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Comparative Analysis of Gradient Operators Based on Content Aware Image Retargeting

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Abstract— ***Liquid content aware image retargeting algorithm is an image resizing algorithm which resizes digital image in content aware fashion. Pixels which are highly noticeable are preserved and unnoticeable pixels are removed from image. Content aware image retargeting algorithm has advantages over traditional methods of image resizing. The performance of content aware algorithm algorithm is based on total number seams, removed from image, resolution of image and image contents. This paper, presents a comparative analysis of various energy map generation methods based on image retargeting algorithm.***

Keywords— ***Image Retargeting, Image gradient, Energy function, Energy Map.***

I. INTRODUCTION

Due to proliferation of display device image resizing algorithm is required to resize image according to size of display screen in content aware fashion. So the important pixels present in the image and unimportant pixels can be removed. The content aware image resizing algorithm algorithm is introduced and discussed by Avidan and Shamir [1]. Later solutions by Wolf et al. [2], Simakov et al. [3] and Guo et al. [4] produce good results by using global optimization techniques. Two energy functions i.e. horizontal and vertical can be applied over the image to find out the importance of pixels in the image. After finding least energy pixels in the image a path of least energy pixels is created. This path of pixels may be from top to bottom or from left to right. Path of least energy pixels is called seam. A pixel is considered unimportant if the magnitude of its gradient value is small. In other words, the brightness values of its color channels do not differ greatly from those of its neighbors. Size of image can be reduced and enlarge after removing or inserting seam in image in both horizontal and vertical direction. In order to preserve important object in the image content aware image resizing algorithm algorithm removes only those pixels which are less noticeable and protect those pixels which are highly noticeable. Traditional methods cropping and resampling can introduce undesirable losses in information [5]. The applications of content aware image retargeting algorithm are image resizing, object removal, object preservation during resizing. Density of pixel can be calculated by various algorithm gradient magnitudes, entropy, visual saliency, eye-gaze movement and more. With the help of energy image E most important pixels and least important pixels can be noticeable. Algorithm can be used in texture synthesis in which large image can be created from small image. Object distortion is major problem with content aware image resizing algorithm (Seam Carving). Straight lines present in the image can be distorted when algorithm is applied over the image. Structure preservation is an important aspect of seam carving algorithm. Another problem with seam carving is no clear distinction between foreground and background. Edge detection is used to identifying discontinuity in an image. Discontinuity is abrupt changes in intensity which characterizes boundaries of objects in a scene [6]. By combining image segmentation techniques with seam carving algorithm foreground and background region in image can be identified easily. Seam carving with image segmentation can give better way to protect objects during image resizing. Various image gradients methods are used to calculate change in intensity in image, in given direction. Convoluting a filter over original image can produce gradient of images. Various filter can be applied over the image i.e. sobel, canny, laplacian, Log, Roberts. In case of edge detection gradient image is computed after applying filters or energy functions over the image. The classical operators such as sobel and Robert's cross use simple calculation to find first derivative. The limitation of these operators is to estimate inaccurate edge detection. Edge detection is the fundamental step in image processing so that true image should be find out. To estimate true edges present in image for an application an accurate operator must be selected for computation. Edge points can be finding out by considering first derivative operator. Edge points are those points in image where maximum gradient value can find. Roberts, prewitt and sobel operators are first derivative operator. Among these operators sobel operator gives better performance. Sobel operator also gives smoothing effects by which spurious edges can be reduced which are generated due to noise present in image. The effect due to spurious noise present in image can be taken care up to some extend by sobel operator but it does not taken care by prewitt operator.

Edge present in image can also find out by second derivative operators. Second derivative operators are generally used to extract secondary information from the image. These operators are very sensitive to noise. Laplacian operator is not used to edge detection but this operator can be used to find whether point in image is present in darker side or in brighter side. This operator also leads to double edge at every transition. Laplacian operator can be used to find exact location of edge in image where zero crossing occurs. In zero crossing detectors, second order derivatives are computed for edge detection while in case of search based methods first order derivatives are computed [7]. The Canny method finds edges by looking for local maxima of the gradient of the image. This operator minimizes false edge points and achieves good localization of edges. The gradient is calculated using the derivative of the Gaussian filter.

