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Corner Detection Using Gradient and Topological Properties Of Digital Images

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Abstract- Detecting points of interest is one important issues in image processing systems and these points could be uses to eliminates the information of the images to minimum number to be used in recognition or data reduction ..etc. in this paper we produce a method to detect corners in images depending on topological and tint information , The gradient of intensity is calculated in two steps one for grayscale to detect curvatures and other for binary to detect corners in curvatures . The method was quite accurate , efficiency and fast , but rather fair with noisy images

Index Terms- Corner detection , Topological concept of corner

I. Introduction

In a computer vision applications we need to extract information about a local features of an image to be used for detecting things or tracking the objects in images despite of the spatial changes that happens to the image like rotation ,zooming in , zooming out …etc. These features are about a points (pixels) in the picture that have a topological properties in the image matrix differs from their neighbors [1].The feature points detected by their values which mostly rejected in farther processing and keeping their spatial locations [2].One of these features is corner point ,Corner is a point that has a conjunction with two edges that are having a different directions or different gradients .Too many approaches presented to detect the corners in the images as a variation of point values in neighborhood .One approach is that depending on second derivative and that type of detectors is noise susceptible and needed to be smoothing by convolving an image with a Difference of Gaussians DoG or Laplacian of a Gaussian LoG as a noise reducer such as the Harris corner detector , Moravec and KLT. Another type of detectors is that searching a small patches of an image to find a point looks like a corner ,this type is more efficiency due to insusceptibility to noise and need to search a small part of an image each time but it could be weak or poorly detected with blured image having larg-scale features [5].

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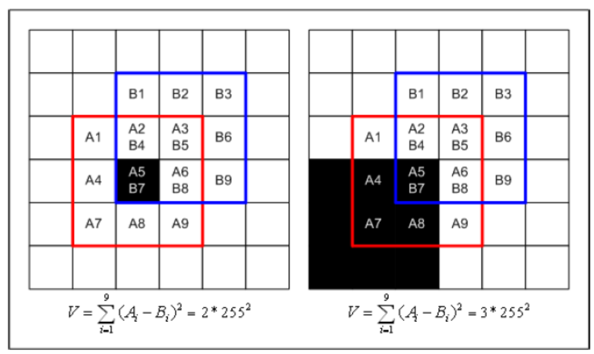
II. Previous Works

Corner detection is used as a primer and essential step of many vision tasks such as tracking, localisation, image matching and recognition, a lot of detectors have been showed in this aspect, one of the most popular is Moravec[13] that used the sum-of-squared-differences (SSD) between the neighbors around a pixel and a patch shifted by offset (x,y), If s(x,y) is high for shifts in all 8 directions, declare a corner.

In Moravec , he proposed measuring the intensity variation by:

- placing a small square window (typically,3×3, 5×5, or 7×7 pixels) centered at center point and than shifting this window by one pixel in each of the eight principle directions (horizontally, vertically, and four diagonals),fig(1). The intensity variation for a given shift is calculated by taking the sum of squares of intensity the corner represented by larger variation of intensity .



fig(1) Measuring the intensity Variation by using 3×3 window

Another most famous corner detection algorithm is the Harris corner extraction methods [5,12]. It is based on the first order Taylor expansion of the second derivative of the local sum of squared differences (SSD) which related to Eigen values in measuring the curvature [14], Eigen values can be computed in closed form:

$$\begin{bmatrix} a & b \\ b & c \end{bmatrix} \quad \begin{array}{l} \lambda_1 = {}^1\!/_2\left(a+c-\sqrt{(a-c)^2+4b^2}\right) \\ \lambda_2 = {}^1\!/_2\left(a+c+\sqrt{(a-c)^2+4b^2}\right) \end{array} \qquad (1)$$

Then searching for values of λ_1 , λ_2 with larger and approximately identical to be a corner ,while values with condition $\lambda_1 > \lambda_2$ or $\lambda_1 < \lambda_2$ is an edge and the smaller unequal value of λ_1 , λ_2 is a flat area. Lowe convolves the image with (DoG) kernel at multiple scales that is similar but faster in computation to Laplacian of a Gaussian (LoG) which is considered as a noise reduction step combined with the Harris approach in [15] which computes Harris corners at multiple scales and retains only those which are also optima of the LoG response across scales[5,16].

