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Survey on Image Processing With Edge Detection Techniques

ROHIT GOEL	ASSISTANT PROFESSOR, DESHBANDHU COLLEGE, UNIVERSITY OF DELHI
Pushpendra Kumar Vashishtha	ASSISTANT PROFESSOR, KAMLA NEHRU COLLEGE
PRIYANKA SAHNI	ASSISTANT PROFESSOR, KAMLA NEHRU COLLEGE
ASHWINI KUMAR	ASSISTANT PROFESSOR, SWAMI SHRADDHANAND COLLEGE

ABSTRACT

Image processing is a method to convert an image into digital form and perform some operations on it, in order to get an enhanced image or to extract some useful information from it. The important steps of image processing are de-noising and edge detection. Images captured by cameras /video cameras have noise due to the electromagnetic and other geographic, atmospheric conditions and incorrect photo count. Removing noise from the original signal is still a challenging problem for researchers. There have been several published algorithms and each approach has its assumptions, advantages, and limitations. This paper presents a review of some significant work in the area of image de-noising. Second, edge detection is one of the first steps of feature extraction. Edge detection characterizes the boundaries in the image and thus reduces the amount of data and also filters out the unnecessary information from the image and provides the structural properties of the image. There are many algorithms for both de-noising and edge detection on images.

It was stated that the edge detection methods structurally are a combination of image smoothing and image differentiation plus a post-processing for edge labeling. The image smoothing involves filters that reduce the noise, regularize the numerical computation, and provide a parametric representation of the image that works as a mathematical microscope to analyze it in different scales and increase the accuracy and reliability of edge detection. The image differentiation provides information of intensity transition in the image that is necessary to represent the position and strength of the edges and their orientation.

KEYWORDS

INTRODUCTION - Digital images play an important role both in daily life applications such as satellite television, magnetic resonance imaging, computer tomography as well as in areas of research and technology such as geographical information systems and astronomy. Data sets collected by image sensors are generally contaminated by noise. Thus, de-noising is often a necessary and the first step to be taken before the images data is analyzed. It is necessary to apply an efficient de-noising technique to compensate for such data corruption. Image de-noising still remains a challenge for researchers because noise removal introduces artifacts and causes blurring of the images.

Edge detection is a process that detects the presence and location of edges constituted by sharp changes in color intensity (or brightness) of an image. Since, it can be proven that the discontinuities in image brightness are likely to correspond to: discontinuities in depth, discontinuities in surface orientation, changes in material properties and variations in scene illumination. In the ideal case, the result of applying an edge detector to an image may lead to a set of connected curves that indicate the boundaries of objects, the boundaries of surface markings as well curves that correspond to discontinuities in surface orientation .

DENOSING - The aim of de-noising technique is removal of noises from an image and thus becomes the first step in image processing. The Technology for removal of noise should be applied carefully; otherwise noise removal introduces artifacts and which causes blurring of the image. The aim of edge detection is to provide the structural properties of the image. Important features can be extracted from the edges of an image and these features are used by higher-level computer vision algorithms.

DE-NOISING TECHNIQUES - De-noising technique is used to restore the image corrupted by noise as close as possible to the original image. Filtering in image processing is a mainstay function that is used to accomplish many things, including interpolation, noise reduction and re-sampling. The choice of filter is often determined by the nature of the task and the type and behavior of the data. Noise, dynamic range, color accuracy, optical artifacts, and many more details affect the outcome of filter functions in image processing.

CLASSIFICATION OF DE-NOISING TECHNIQUES - There are two basic approaches for image de-noising. They are spatial domain filtering and transform domain filtering. In this paper we discuss about spatial domain filters; which are further classified into linear filter (Gaussian filter,Mean filter) and non-linear filter (Median filter).

1. **Gaussian Filter :** A Gaussian filter modifies the input signal by convolution with a Gaussian function; The one-dimensional Gaussian filter has an impulse response given by

by $g(x) = \sqrt{\frac{a}{\pi}}..e^{-a\,x^2}$

and the frequency response is given by the : $\hat{g(f)} = e^{-\pi\,f^2/a}$

with f the ordinary frequency.

2. Mean Filter : Mean filter is the optimal filter for removing grain noise in an image. It is the linear filter which uses a mask over each pixel in the image. The components of the image which fall under the mask are averaged together to form

an output pixel. This filter is also called average filter and it becomes weak when the noise in the image is adaptive noise. Generally this filter is applied for noise suppression.

3. MEDIAN FILTER : This is the most favorite filter in digital image processing. Unlike mean filter, it takes median of neighboring pixels. It is often used when the noise in image is of type 'salt and pepper'[2]. It is used to simultaneously reducing noise and preserving the edges.

Edge detection refers to the process of identifying and locating sharp discontinuities in an image. The discontinuities are abrupt changes in pixel intensity which characterize boundaries of objects in a scene. Classical methods of edge detection involve convolving the image with an operator (a 2-D filter), which is constructed to be sensitive to large gradients in the image while returning values of zero in uniform regions. Variables involved in the selection of an edge detection operator include:

- **Edge orientation:** The geometry of the operator determines a characteristic direction in which it is most sensitive to edges. Operators can be optimized to look for horizontal, vertical, or diagonal edges.
- **Noise environment:** Edge detection is difficult in noisy images, since both the noise and the edges contain high-frequency content. Attempts to reduce the noise result in blurred and distorted edges. Operators used on noisy images are typically larger in scope, so they can average enough data to discount localized noisy pixels. This results in less accurate localization of the detected edges.
- **Edge structure:** Not all edges involve a step change in intensity. Effects such as refraction or poor focus can result in objects with boundaries defined by a gradual change in intensity. The operator needs to be chosen to be responsive to such a gradual change in those cases. Newer wavelet-based techniques actually characterize the nature of the transition for each edge in order to distinguish, for example, edges associated with hair from edges associated with a face.