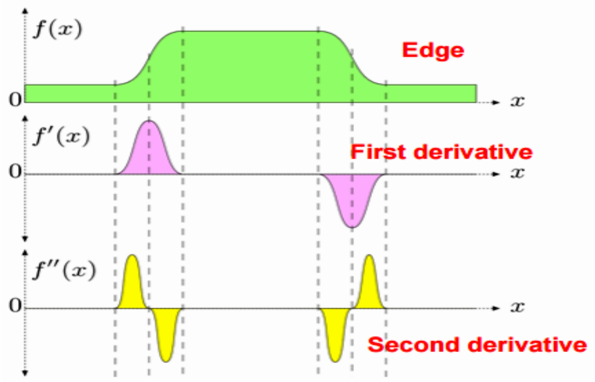


Fig. 1. First and second derivative operator to detect Edge

The method uses two thresholds to detect strong and weak edges. One of the most common uses is in edge detection. After gradient images have been computed, pixels with large gradient values become possible edge pixels.

This paper is organized as follows: I. Introduction in section II, Process of seam carving algorithm in detailed in section III, steps to compute gradient of image in section IV, Generating Energy Map in section V, Steps to about gradient operators in section VI, Testing environment and in VII brief conclusions about the results.

II. FLOW OF SEAM CARVING

1. Using energy generation methods energy of every pixel can be calculated. Various energy generation operators can be applied on image i.e. Sobel, Laplacian, Canny, and LOG. These energy generation methods are used to calculate gradient of image in horizontal and vertical direction. The gradient of images measures change in intensity, in given direction.
2. A least energy seam can be found using dynamic programming. A seam is a connected path of pixels in vertical or horizontal direction. A seam in vertical direction must have at least one pixel per row.
3. Removing seam from image means removing pixels from the less interesting part of image and keeping those pixels in the image which are highly noticeable by human eyes.

III. STEPS TO COMPUTE GRADIENT OF IMAGE

1. Convolve the original image with mask 1. This gives the gradient along x-direction.
2. Convolve the original image with mask 2. This gives the gradient along x-direction.

Add the result of 1 & 2. The advantage of this prolonged method is that, effect of each mask can be visible separately. There is another direct method of implementing the ordinary operator practically. It gives results that are almost similar.

Add mask 1 & 2. Convolve the original image with this resultant mask to get the gradient image.

- Image derivatives in horizontal and vertical direction

$$\frac{\partial I}{\partial u}(u,v) \quad \& \quad \frac{\partial I}{\partial v}(u,v) \qquad (1)$$

- Image gradient at location (U,V)

$$\nabla I(u,v) = \begin{bmatrix} \frac{\partial I}{\partial u}(u,v) \\ \frac{\partial I}{\partial v}(u,v) \end{bmatrix} \qquad (2)$$

- Gradient Magnitude

$$|\nabla I|(u,v) = \sqrt{\left(\frac{\partial I}{\partial u}(u,v)\right)^2 + \left(\frac{\partial I}{\partial v}(u,v)\right)^2} \qquad (3)$$

Gradient Based Edge Detection

- Compute image derivatives by convolution

$$D_x(u,v) = H_x * I \quad \text{and} \quad D_y(u,v) = H_y * I \qquad (4)$$

- Compute edge gradient magnitude

$$E(u,v) = \sqrt{(D_x(u,v))^2 + (D_y(u,v))^2} \qquad (5)$$

- Compute edge gradient direction

$$\phi(u,v) = \tan^{-1}\left(\frac{D_y(u,v)}{D_x(u,v)}\right) = ArcTan\left(D_x(u,v), D_y(u,v)\right) \qquad (6)$$

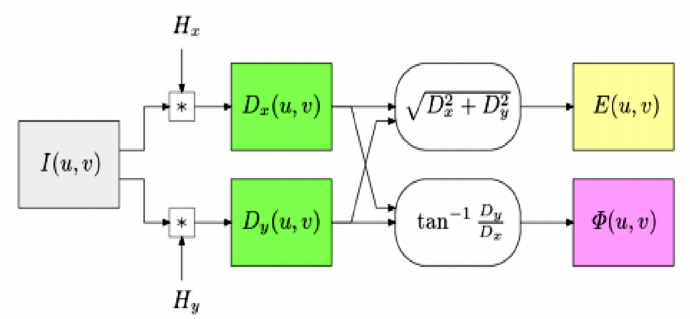


Fig. 2. Process of Gradient Based Edge Detection

IV. GENERATING ENERGY MAP

Energy map can be generated by following methods.

