين من الكاميرات (سامسونج وسوني). حيث تم التحكم بالاضاءة بأعتماد منظومة إضاءة تتكون من ثلاث مصابيح فلورسنت مختلفة الاحجام والقدرة. إذ تم دراسة صور إختبارية (اسود وابيض) من حيث التشوهات المتكونة في حافات الصور نتيجة قلة الإضاءة. حيث تركز البحث على دراسة التباين في مناطق الحافات، عدد نقاط الحافات كدالة لتغير شدة الاضاءة المعتمدة أثناء التصوير وكذلك مقارنة بين نقاط الحافات لصورة جيدة الاضاءة (٨٠ Lux) مع مجموعة صور ذات إضاءات خافتة (١ Lux). من خلال النتائج تبين ان كاميرا سوني أفضل من كاميرا سامسونج بالأعتماد على الطرق المقترحة. تعتبر هذه الطرق جيدة لتخمين جودة الصور وجودة الكاميرا الرقمية.

1. Introduction

The amount of light coming to the eye from an object depends on the amount of light that strike the surface, and on the proportion of light that is reflected. If a visual system only made a single measurement of luminance, acting as a photometer, then there would be no way to distinguish a white surface in dim light from a black surface in bright light. Yet humans can usually do so, and this skill is known as lightness constancy [1]. Most vision applications such as surveillance, security, etc. require robust detection of image features. Images captured under low-light conditions (e.g. night time, indoor and underexposure) are suffer from poor lightness and severely distorted color and thus exhibit very little scene information. Therefore, it is imperative to study lightness, contrast and color fidelity in order to provide a clearer view of the scene and make vision systems more reliable [2]. Images formed at low-light levels are corrupted by the noise associated with the discrete nature of light. This noise is labeled as Poisson noise, because the emission of photons is governed by a Poisson random process. Noise is clearly signal dependent. Therefore, the variance of the Poisson probability density is equal to its mean [2].

The previous works within this section focus on the analytical study of edge images captured under low lighting conditions. A brief description to each of them is:

- ***Thuy Tuong et al.*** **(2008)** proposed a method which doesn't depend on a reference image and it calculates the entropy of the first derivative of the lightness component and evaluates probability of edges region [3].
- ***Salema S. Salman*** **(2009)** studied effect of different lighting operations in type and intensity on test images using different light sources (tungsten and fluorescent lamp). She studied the distribution homogeneity of light intensity of a line partitioned from the middle of white test image width and height and focused on the contrast ratio as a function for light intensity using a test image with one half white and the other half black [4].
- ***W. S. Malpica, A. C. Bovik*** **(2009)** suggested full image quality assessment using structural similarity index, this method requires two images (optimal and original image) and then evaluation of three different measures like luminance, contrast, and structure comparison [5].
- **G.T. Shrivakshan (2012)** studied observation of shark fish classification through image processing using various edge detector filters like Roberts, Sobel, Prewitt, Laplacian and Canny. Then compared between the advantages and disadvantages of these filters [6].
- ***Ji-Hye k., et al.*** **(2014)** proposed an image fusion method using two different exposed images in low light condition. It based on the weighted summation approach. Weights are computed by estimating the amount of blurriness and noisiness. Blur is measured by detecting edges and estimating the amount of blurriness at detected edges in the compensated long-exposure image [7].

2. Edge Detection For Low Lightness Images

Low light imaging system is widely used in scientific research and technology. The computer vision methods are being used in this mode. The applications of low light imaging systems can be summarized by the following fields [8]: surveillance, security, underwater imaging, night vision, pipelines, astronomical imaging, archaeology, medical imaging, aerial imaging and imaging inside the caves and indoor.

Edge detection is based on one of the discrete differentiation forms. It is the foundation of many applications in computer vision which consider important task. It is a main tool in pattern recognition, image segmentation, and scene analysis. An edge is loosely defined as an extended region in image that undergoes a rapid directional change in intensity [9]. Edge detection algorithms usually detect sharp transition of intensity and/or color within an image. These transitions are characteristic of an object's edges. Once edges of an object are detected, other processing such as region segmentation, text finding, and object recognition can take place [10].

The goal of edge detection is to locate pixels within an image that corresponds to object edges. This is usually done with a first and/or second derivative function followed by a threshold value which marks pixel as either belonging to an edge or not. The result is a binary image, which contains only the detected edge pixels. Edge detection can be used to find complex object boundaries by making potential edge points corresponding to places in an image where rapid changes in brightness occur. After these points have been marked, it can be merged to form lines and object outlines [11].

2.1 Sobel Operator

Sobel edge masks look for edges in both horizontal and vertical direction and then combine these information into single metric. Sobel operator performs 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial difference that corresponds to edges. The operator consists of a pair of (3x3) convolution kernel [12].