KLT corner detector is produced by Kanade-Lucas-Tomasi is very similar to Harris, but with a greedy corner selection criterion, put all points for which $\lambda 1$ > threshold in a list L then sort the list in decreasing order by $\lambda 1$,declare highest pixel p in L to be a corner. Then remove all points from L that are within a DxD neighborhood of p until L is empty[17],the detectors that depends on derivatives is noise sensitive and need for smoothers as additional step and the smoothing some time change some image countenance .

The SUSAN detector was a simple and efficient based on computing the pixels in neighborhood which have similar intensity to the center pixel. Corners can then be localized by thresholding this measure and selecting local minima [11], this detector is not susceptible to noise due to its independently from second derivative calculation.

Other one of similar approaches detectors is FAST detector based on the property of comers that the change of image intensity should be high in all directions. Consequently, the comer response function (CRF) is computed as a minimum change of intensity over all possible directions. To compute the intensity change in an arbitrary direction an inter_pixel approximation is used. A multigrid approach is employed to reduce the computational complexity and to improve the quality of the detected corners. This algorithm is significantly faster to compute. In this paper we introduce a new way to detect corner depending on topological properties of the point that represent a corner .

III. CORNERS ESTIMATION

3.1 digital concepts [8 ,9,10]:

If a digital set X represents a digital image then the ordered pair *(p,f(p))* $p \in X$ is a pixel where p is the coordinates and $f(p)$ is the brightness level of the pixel. there are two types of pixels : object points that are the set $F = \{p \in X | f(p) = 1\}$ and a background points which are the set $B = \{p \in X | f(p) = 0\}$.

Topological definitions: Let $p(x, y)$ and $g(x`, y`) \in X$ (digital set) in 2D and belonging to the same neighborhood structure we can define the following relations:

- *N_4 or 4-adjacent* :

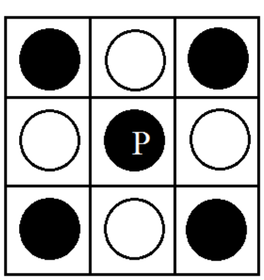
$$(p,q) \in N_4 \Leftrightarrow |x-x'|+|y-y'|=1 \qquad (2)$$

- *N_I or i-adjacent* :

$$(p,q) \in N_I \Leftrightarrow |x-x'|=|y-y'|=1 \qquad (3)$$

- *N_8 or 8-adjacent* is $N_4 \cup N_I$ (4)

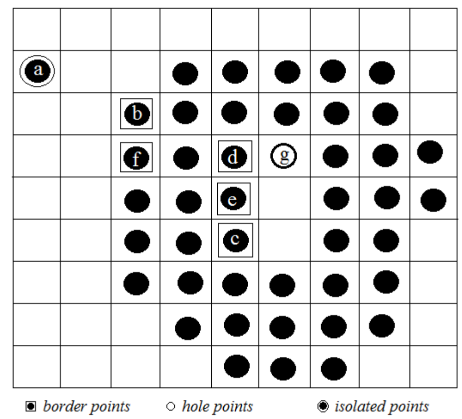
  fig (2) illustrates the defined concepts .



fig(2) N_4 represented by white circles◌, N_I by black circles◙ and N_8 which is $N_4 \cup N_I$

- *Hole*: the set of pixels P is a hole if $P \in B$ (a background pixels) that is adjacent to and surrounded by a object pixels F .