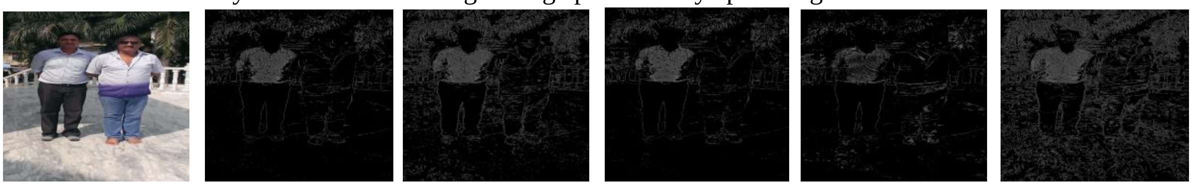
A. Gradient Magnitude

Basic method to extract unnoticeable pixel from image is use of gradient operator (Sobel, prewitt, Robert or Laplacian). These operators can be first and second derivative operator. These operators compute gradient of image in X direction and Y direction.

In this method energy function can be define as:

$$e(x,y) = \left|\frac{\partial I}{\partial x}\right| + \left|\frac{\partial I}{\partial y}\right|$$

Among all first and second derivative operators canny operator detect large number of edges present in image. An image with resolution 1458 x 2592 has been taken to detect edges in the image. After detecting edges, all edge pixels are detected where intensity >127. After counting all edge pixels canny operator gives better result.



(a) (b) (c) (d) (e) (f)

Fig. 3. Detection of edges using (a) Original Image, (b) Sobel (c) Canny, (d) Prewitt, (e) Roberts, (f) LOG

Table I. Detection Of Edge Points Using Operators

Edge Detection Operators	Number of Edge pixels
Sobel Operator	171902
Canny Operator	290791
LOG Operator	249664
Prewitt Operator	170494
Roberts Operator	119441
ZeroCross Operator	249664

B. Entropy

To improve gradient energy map a local entropy filter is used. Entropyfilt ( ) function available in matlab is used to calculate local entropy of grayscale image. In some case Entropy function works better than image gradient function while in others image gradient function gives better performance. A hybrid algorithm which can combine both metrics to assign score to each pixel can give better result.

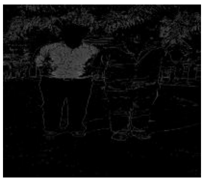
(a) (b)

Fig. 4. (a) Original Image (b) Entropy Map

C. Histogram of Gradient (HOG)

Energy map of image can be computed by histogram of gradient (HOG) method.

$$eHoG(I) = \frac{\left|\frac{\partial}{\partial x} I\right| + \left|\frac{\partial}{\partial y} I\right|}{\max\left(HoG\left(I(x,y)\right)\right)} \quad (7)$$

(a) (b)

Fig. 5. (a) Original Image, (b) HOG Map

V. GRADIENT OPERATORS

A. Sobel & Prewitt Operators

Sobel operator is conventional operator for detecting edges present in image. In sobel operator 3 X 3 mask is applied over the image. This gradient based operator has two 3 X 3 kernels, one is used to find gradient in X-direction and other is for calculating gradient in Y-direction. Gradient in X and Y direction are finally combined in order to get gradient at each point.

-1	0	+1
-2	0	+2
-1	0	+1

Gx

-1	0	+1
-2	0	+2
-1	0	+1

Gy

Fig. 6. Convolution Mask of Sobel Operator

$$|G| = \sqrt{G_x^2 + G_y^2} \quad (8)$$

Where |G| denotes gradient of image and G_x^2 and G_y^2 represent particular gradient magnitude of image. Prewitt edge detector operator is similar like Sobel operator. This operator is used to estimate first derivative with the used of 3 X 3 mask. Mask used in prewitt operator [9] computes highest peaks and work in that direction. Edges in both directions can be computed by using Prewitt operator. Prewitt operator is used to estimate the magnitude and orientation of edges.