Sobel operator is slower than Robert Cross operator, however, it has larger convolution kernel that smooth the input image to a greater extent and so makes the operator less sensitive to noise. Generally, the operator also produces a considerably higher edge points for similar image compared to Roberts Cross operator [13]. Sobel operator for x-axis and y-axis can be write as [14]:

$$M_x = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} \qquad (1)$$

$$M_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \qquad (2)$$

2.2 Thresholding

Thresholding converts gradient intensity-level image into binary image. This can be done by setting all pixel magnitude above a certain value to (1) and all those below to this value to (0) [15]. A threshold is a minimum acceptable gradient modulus to determine an edge [16].

Black pixels correspond to edge regions and white pixels correspond to homogenous (non-edge) regions (or vice versa) [17]

.

$$I(x,y)=\begin{cases}0 & edge\ \ |E(x,y)|\geq th\\ 1 & else\end{cases} \quad (3)$$

where *E(x, y)* is image gradient, *th* is certain threshold, and *I(x, y)* is output binary image.

3. Image Statistics

An image can be presents statically in different ways. It can be presented by the following subsection:

- ***Mean (μ):***

Image mean brightness is known as the mean brightness for image elements (or sub image) and it determines from the following relationship [18]:

$$\mu=\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} f\,(i,j) \quad (4)$$

Where *M* and *N* denote to image high and width (or sub image), and the multiplication of them equals to the number of image elements.

- ***Standard Deviation (STD or σ):***

Standard deviation represents the mean of variations of the element values with respect to its mean. It determined from the following relationship [18]:

$$\sigma=\sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(f(i,j)-\mu)^2}{M*N}} \quad (5)$$

- ***Image Contrast***

Contrast is relative measure of intensity of a stimulus as compared to its surroundings (It is dimensionless). In psychophysical studies, the typical measure of contrast between two intensities L_{max} and L_{min} (L_{max} brighter) is the Michelson contrast that defined in eq. (6):

$$C_t = \frac{L_{max-} L_{min}}{L_{max}+L_{min}} \qquad (6)$$

Where L_{max} and L_{min} refer to the maximum and minimum luminance value in the pattern respectively. There is another type of statistical variation and can expressed as:

$$\mathrm{CT} = \frac{\sigma}{\mu} \qquad (7)$$

4. Experimental Data

In this study, captured test image (Black and white target image) studied in geometry depict in figure (1). This image is placed one meter apart of two cameras type Samsung (SN-Cam) and Sony (SN-Cam) and light source placed behind cameras. Light source composed of three fluorescent lamps. Intensity light measured using Lux meter device. Then this image captured in different lighting values (1-240) Lux. These images saved in JPEG format and size 640×480 pixel under low lightness as shown in figure (2).

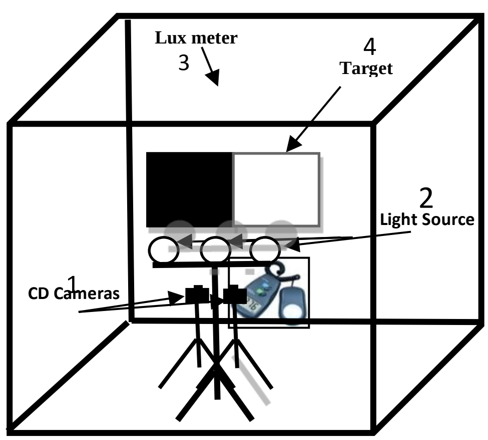
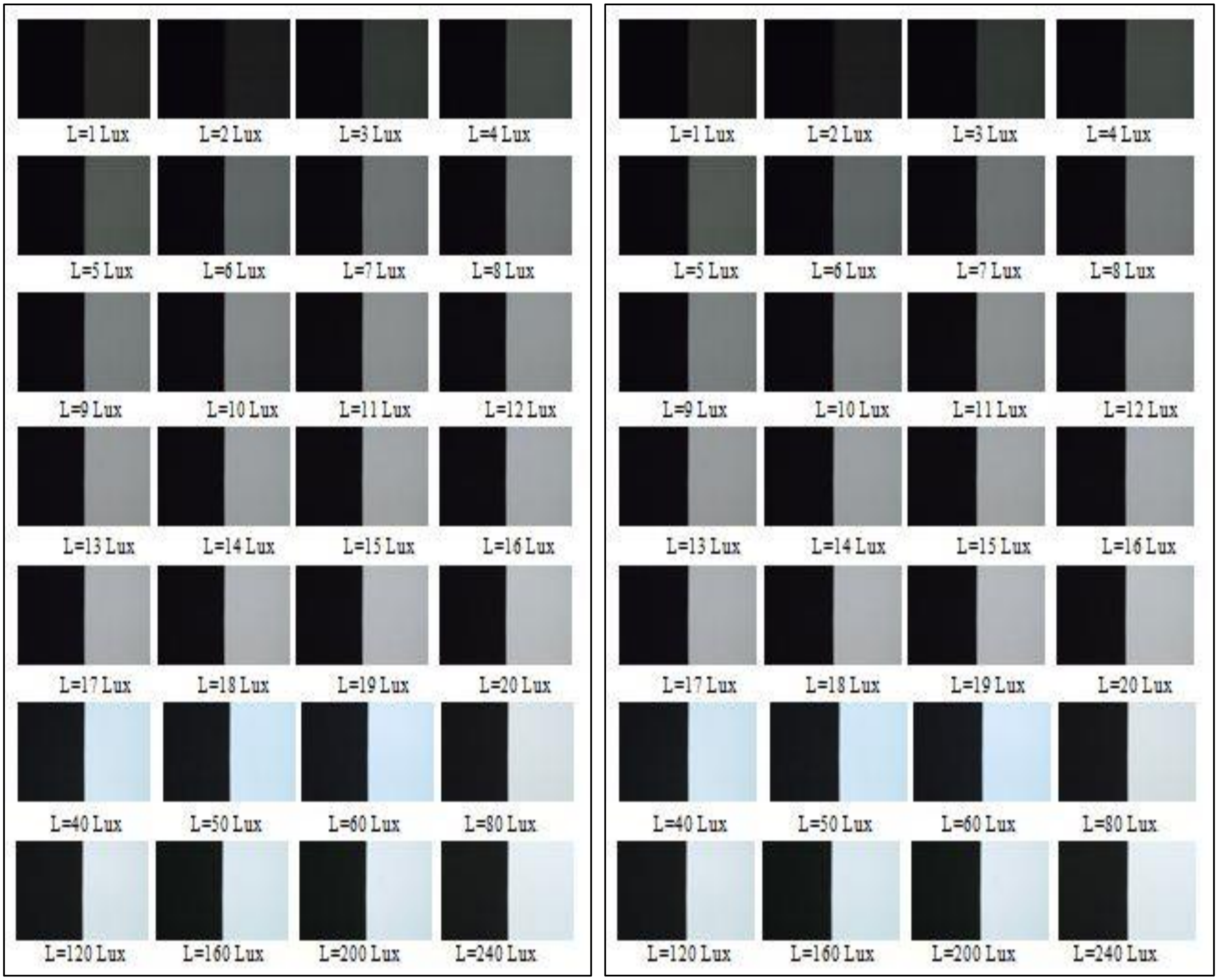


