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A Comparative Between Corner-Detectors (Harris, Shi-Tomasi & FAST) in Images Noisy Using Non-Local Means Filter

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ABSTRACT

A comparative study was conducted in this paper , between three algorithms which (Harris , Shi-Tomasi , FAST) interested-points detection to identified the features that required to match , recognize and track objects in images noisy .

Detect the interested-points in image noisy one of the most challenges in field of image processing . The noise consider the main cause for damage the natural images during the acquisition and transition , and detect the interested-points of these images doesn't give the desired results , so eliminating noise from this images is very important , Non-local means approach is applied for solve this problem .

1 . Introduction

Can be defined the corner as point where there are two different directions of the edges in a local neighborhood, can also defined the corner as a two-edged intersection, where the edge represents a intense change in the brightness of the image. corner detection considered methodology used in machine vision systems such as pattern recognition like face recognition , motion detection by exploiting the advantages of matching points and 3D reconstruction to obtain specific features from a particular image.[1-2]

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The first algorithm concept of "Interested-Points" in an image, can be used to find regions of matching in tow or more images, was produced by Harris and Stephens in 1988 upon the improvement the (detector of Moravec) by taking into account the difference between the score of corner with respect to the direct direction, rather than using modified corrections . The second operator is (Shi-Tomasi Detector) which produced by(Shi and Tomasi) in 1994 , where they are made a small adjustment to Harris's algorithms, The last operator is (FAST Detector) which can be used to identified features points and used to objects tracking in a lot of machine vision tasks.

FAST detector produced originally in 2006 by (Rosten and Drummond) . The most hopeful feature of the FAST detector is its efficiency of computational .

One of the most popular ways to remove noise from image is using linear filters such as (mean filter) . In case of found added noise , the result of image noisy, through linear filters, obtain smoothed & blurred with bad feature localization & insufficient suppression of noise. To get over these challenges, used the Non-linear filters such as (Non-Local Mean filter). Non-Local Mean approach gives the solve and good result [4] .

2. Related Work

In the section of related work , the corner detection algorithms that have been used for comparison are briefly described. which algorithm used in each technique has been explained below as well as the filter of non-local means has been explained .

3- Harris Detector

The detector of Harris is a good-known detector for corner because of its powerful stability in noisy images . It determines which small image patches (windows) produce quite variations in intensity when window is moving in both (a) and (b) directions .The function of auto-correlation measures the variation of intensity with move the window by a little amount in more than one direction given a shift (Δa, Δb) and a point(x , y) [7]. The function of auto-correlation can be defined as [8] :

$$H(u,v) = \sum x,y\, z(x,y)[I(x+u\,,y+v\,)- I\,(x\,,y\,)]^2 \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where :

- $z\,(\,x\,,y\,)$ function of window.
- $I\,(\,x\,,y\,)$ is the original intensity .
- $I(x+u\,,y+v\,)$ the intensity at shifted window .

depends The algorithm of Harris on intensity when the window is shifted in order to detect and identify the corner. To do this , expanding the equation (1) :

$$[I(x+u\,,y+v\,)- I\,(x\,,y\,)]^2$$

using Taylor series :

Taylor Series $T\,(x,y) \cong \mathrm{H}(\,u\,,v\,) + \,(\,x - u\,)h_x\,(x\,,y\,) + \,(\,y - v\,)h_y\,(\,u\,,\,v\,) + \ldots$

To have good score of (H) [10] :

$$\mathrm{H}\,(\,x\,,y\,) = \sum x,y\,[I(x,y)\; + uIx + vIy - I\,(x\,,y\,)]^2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Can be write the equation in matrix form :

$$H\,(\,u,v\,) = [\,u\,v\,]\left(\sum\nolimits_{x,y} w(x,y)\begin{bmatrix} I_x^2 & I_x\,I_y \\ I_x\,I_y & I_y^2 \end{bmatrix}\right)\begin{pmatrix} u \\ v \end{pmatrix} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Then shortening the array and indicate it to be N :