-1	0	+1
-1	0	+1
-1	0	+1

Gx

-1	0	+1
-1	0	+1
-1	0	+1

Gy

Fig. 7. Convolution Mask of Prewitt Operator

B. Robert's Cross Operator

The Robert's Cross operator estimates 2-D spatial gradient measurement on an image. Kernel of this operator is design maximally to compute edges which make 45^0 angle to the pixel grid. These mask can be applied to measure gradient in both x and y direction similar to sobel and prewitt operator.

+1	0
0	-1

Gx

0	+1
-1	0

Gy

Fig 8: Mask of Robert's Cross Operator

Table I. Execution time of algorithm after seam removal from images

Seam Removes vertically & Horizontally using various Edge Detection Operators					
Operators	**Image**	**Time to Removed Seam (50)**	**Time to Removed Seam (100)**	**Time to Removed Seam (150)**	**Time to Removed Seam (200)**
Sobel	Applying Sobel Operator on Image1 Resolution (338 X 600).	.65562	1.10646	1.46687	1.64545

	Applying Sobel Operator on Image2 Resolution (800 X 600).	2.25062	4.00437	5.58733	7.04784
Prewitt	Applying Prewitt Operator on Image1 Resolution (338 X 600) using Prewitt	.59436	1.02785	1.3581	1.5453
	Applying Prewitt Operator on Image2 Resolution (800 X 600).	2.23919	4.03292	5.56555	6.99741
Robert	Applying Roberts Operator on Image1 Resolution (338 X 600).	.65481	1.15937	1.40535	1.58075
	Applying Roberts Operator on Image2 Resolution (800 X 600)	2.14931	3.90834	5.45547	6.78188
Canny	Applying Canny Operator on Image1 Resolution (338 X 600).	.73959	1.25322	1.52539	1.69525
	Applying Canny Operator on Image2 Resolution (800 X 600).	2.26726	4.38023	5.98986	7.44498
LOG	Applying LOG Operator on Image1 Resolution (338 X 600).	.67595	1.14371	1.4701	1.61357
	Applying LOG Operator on Image2 Resolution (800 X 600).	2.26382	4.27874	5.95167	7.32398
Zero Cross	Applying LOG Operator on Image1 Resolution (338 X 600).	.73043	1.23469	1.50878	1.69169
	Applying LOG Operator on Image2 Resolution (800 X 600).	2.42297	4.31859	5.97287	7.11282