Figure (1): proposed imaging system using target image with variant lighting strength.



(a) ***(b)***

Figure (2): Captured images with different lighting intensity using (a) Samsung camera and (b) Sony camera.

5. Proposed Methods Algorithms

Several algorithms have been proposed to study edges within an image captured under low lightning conditions written in MATLAB code. One of algorithms that used is Sobel operator with fixed threshold value (th=0.35) to determine image edges. Within second algorithm, edge image contrast calculated and average of contrast. Also calculate the number of image edge points. Third algorithm used to determine the common added/removed image edge points.

5.1 Algorithm of Edge Detection Using Sobel Operator

Sobel operator one of the important operators that can be used to determine image edges. Test images captured using two camera types (SM and SN) in different lightness conditions were used. Threshold value is fixed for all images within algorithm (th=0.35). The performed algorithm for Sobel edge detection can be written as:

"Algorithm 1: Edge Detection Using Sobel Operator"

Input:

1. Gray scale image (img) of size (S).
2. Number of images n.

Output: The output is (E)

Start:

1. Put threshold value th=0.35.
2. Start loop i = 1 to n
3. Load image (img).
4. Uses two 3×3 masks (Mx and My) which are convolved with (img) to calculate approximations of the derivatives, one for horizontal changes and another for vertical. The computations are as shown in eqs. (1 and 2).
5. Compute horizontal and vertical gradients using:

$$G_x = M_x \otimes img \qquad // \ M_x \ \ getten \ \ from\, eq.(1)$$

$$G_y = M_y \otimes img \qquad // \ M_y \ \ getten \ \ from\, eq.(2)$$

6. At each point in (img), the resulting gradient approximations can be combined to give the gradient magnitude, using:
   $G_1 = abs\ (G_x)/4$, $G_2 = abs\ (G_y)/4$.
7. Calculate the maximum gradient in two directions**:**
   $G = max\ (G_1, G_2)$
8. The output G (which represents point edge point. (eimg)), can be determined using the following condition:
   If G>th then E=1 else E=0
9. eimg =E
10. Save edge image (eimg).
11. End loop i.

End algorithm.

5.2 Calculate The Contrast of Image Edges

Design an algorithm to calculate the contrast in two ways for the captured test images in different lightings conditions. The first method is the statistical contrast calculate according to eq. (6). While the second method is the average contrast, which calculated according to the eq. (7). These contrast values computed using the following algorithm:

"Algorithm 2: Compute the number of image edge point and edge image Contrast"

Input:

1. Color image (img) of size (S).
2. Edge image (eimg), same size of (img), get from algorithm(1)
3. Number of images n.

Output: the output is the contrast value (Ct).