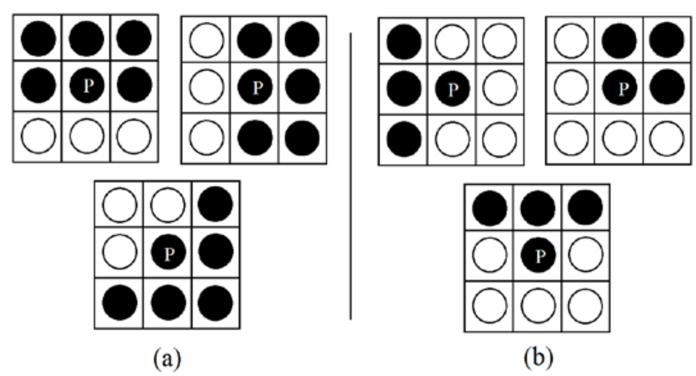
- *Isolated , Border and Interior Point*: An object point $P \in F$ is said to be *isolated* if it is not adjacent to any other object point, while a *border* point is the point that is adjacent to one or more background points ; otherwise the object point is called an *Interior* point, fig (3).



fig(3) Isolated , border and interior pixels

After defining the basic components of the digital image we can define the corner and edge concepts by using above definitions:

- *edge and corner*: let $P \in F$ and is a border pixel then it called an edge pixel ,while edge pixel called a corner point if it is not connected to two pixels on the same direction as in fig(4).



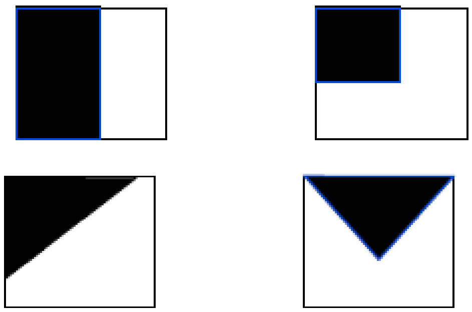
fig(4) (a) P is edge (b) P is a corner

We can write it mathematically depending on the illustrative sketches within the fig(4) :

- *edge* : $P \in \text{egde} \Leftrightarrow \forall P \in N_8, \sum_{i=1}^{8} P_i = 5$. (5)
- *corner* : $P \in \text{corner} \Leftrightarrow \forall P \in N_8, \sum_{i=1}^{8} P_i = 3$. (6)

3.2 Gradient concept [4]:

A corner is characterized by a region with intensity change in two different directions, to detect that change as gradient oriented in different directions a local derivative estimation is used as in Harris corner detector ,KLT and Moravec.



fig(5) Corners examples

To estimate the gradient for pixel P as in fig (5):

$P1$	$P2$	$P3$
P_4	P	P_5
P_6	P_7	P_8

- Take the Horizontal gradient at P with x-direction Mask [-1,0,1] by formula :

$$\frac{\partial I_P}{\partial x} \cong (I_{P5} - I_{P4}) = I_P \otimes [-1,0,1] \qquad (7)$$

- Take the Vertical gradient at P with y-direction Mask [-1,0,1]^T by formula :

$$\frac{\partial I_P}{\partial y} \cong (I_{P2} - I_{P7}) = I_P \otimes \begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix} \qquad (8)$$

Now it is the time to articulate the research work with ideas gathered in above steps by adopting any of below suitable approaches:

A. Bits and Pieces together

In this approach combine all your researched information in form of a journal or research paper. In this researcher can take the reference of already accomplished work as a starting building block of its paper.
Jump Start
This approach works the best in guidance of fellow researchers. In this the authors continuously receives or asks inputs from their fellows. It enriches the information pool of your paper with expert comments or up gradations. And the researcher feels confident about their work and takes a jump to start the paper writing.

B. Use of Simulation software

There are numbers of software available which can mimic the process involved in your research work and can produce the possible result. One of such type of software is Matlab. You can readily find Mfiles related to your research work on internet or in some cases these can require few modifications. Once these Mfiles are uploaded in software, you can get the simulated results of your paper and it easies the process of paper writing.