N = $\sum_{x,y} w(x,y) \begin{bmatrix} I_x^2 & I_x\, I_y \\ I_x\, I_y & I_y^2 \end{bmatrix}$ ……………………….. ………………..(4)

To be the equation : H(u , v) = [u v] N $\binom{u}{v}$ ……………………………… (6)

- by the following formula can Calculate measures of corner response [9] :

$$R = \text{Det (N)} - K\,(\text{Trace (N)})^2 \quad \text{.............................(6)}$$

where :

- Det (N) = λ1*λ2 , Trace (N) = λ1 + λ2
- λ1 and λ2 are eigenvalues of (N) , and (k) is a constant with value ranging (0.04 – 0.06)

Depending on the value of R , the window is classified as consisting of flat, edge, or a corner or others A large value of R indicates a corner (λ1 & λ2 are top, the point is corner) , a negative value indicates an edge(λ1is top and λ2 is button) . Also, to pick up the optimal corners, we can use non-maximum suppression . [6]

4- The Shi-Tomasi Detector

A Shi-Tomasi detector is a fully based on the detector of Harris . only, there is one difference in a " criteria of selection " recognize this detector on the detector of Harris . It works very good where even the Harris detector fails. hence a little change that this detector did to the Harris detector. [14]

The Deference :

The detector of Harris has a criteria for select corners. Where calculate the score for all pixel, then compare the score with particular value , if above then the pixel is considered as a corner. value of (R) is computed by two eigenvalues. That is, tow eigenvalue are given to a function. The function handled them, and back the score.

Developer of Shi-Tomasi detector suggested that the function must be disposed of. Only the eigenvalues to be used to test the pixel if interested-point or not.

The score of **Harris** detector was computed such this (the score of R) :

$$R = \lambda1 * \lambda2 - (\lambda1 + \lambda)^2$$

For **Shi-Tomasi** , it's calculated like this :

$$R = \text{Minimum}\ (\lambda1\ ,\ \lambda2\ ) \text{..................................(1)}$$

Shi- Tomasi Empirically proved that this criteria of the score was much better. compare the value of (R) with a particular value if greater than , can be identified as a interested-point . therefore , region of the effect for a pixel to be a interested-point is something like following figure:

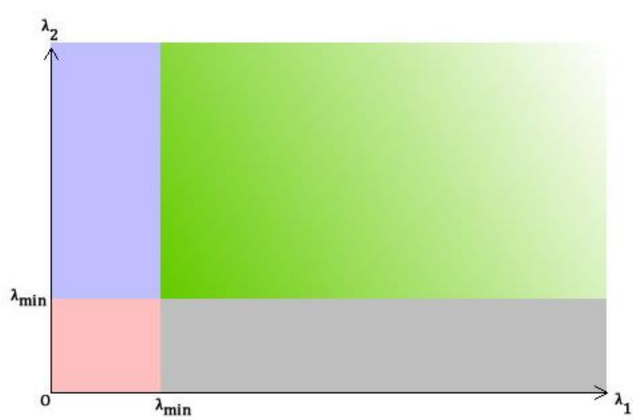


Figure (1) (region of the effect for a pixel to be interested-point)

- Green: (λ_1 & λ_2) are greater than a particular predefined value. therefore, this area of pixels "identified" as interested-point.

- In the blue and gray area : one of the eigenvalues is less than its minimum requirement
- In area of the red : tow eigenvalues are less than minimum requirement.
  by Compare figure (1) with the graph of Harris detector... the gray and blue region are equal to the area of edges. Where the area of the red is for "flat". And the region of the green is for interested-points .[7]

5- (FAST) Detector

FAST is an algorithm for interested-point detector proposed in (2006) by Rosten and Drummond . In application of real video like SLAM on a mobile robot , FAST algorithm give a high results in detect of corners. The standard of segment test run in the image by taking a circle of 16 pixels called (Bresenham circle) which around the pixel (p) . [11]