Start:

1. Start loop for i = 1 to n
2. Load (img) and edge image corresponding, (eimg).
3. Start two loops:
   i = 1 to row
   j = 1 to column
4. Two square windows (*W*) each of size (3×3), are used to scan across the complete image (eimg), from left to right and from top to bottom. At start algorithm:
   If eimg (m,n) = 1
   e=e+1;
   Then the filter at center point (i,j) output is:
   Max = max (W), Min = min(W)
   where e = no. of edge points in (eimg).
5. Compute contrast value Ct1, using following eq.:
   Ct1 = (Max-Min) / (Max+Min)
6. Compute (3x3) mask mean (μ) and stander deviation (σ) centered on pixel location (i, j) in the img. to compute contrast value Ct2, using:
   Ct2 = σ / μ
7. End loops.
8. **Save** Ct1, Ct2 , and e

End algorithm.

5.3 Determine Image Edge Characteristic

Analytical study deducted image edge from algorithm (1) for all captured images in different lightness conditions. Which identify image with good lighting and compared with other images of lightness start from (0 to 240 lux) as shown figure (3). The designed algorithm calculate number of common edges points (K) by subtracting the good lighting image ($eimg_b$) that obtained from algorithm (4) (L=80 Lux) from other images ($eimg_i$), then calculate the number of edges points (added) (K_{add}) ; also calculate the number of removed edges points (K_{rem}) from the image, the following algorithm steps:

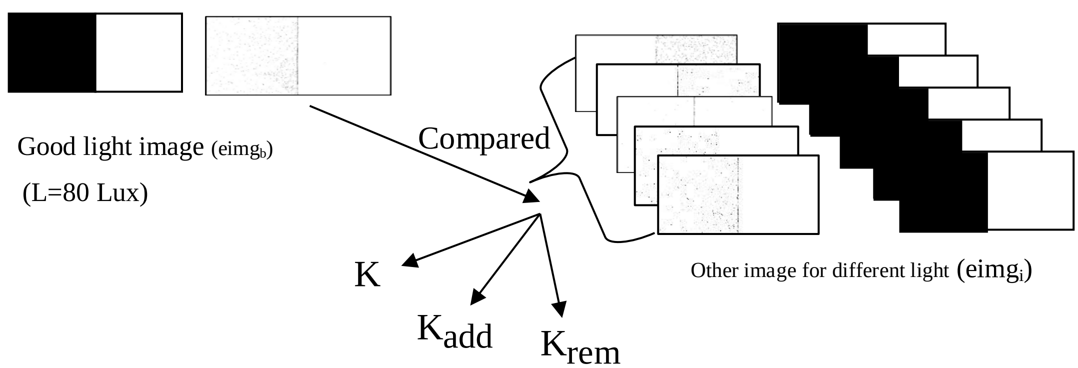


Figure (3) Shown Actual Edges.

***Algorithm3*: Determine Common, input, and output edge pointsInput:**

1. Edge image ($eimg_b$) for best capture lighting image (L=80 Lux), of size (S).
2. All others edge images ($eimg_i$) for low quality to good quality lightness, where (i=1 to n)

Output: the number of common edges points (K), number of (added) edges points (K_{add}), and number of removed edges points between ($eimg_b$) and ($eimg_i$).

Start:

1. Load edge image ($eimg_b$). for best capture lighting image(img)
2. Start loop i = 1 to n
3. Load edge image ($eimg_i$).
4. Start two loops

   r = 1 to row : h = 1 to col
5. Common, added, and removed edge points between ($eimg_b$) and ($eimg_i$) can be determine using the following conditions:

if $eimg_b$ (r,h)= 1then

e=e+1; // e: represent the total edge point in img_b

if $eimg_i$ (r,h)=1

k = k+1; // k = no. of common edge points

else

k_{rem} = kout+1; // k_{rem} = no. of removed edge points (found in ($eimg_b$), but not found in ($eimg_i$))

imgeout (m,n)=1; // Image of the points removed

end if

else

if $eimg_i$ (r,h)=1

K_{add} = k_{add}+1;// k_{add} = no. of added edge points (found in ($eimg_i$), but not found in ($eimg_b$))

imgein (r,h)=1; // Image of the points added

End if

End if

Where e = no. of edge points of ($eimg_b$).

6. **Save the results obtain in step 5.**
7. **End loops**
8. **End Algorithm**

6. Results and Discussions

The results of edge image analysis for the captured images under low lighting can be classified into several classes: edge contrast results, number of image edge points results, analysis of adding and removing edge point, homogeneity for homogeneous and mixed targets results and the results of image edges properties in true image edge region.