- Take the upper-right diagonal at P with mask $\begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ -1 & 0 & 0 \end{bmatrix}$ as :

$$\frac{\partial I_P}{\partial h} \cong (I_{P3} - I_{P6}) = I_P \otimes \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ -1 & 0 & 0 \end{bmatrix} \qquad (9)$$

- then involving a Gaussian window to estimate intensity variation,fig(6) :

.04	.12	.04
.12	.36	.12
.04	.12	.04

fig(6) Gaussian window

$$V_{u,v}(x,y) = \sum_{i=1}^{8} w_i \left(u\frac{\partial I_i}{\partial x} + v\frac{\partial I_i}{\partial y} \right)^2 \qquad (10)$$

Where w_i is the weight of the Gaussian window at position i.

- For a shift in the x-direction (u,v)=(1,0) or y-direction where (u,v)=(0,1) .

By steps up the gradient is simply estimated for pixel P in all direction , in our paper we combine the two approaches to detect a corners with more precisely .

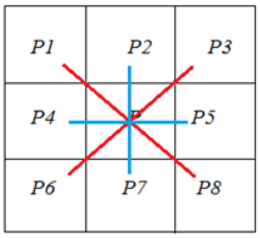
IV. Proposed System

The proposed algorithm was implemented with matlab7.11 (2010b) to detect the interesting points in images called corners . the system makes use from gradient information for the points within 8-neighborhood as in following steps:

- ✓ Reading an image and convert it to GRAY-SCALE image.
- ✓ Adjusting GRAY-SCALE image contrast.
- ✓ Calculating the sum of the gradient in all directions for each pixel.
- ✓ Filtering the results by choosing the high values of the sum .
- ✓ building a binary image with high value as ones otherwise zeros.
- ✓ estimating the gradient in both direction .
- ✓ the pixel with two horizontal and vertical gradient declares as a corner .

In this method as a first step converting the image to gray scale then maping the intensity values in grayscale image I to new values in $I_{adjusted}$ such that 1% of data is saturated at low and high intensities of I. This increases the contrast of the output image .

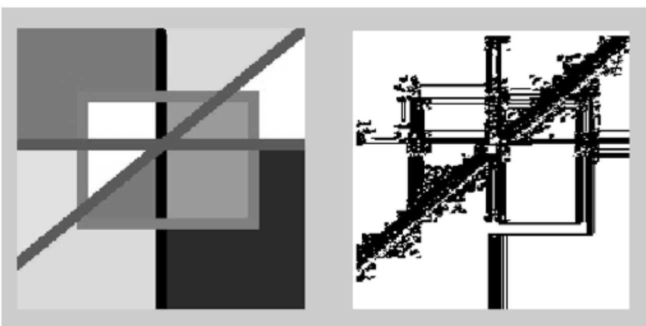
After that we take the gradients of the adjusted image to detect the changes in intensity in all direction as in fig (7),fig (8):



estimation the gradient in all direction

$$d1(i,j) = |P5-P4|;$$
$$d2(i,j) = |P2-P7|;$$
$$d3(i,j) = |P1-P8|;$$
$$d4(i,j) = |P3-P6|;$$
$$Tot\_d(i,j) = \sum_{k=1}^{4} d_k(i,j)$$

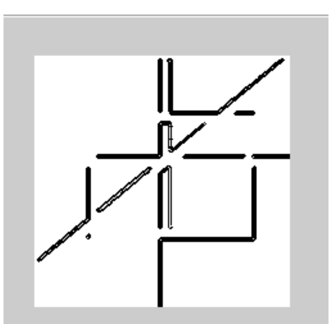
fig(7) Estimation the gradient in all directions



(a) (b)