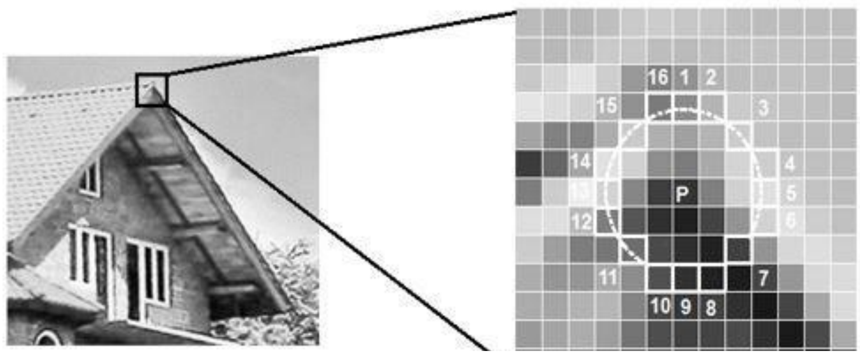


Figure (2). Candidate pixel under test and circle of the 16 pixels around it

Can describe the algorithm as :

1. in an image identified a pixel-point (p) . suppose the intensity (I) for the candidate pixel-point , which is to be candidate as an interested-point or not. (as shown in fig.2)
2. Make the value of intensity of the threshold (T) , (let be 25% of the pixel value)
3. Draw a circle around candidate pixel which (Bresenham circle) of sixteen pixels (with radius 3) .
4. (N) neighboring pixel-points out of the sixteen pixels should be more bright than (threshold + I) or more dark than (I – Threshold) , to be identified as an interested-point. (often used N = 12) .
5. first exam the intensity of pixel (I1, I5, I9 and I13) (at clockwise direction) of the circle and compare with (I). As shown in figure ,to be the algorithm more-speed at least three of four pixels should satisfy the criterion of threshold (T) hence the interested-point will detected.
6. Initially test (I1 and I9) pixels if more bright or more dark, if so it test (I5 and I13) . to be (p) an interested-point , a minimum of (three) of these (four) pixels should be more bright than (I+ threshold) or more dark than (I – threshold) . If neither of those , then (p) isn't interested-point .
7. Repeat the steps for each pixel in an image.[13]

   There are a several challenges with this detector. Firstly, when (N) less than12, the detector does not act good in all because if (N) is less than12 , the results of corner points discovered are very many. Secondly , the arranging , in which the sixteen pixels are queried and this limiting from speed of the detector .

   An approach of the learning of machine has been additive to the (FAST) detector algorithm to manipulate these limitations . [12]

6- (NL-Means) filter

(NL-Means) Non-local means is an algorithm presented in (2005) by Antoni Buades for remove noise from image in field of image processing . Non-local means Unlike other algorithms in remove noise which try to isolate the image into original image (smooth part) and noise image (wavering part) via excepting the normal hesitation from the high hesitation, this filter depend on the useful of self-similarity to isolate the frequencies.[13]

Figure 3 . methodology of Nl-means. Where if pixel neighborhoods is similarity will give a big weight and w1 & w2 , and give different pixels small weight w3 .

6-1 NL-Means algorithm Description : let be (V) a noisy image where V = {V(x) | x ∈ X},for pixel-point (x) the value of NL[V](x) , is calculated as a weighted average of all pixels in an image .

$$NL[\mathrm{V}]\,(\mathrm{x}) = \frac{1}{\mathrm{G(x)}} \Sigma_{\,y\,\in \mathrm{V}}\, \mathrm{w}(x,y)\mathrm{v}(y)\ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

where the weights {w(x, y)} based on likeness between the neighborhoods of pixels x & y , and meet the conditions 0 ≤ w(x, y) ≤ 1 & Σy w(x,y) = 1. [3]

The likeness between (x & y) based on the likeness of the level vectors of intensity gray (V(Nx) & V(Ny)), (Nk) refer to a square pixel- neighborhood of constant size and concentrated at a pixel-point (k). Use the Euclidean distance to measured This similarity as a decreasing function , $||\mathrm{v}(\mathrm{P_x}) - \mathrm{v}(\mathrm{Q_y})||_{2,s}^{2}$, where s > 0 is the standard deviation [5]. The value of Euclidean distance to the noisy pixels-neighborhoods is raises , then can be defined The weights as following: [3]

$$\mathrm{w}(x,y)= \frac{1}{\mathrm{G(x)}}\, e^{-\frac{||\mathrm{v}(\mathrm{P_x})-\mathrm{v}(\mathrm{Q_y})||_{2,s}^{2}}{h^2}} \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