6.1 Edge Image Contrast Results

Image contrast is computed from algorithm (2). In figure (4 a), it can be noticed that the values of the statistical contrast for the test (Black & White image) that computed for images captured by (SM.com) shown in figure (2a) at low lightness. Here can be seen increasing (C_t) with increase intensity of light when up to the lighting (12 Lux). While images captured by (SN-cam) shown in figure (2b) can be noted that the stability in statistical contrast values see figure (4b). At a good lightness for SM-Cam can be noticed stability in statistical contrast values for increasing lightness as shown in figure(5 a). This meaning that the information contained be regular in the images higher than (12 Lux). Statistical contrast reach to unity value. While for (SN-cam) can be noted that the instability "fluctuation" in statistical contrast values as shown in figure (5 b).

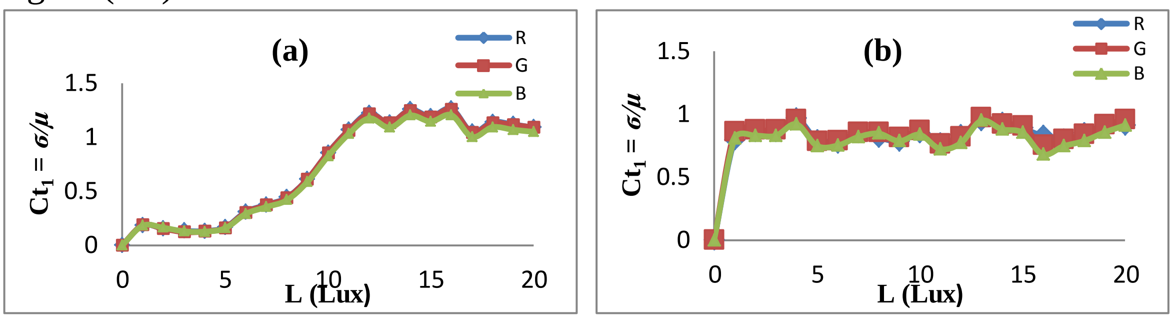


Figure (4): the relationship between statistical contrast (Ct) and the changing intensity of light (L) for captured image under low lightness by: (a) SM-cam. (b) SN-cam.

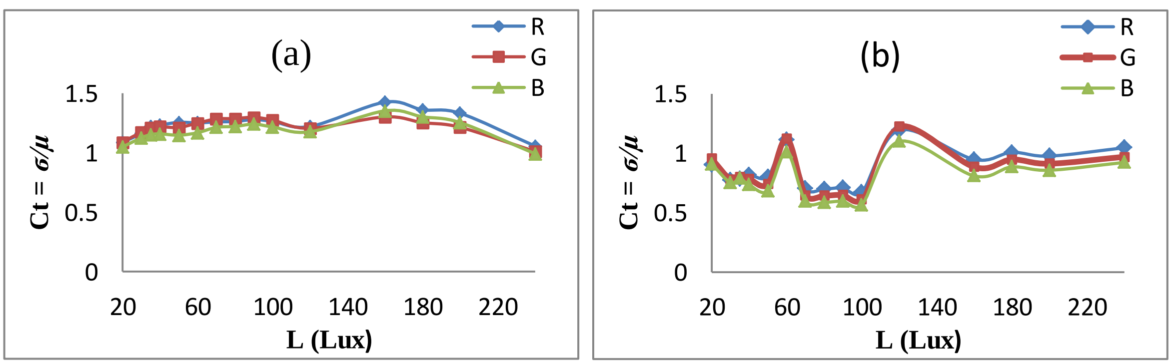


Figure (5): the relationship between statistical contrast (Ct) and the changing intensity of light (L) for captured image under high lightness by: (a) SM-cam. (b) SN-cam.

Results of average contrast ($\overline{Ct}$) that computed from algorithm (2), see figure (6) where can be noted that the average contrast ($\overline{Ct}$) for images captured by (SM-Cam) under low lightness an increased with increased lightness then slightly decreased before be oscillatory until reach steady state at light intensity (15 lux) as shown in figure (6 a). While the results of average contrast values for the images captured by (SN-cam) under low lightness shown in figure (6b) increased with the increasing in lightness and continue increased with some oscillatory fluctuation. But at good lightness for (SM-cam), noticed that ($\overline{Ct}$) values are stability at moderate lighting (40-120 Lux) then increased at high lighting after that decreased to reach (0.2) as illustrated in figure (7a). While the average contrast results for images captured by (SN-Cam) at good lightness decreased slightly too finally reach (0.28) as shown in figure (7 b).