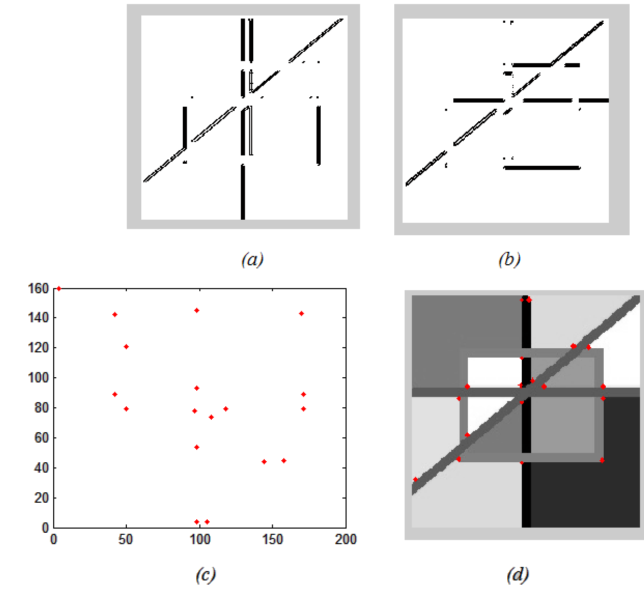
fig(8)(a) Grayscale image (b) the black pixels represents the gradient values of the points as darker color as grater value

As showed in fig(8)(b) the black points represent the value of intensity changes in all direction the value of the pixels(points) ranged between 0-255 ,the pixels with high value is the pixels that have more than one difference in neighbor values, then we chose a threshold (experimentally >=150) to form a new image (binary) with high values as object pixels, fig(9).



fig(9) Binary image represents the high gradient pixels ,0(white):no gradient ,1(black):high gradient

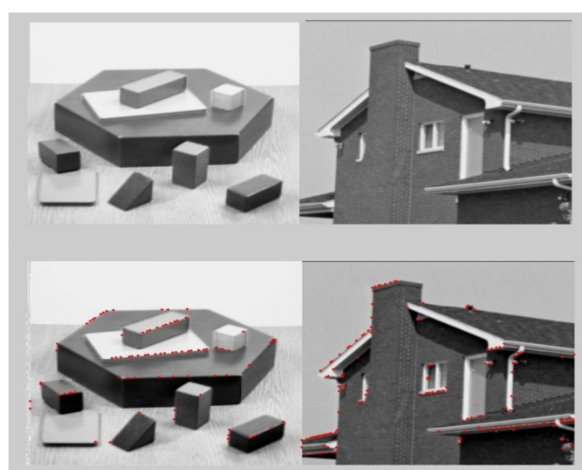
The resulted image in fig(9) is keeping only pixels with high gradients it could be used to determine edges, curvatures and objects ,As we know the corner connects between two rectums in different direction that means it have two gradient one in x-direction and other in y- direction, so we calculate the gradient again in two direction and the pixel with two values declares as a corner, fig (10)



fig(10) (a) the pixels with horizontal gradient x-direction (b) the pixels with vertical gradient y-direction (c) distribution of corner points (d) localization of corners detected as final result