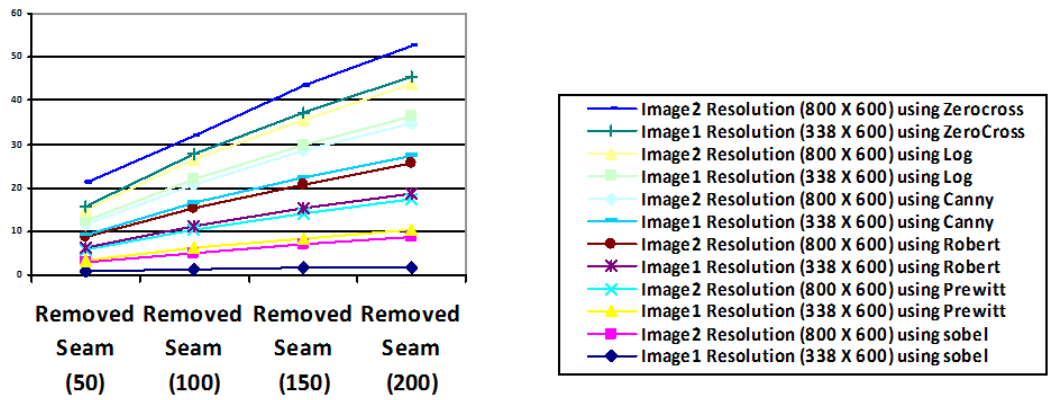


Fig 8. Execution time of seam removal from image based on gradient operators

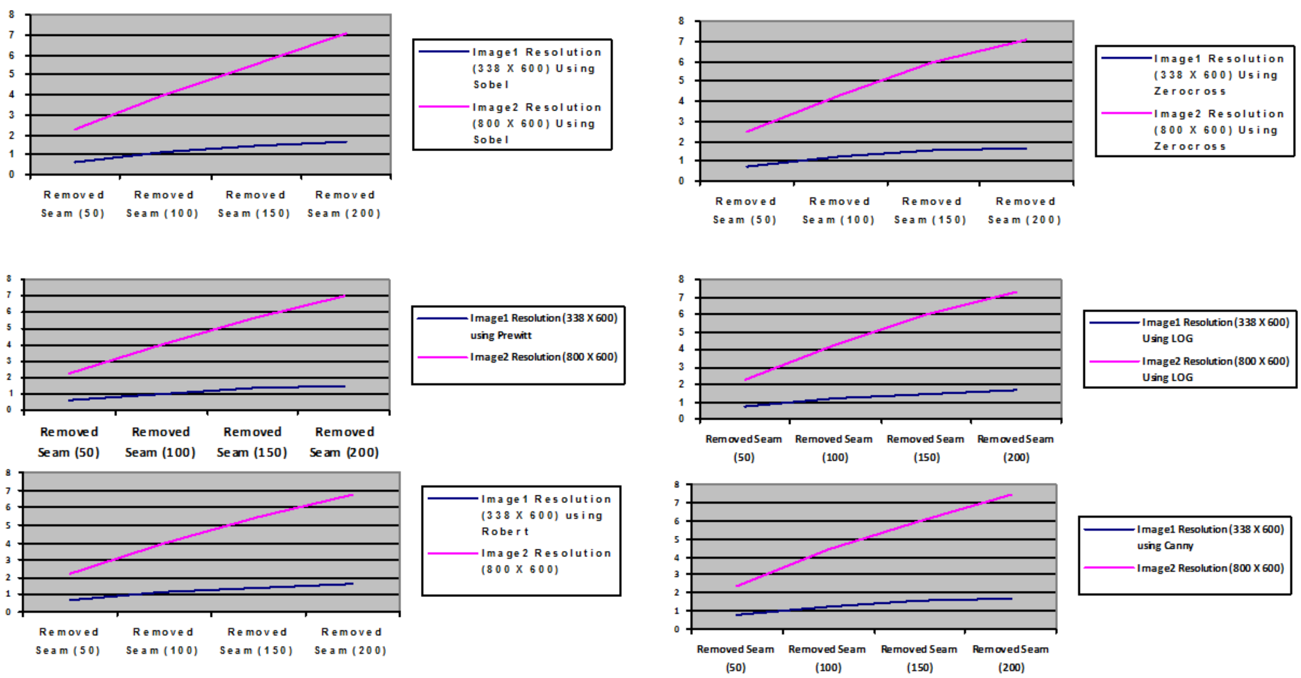


Fig. 9. Execution time of Content aware algorithm based on gradient operators

C. Canny Operator

Canny algorithm [10] is most popular algorithm for edge detection because it give optimum performance than other conventional edge detection operator. Three parameter are implemented in canny operator i.e. localization, error rate and single response to single edge. The steps followed in Canny Algorithm are explained below:

1. **Smoothing:** In order to eliminate noise from the image a low pass Gaussian filter is used. After applying Gaussian filter noise and unwanted details and textures can be reduced. Commonly used filter to smooth image is 5 X 5 filter. The size of convolution mask is usually smaller then the size of image. When mask is slide over the image it manipulates intensity of pixel.
2. **Finding Intensity Gradient of Image:** After applying Sobel kernel to find Gradient of image in horizontal (G_x) and vertical direction (G_y). Gradient direction is always perpendicular to edges.

$$Edge\_Gradient(G) = \sqrt{G_x^2 + G_y^2} \qquad (9)$$

$$Angle(\theta) = \tan^{-1}\left(\frac{G_y}{G_x}\right) \qquad (10)$$

3. **Non-Maximum Suppression:** Sobel Operator is used as a first order image gradient to detect the actual edges.
4. **Double Threshold:** Edge thinning is performed to sharpen the edges.
5. **Edge tracking by Hysteresis:** Double thresholding is performed to remove the weak edges from the image.