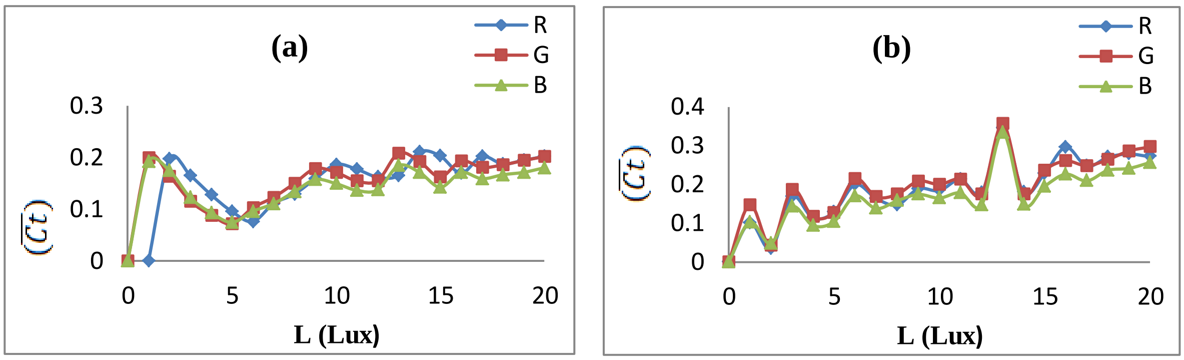


Figure (6): the relationship between average intensity contrast $(\overline{Ct})$ and changing intensity of light for captured image under low lightness by: (a) SM-cam. (b) SN-cam.

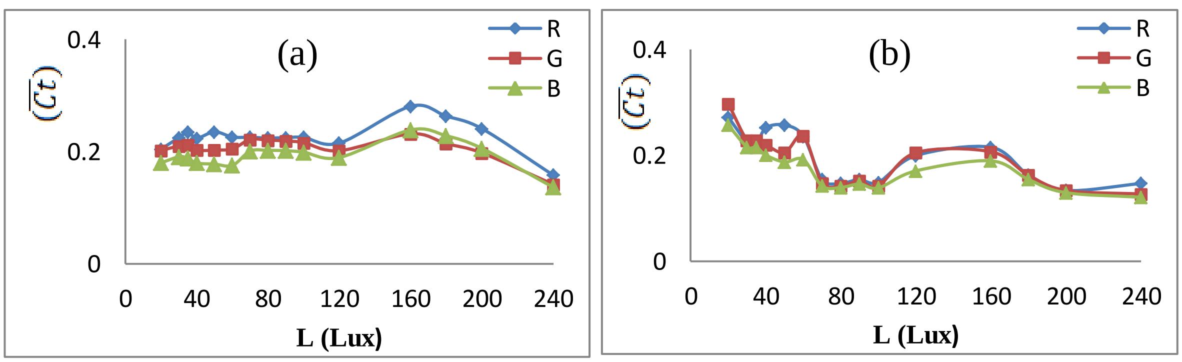


Figure (7): the relationship between average intensity contrast $(\overline{Ct})$ and changing intensity of light for captured image under high lightness by: (a) SM-cam. (b) SN-cam.

6.2 Image Edge Points Results

Results of image edge points as a function of lightness (L) using algorithm (2) for the test (Black & White block image) which captured by two types camera (SM-Cam and SN-Cam) shown in figures (2a) and (2b) respectively. Figure (8) represents the edge points for images captured by (SM-cam) under low lightness reach (17,000) points at lighting (3Lux) as shown in figure (8 a); this is an indicator to the noise within the image. Then the number of edge points decrease with increasing lighting (L). Then the edge points number reach stationary value after increased lightness than (10 Lux) for images captured by (SM-cam). While the results for images captured by (SN-cam) shown in figure (8 b), that appears the stability in number of edge points with increase lightness, which means that the sensor within this camera is better than Samsung camera. Whereas at good lightness noted irregular increasing of number of edge points for (SM-cam) images then at lightness higher that (180 Lux) decreased in number of edges point to about (1000 points) see figure (9 a). While for (SN-cam) images can be noted that higher stable in number of edge points, then after (L=160 Lux) the number of edge points reduced about (1000 points) see figure (9 b).

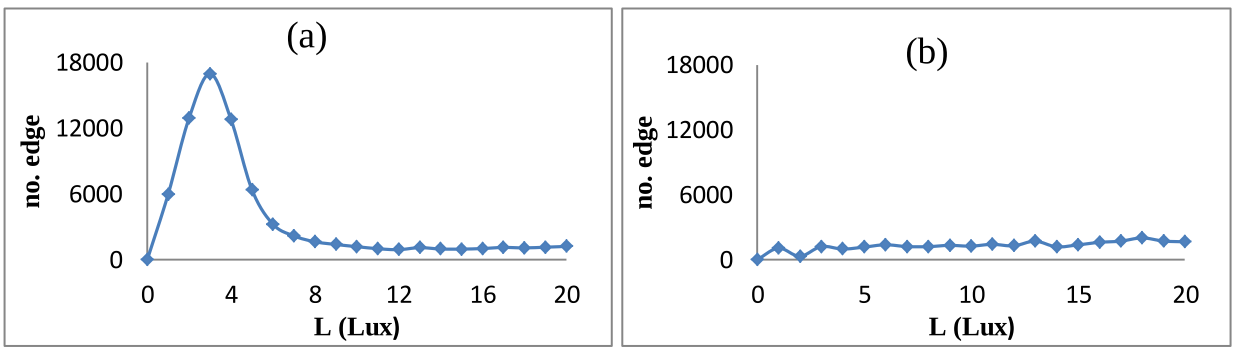


Figure (8): the relationship between the no. of edge points and changing intensity of light (L) under low lightness for: (a) SM-cam images. (b) SN-cam images.