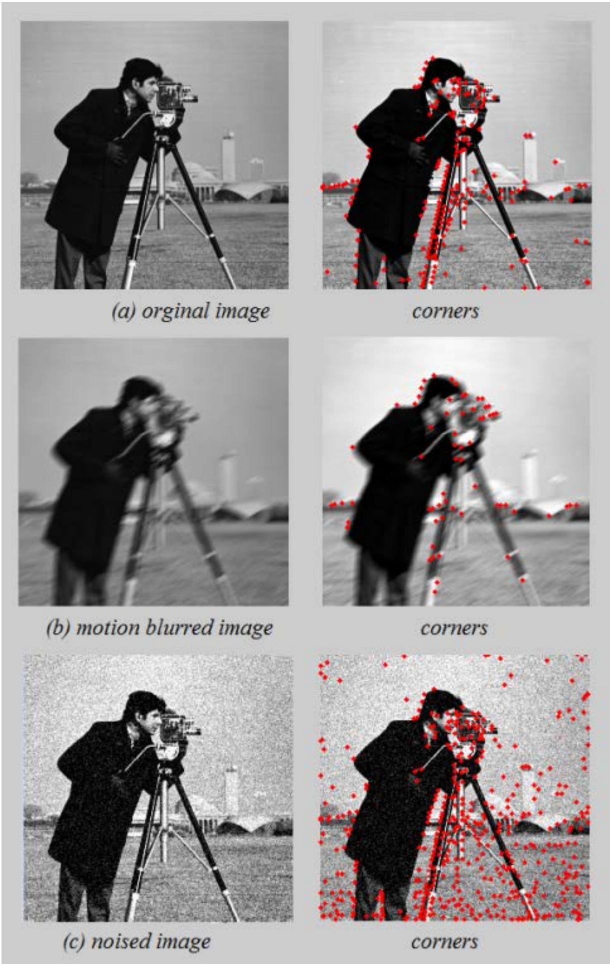
V. RESULTS AND DISCUSSION

This method proves its efficiency in detecting corners rate that the number of right detected is higher than false and missing once which could be limited to minimum in all examples,fig(11,12).



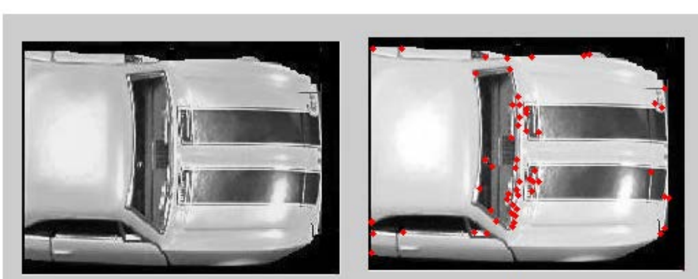
(a) (b)

fig(11) examples of detected corners in images



fig(12) More examples for detecting corners in : (a) normal image (b) blurred image (c) noised image

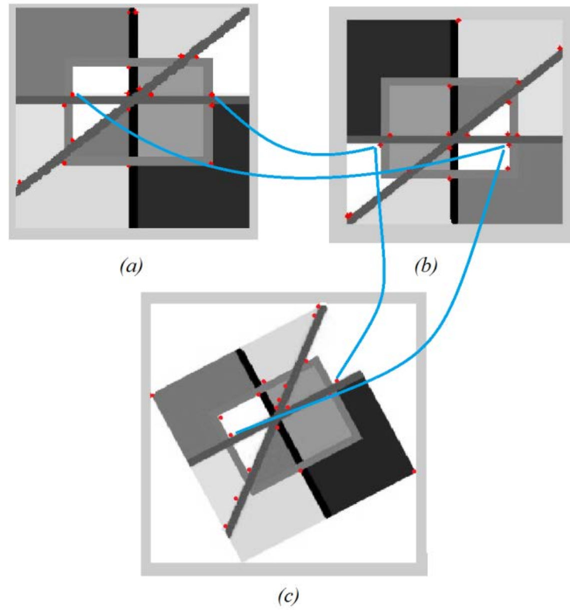
The method is good in localization of different shapes of corners (×,↑,∟,T, Y) such as that type T is detected once in one side and it gives an excepted localization results with blurred images, fig(12)(b). In the same fig(12)(c) it obvious that this method is able to detect corners in noisy images but also reports false detection as much as the noise was thick , it recorded a high score of success in determining the sharp corners as well as the curvatures with high degree of curving and also it reduces as less as possible in detecting the curvature as a corner as showed in fig(13) .



(a) (b)

fig (13) Detecting corners and sharp curvature

The success of detecting corner is good even in rotation situation as in fig (14):



fig(14) Detecting corners under rotation situation

The speed in implementation was rather high and good for online corner detection applications that uses medium resolution.

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