D. Laplacian of Gaussian (LOG)

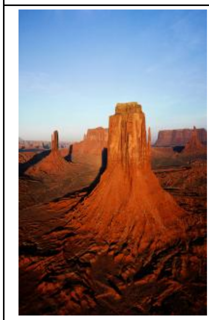
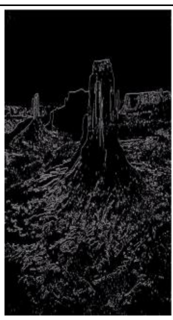
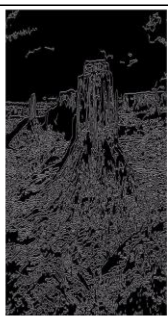
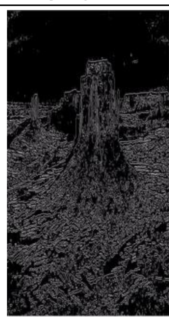
This operator is invented by Marr and Hildrethw in 1980. The Laplacian of image highlights those regions where it is concluded that performance of seam carving algorithm is totally depend upon the operator by which energy map is generated. As a future work, different energy function can be investigated to increase the execution time and performance of seam carving algorithm. A hybrid algorithm can be find out which can combine all the energy map generation methods. Energy function generated by hybrid intensity changes rapidly. The Laplacian usually applied over the image after applying Gaussian smoothing filter to reduce its sensitivity to noise. The Laplacian L(x, y) of an original image with intensity values of the pixels I(x,y) is given as:

$$L(X,Y) = \frac{\partial^2 I}{\partial X^2} + \frac{\partial^2 I}{\partial Y^2} \qquad (11)$$

E. Zerocross Operator

Output image obtain from Zero crossing is binary image. Lines in binary image with single pixel thickness show zero crossing points. Zero crossing in image always occurs on the points where gradient of image starts increasing or decreasing.

Table II. Images after Applying Various Image Gradient Operators

Original Image	**Image using Sobel**	**Image using Canny**	**Image using Roberts**	**Image using LOG**	**Image using Prewitt**	**Image using Zerocross**
 *Image-1(338 X 500)*	 *(a)* *No of edge=30729*	 *(b)* *No of dge=58658*	 *(c)* *No of edge=16519*	 *(d)* *No of edge=51324*	 *(e)* *No of edge=30509*	 *(f)* *No of edge=51324*
 *Image-1(800 X 600)*	 *(a)* *No of edge=24650*	 *(b)* *No of edge=9173*	 *(c)* *No of edge=3076*	 *(d)* *No of edge=7181*	 *(e)* *No of edge=3259*	 *(f)* *No of edge=7181*

It has been observed that most important part of seam carving algorithm is to decide energy function to calculate energy map of image. Execution time of seam carving algorithm is totally depend upon energy map of image. Seam carving algorithm takes more time over image on which canny edge operator is applied. Table I. shows that execution time of seam carving algorithm is also depending upon complexity and resolution of image. Distortion of object is highly unnoticeable if image is less complex. Seam carving algorithm takes less execution time on images having resolution 338 x 600 and 800 x 600. Edges are detected using prewitt operator and Roberts operator respectively. Canny operator gives best result and good visual quality. In Table II images are given after edges detection using gradient operators. In Table II number of edge pixels detected by image gradient operators is given. It has been prove that number of edges detected by canny edge detection operator is larger than other image gradient operators.

VI. TESTING ENVIRONMENT

In this performance analysis we use Intel Core i3 processor. Matlab is used to run algorithm on image to calculate estimated time of algorithm on different image which are obtain after using different image gradient operators.

VII. CONCLUSION

After executing seam carving algorithm over different images, obtained after applying various image gradient operators over images. Algorithm takes more time when it is applied on the image which has large number of edges. Time complexity of algorithm is depend upon number of edges present in the image, complexity of image, type of operator applied over image, and number of seam removed from the image. Finally

It is concluded that performance of seam carving algorithm is totally depend upon the operator by which energy map is generated. As a future work, different energy function can be investigated to increase the execution time and performance of seam carving algorithm. A hybrid algorithm can be find out which can combine all the energy map generation methods. Energy function generated by hybrid algorithm can give better result when it will be applied over image in order to assign energy of each pixel in the image.

It also concludes that canny edge operator detects more number of edge points as compare to other image gradient operators. MATLAB code is implemented to find edges pixels in the gradient image which are obtained after applying various image gradient operators where threshold value is > 127.

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