- G(x) represent normalization constant that can define by :

$$\mathrm{G(x)} = \sum_y e^{-\frac{||\mathrm{v}(\mathrm{P_x})-\mathrm{v}(\mathrm{Q_y})||_{2,s}^{2}}{h^2}} \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

- (h) represent weight decay of control parameter of exponential function .

7 - Results

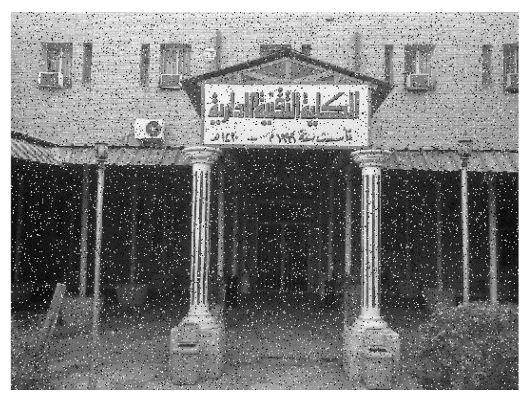
as shown in figure (4) used three-types of noise are : Gaussian (mean = (0) & variance = 0.001) , salt & pepper (density of noise = 0.07) and Speckle (variance = 0.03 and mean= 0) to original image with sized of 1200*1600 grayscale image . where when apply Harris on the original image detect (1426) corner-point , whereas when apply Shi-Tomasi identified (15134) and with FAST detector (27775) corners , and then the corners detected in all types of noisy image , the results are shown in below table .

Table (1)

Show detect corners by three detectors in the original image, images -noisy and images de-noised using NL-means filter

Type of filter		**Non-local mean filter**		
Type of detector		**Harris**	**Shi-Tomasi**	**FAST**
Original Image		1426	15134	27775
Salt and peppers	**Noised**	30599	39698	111650
	De-noised	7673	25220	67450
Gaussian	**Noised**	2752	56442	57687
	De-noised	1757	11183	28072
Speckle	**Noised**	26598	58655	114091
	De-noised	6638	18238	41328

(I)



(II)

(III)

(IV)

Figure (4) : (I) Original image. (II) Salt and pepper. (III) Gaussian. (IV) Speckle

Then remove the noise from the images that damage previously by the types of noise (Gaussian , salt & pepper and speckle) , as shown in figure (5).

(V) (VI) (VII)

Figure(5): (V) De-noised Salt and pepper. (VI) De-noised Gaussian. (VII) De-noised Speckle.

Harris , Shi-Tomasi and FAST corner detection is done in order to get the conclusive results of the study , corners that detected by all detectors are shown in table (1) and As shown in table, the corners (interested-points) are obtained from the images after remove noise and it is nearby to the corners that detected in the original-image.
Based on the results obtained from table (1), FAST corner detection shows results better than Shi-Tomasi & Harris corner detection in finding the actual numbers of corners in Gaussian while Shi-Tomasi corner detection was the best in speckle noise cases while Harris corner detection surpassed Shi-Tomasi & FAST in salt and pepper noise case. In addition, Shi-Tomasi corner detection performs in more flexible ways than Harris & FAST in noisy environments, in other words Shi-Tomasi is more powerful to noise than Harris & FAST .

8- Conclusion

Via this study, filter of NL-Means consider one of the most filter that plays an main role in eliminate noise from images comprehensive (salt & pepper, Gaussian and speckle) noise. FAST detector has better than Shi-Tomasi & Harris in detecting precise and actual corners-points . Shi-Tomasi corner detection is more stronger to noise than FAST & Harris.
in each type of noise (Gaussian, salt&pepper and speckle) one of the aforementioned algorithms was the best than other .

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