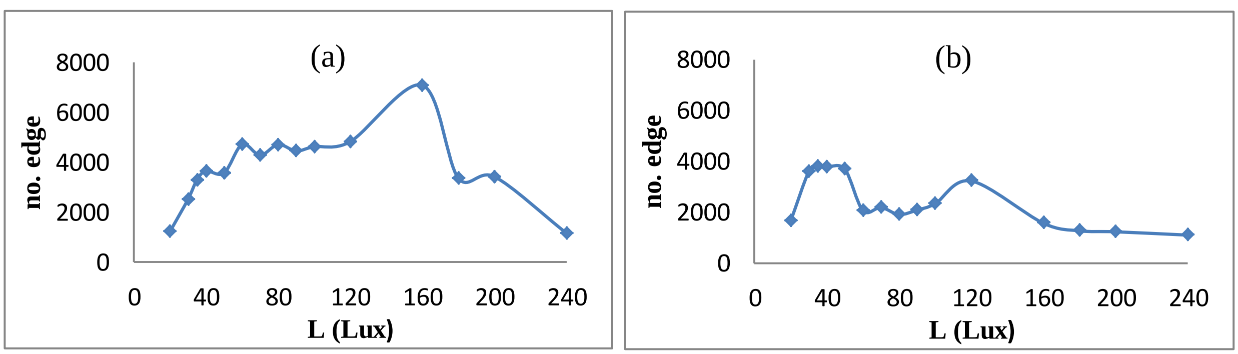


Figure (9): the relationship between the no. of edge points and changing intensity of light (L) under high lightness for: (a) SM-cam images. (b) SN-cam images.

6.3 Common Edge Points

Figure (10) shows the results that obtained from algorithm 3 for calculating common edge points for two cameras. Figure (10 a) shows the common edge points which increase slightly with increasing lightness to reach (78) at lightness (L=40 Lux) for SM-Cam. While (SN-cam), the common edge points increasing slightly to (L=20Lux) and it increase dramatically up to (444) at lightness (L=40 Lux) as shown in figure (10 b).

Figure (11) shows high lightness results. Figure (11 a) shows the common edge points (K), using SM-Cam, are not exceed (200) points. For (SN-Cam images) the common edge points (K) increase with increasing lightness to reach (1000) at lightness (L=100 Lux) and decreases suddenly at 160 Lux then it settle down after that as shown in figure (11 b).

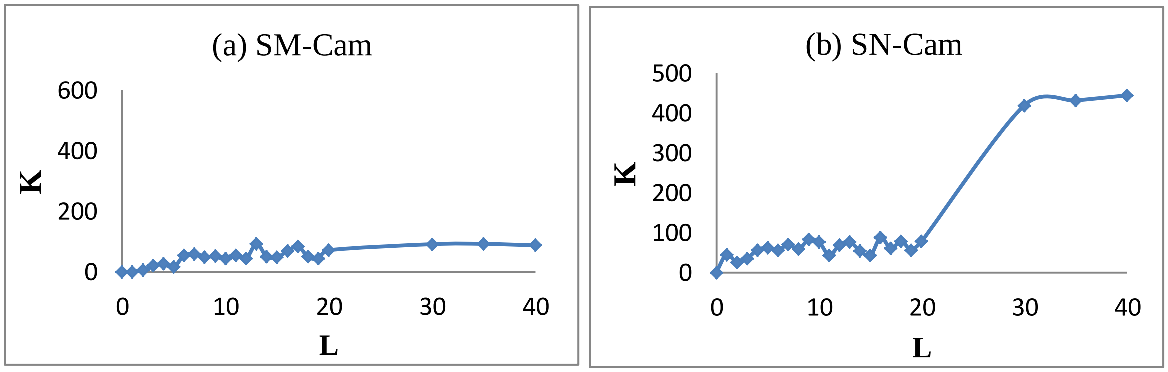


Fig (10): the relationship between the no. of image edge points (common) (K) with the changing intensity of light (L) for low lightness for: (a) SM-Cam image. (b) SN-Cam image.

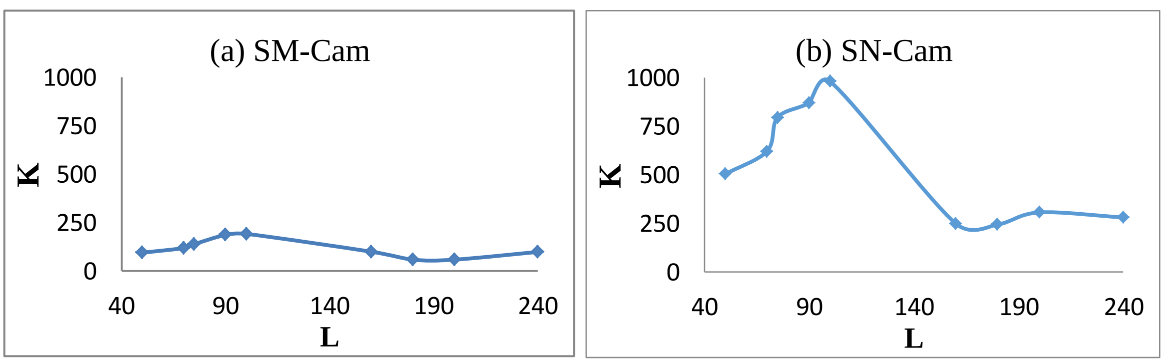


Fig (11): the relationship between the no. of image edge points (common) (K) with the changing intensity of light (L) for good lightness for: (a) SM-Cam image. (b) SN-Cam image.

6.4 Image Edge Points (Added and removed) Results

The results of number of an added edge points ($\mathbf{K_{ad}}$) (existent in a good lightness image and non-existent in the other test images) and the results of number of edge points of the removed or deleted edge points ($\mathbf{K_{rm}}$) (existent in other image and non-existent image in good lightness image) where represent other images that have been captured images in figures. (2 a) and (2b) by two camera types (SM-Cam and SN- Cam) respectively; which calculated from algorithm (3). In figure (12 a) can be noted that the number of the removed edge points (**K_{rm}**) it was fixed in the form of a straight line, while the results of number of edge points added (**K_{ad}**) for images captured by (SM-cam) under low lightness great up to reach (10,000) points at lighting (3Lux) this evidence of a high amount of noise. Then decreases the number of added edge points (**K_{ad}**) with increased lightness (L). Also increase again slightly with increase lighting for images captured by (SM-cam). While the results of captured images by (SN-Cam) can be noted that the number of the removed edge points (**K_{rm}**) it was fixed in the form of a straight line but the results of number of added edge points (**K_{ad}**) increased slightly with increasing as shown in figure (12b).

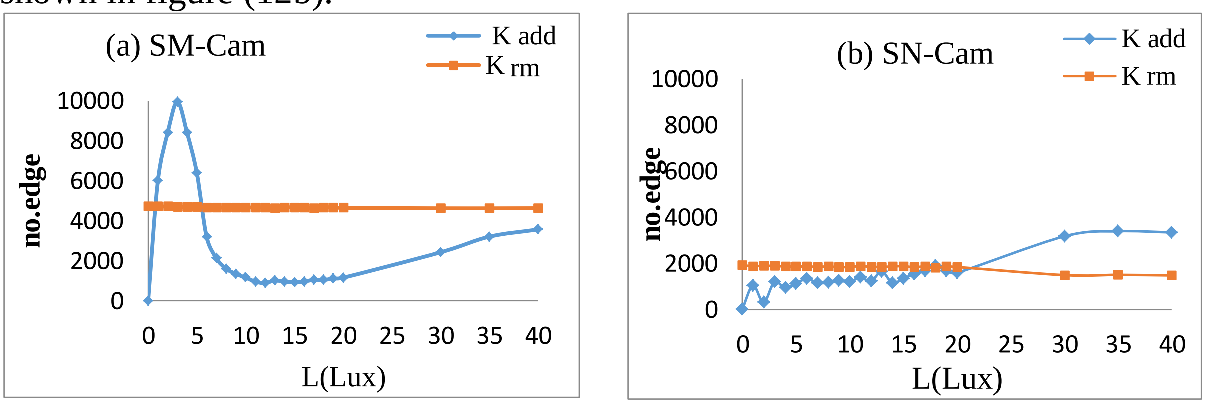


Figure (12): Shows the relationship between the no. of added and removed edge points (K_{ad} and K_{rm}) with the changing intensity of light (L) for low lightness for: (a) SM-cam images. (b) SN-cam images.

7. Conclusions

Image contrast in Sony camera is better than Samsung camera. This can be shown from the results of contrast image edges. Contrast values are stable at low and high lighting conditions, except at low lighting has small values using Samsung camera which mean poor contrast of image.

The sensitivity for Sony camera is better than Samsung camera depending on number of edge points at low lighting condition. Edge points number represents noise at low lighting condition, which was bigger within the images captured using Samsung than Sony camera.

Sony sensor is better than Samsung especially in the range (30-120 Lux). This range can be considered to be best sensing range. By depending on the common edge points, Sony sensor detect large common edge points within this range than Samsung sensor because of the good matching between good light image and remaining images of different lighting (30-120 Lux).

Noise range specified depending on add/removed edge points which is consider an indicator of noise. This range found to be at very low lighting (0-6 Lux) because of the high number of edge points in Samsung camera rather than Sony. This can be understood that Sony is better because the low noise at this range. Removed edge points doesn't give any indicator for the noise range while the added edge points give a noticeable behavior at low light condition.

8. References

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