STEPS IN EDGE DETECTION

The fundamental steps performed in edge detection:

1. Image smoothing for noise reduction suppress as much noise as possible, without destroying the true edges.
2. **Enhancement:** apply a filter to enhance the quality of the edges in the image(sharpening).
3. **Detection**: determine which edge pixels should be discarded as noise and which should be retained (usually, thresholding provides the criterion used for detection).
4. **Localization**: determine the exact location of an edge (sub-pixel resolution might be required for some applications, that is, estimate the location of an edge to better than the spacing between pixels). Edge thinning and linking are usually required in this step.

EDGE DETECTION METHODS: This Section presents dominant works of edge detection methods in nine categories, and explains their advantages and disadvantages and the relationships among them. Some works, because of their importance and fundamental impacts, are described in more details, while some have been reviewed with just referring to their main contributions.

Classical Methods : Classical edge detectors have no smoothing filter, and they are only based on a discrete differential operator. The earliest popular works in this category include the algorithms developed by Sobel (1970), Prewitt (1970), Kirsch (1971), Robinson (1977), and Frei-Chen (1977). They compute an estimation of gradient for the pixels, and look for local maxima to localize step edges. Typically, they are simple in computation and capable to detect the edges and their orientation, but due to lack of smoothing stage, they are very sensitive to noise and inaccurate.

$$|\nabla g(c,r)| = \sum_{\alpha} g_{\alpha}(c,r) \quad \ldots(1)$$

The Sobel operator is the most known among the classical methods. The Sobel edge detector applies 2D spatial gradient convolution operation on an image. It uses the convolution masks to compute the gradient in two directions (i.e. row and column orientations), and then works out the pixels' gradient through g=|gr+gc|. Finally, the gradient magnitude is thresholded. Sobel edge detector is a simple and effective approach, but sensitive to noise. Moreover, the detected edges are thick, which may not be suitable for applications that the detection of the outmost contour of an object is required.

$$H_c = \frac{1}{4}\begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \quad H_r = \frac{1}{4}\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \quad \ldots(2)$$

Though the classical methods were not in benefit of an independent smoothing module, they attempted to ease this drawback through the calculation of average over the image. This is because estimation of a derivative calculated using a relatively large set of neighbouring pixels is more robust to noise than using only two pixels. Following this idea, several operators have been proposed, some of them are an extended version of the 3x3 detectors mentioned earlier. For example, a mask adopted by the 7x7 Prewitt based operator to estimate the horizontal (column orientation) first order derivative of the image is presented as

following.

Right from the early stages of edge detection, it was recognized that we can use operators of several dimensions. Rosenfeld et al. proposed an algorithm to detect edges, commonly known as ―difference of boxes‖, that relies on the use of pairs of neighbourhoods

$$H_c = \frac{1}{21}\begin{bmatrix} -1 & -1 & -1 & 0 & 1 & 1 & 1 \\ -1 & -1 & -1 & 0 & 1 & 1 & 1 \\ -1 & -1 & -1 & 0 & 1 & 1 & 1 \\ -1 & -1 & -1 & 0 & 1 & 1 & 1 \\ -1 & -1 & -1 & 0 & 1 & 1 & 1 \\ -1 & -1 & -1 & 0 & 1 & 1 & 1 \\ -1 & -1 & -1 & 0 & 1 & 1 & 1 \end{bmatrix} \quad \ldots(3)$$

(one neighbourhood on each side of the point under analysis) of several dimensions and orientations. By convenience, they suggested that the neighbourhoods should have a square shape and have sizes related to the powers of two. The output value of this operator is just the difference of the mean intensity values, calculated over the pair of neighbourhoods. Also, they indicated that one of the possible ways to find the ―ideal‖ operator size is to look for the largest one that does not originate a significant decrease on the output value, when compared with the output value of the immediately smaller operator.

4.2 Gaussian Based Methods : Gaussian filters are the most widely used filters in image processing and extremely useful as detectors for edge detection. It is proven that they play a significant role in biological vision particularly in human vision system. Gaussian-based edge detectors are developed based on some physiological observations and important properties of the Gaussian function that enable to perform edge analysis in the scale space. Marr and Hildreth were the pioneers that proposed an edge detector based on Gaussian filter. Their method had been a very popular one, before Canny released his detector. They originally pointed out the fact that the var-

iation of image intensity (i.e. edge) occurs at different levels. This implied the demand to smoothing filters with different scales, since a single filter cannot be optimal for all possible levels. They suggested the 2D Gaussian function, defined as following, as the smoothing operator.

$$G_\sigma(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad \ldots(4)$$

Where σ is the standard deviation, and (x, y) are the Cartesian coordinates of the image pixels. They showed that by applying Gaussian filters of different scales (i.e. σ) to an image, a set of images with different levels of smoothing will be obtained.

Then, to detect the edges in these images they proposed to find the zero-crossings of their second derivatives. Marr and Hildreth achieved this by using Laplacian of Gaussian (LOG) function as filter. Since Laplacian is a scalar estimation of the second derivative, LOG is an orientation-independent filter (i.e. no information about the orientation) that breaks down at corners, curves, and at locations where image intensity function varies in a nonlinear manner along an edge. As a result, it can't detect edges at such positions. According to (24), the smoothing and differentiation operations can be implemented by a single operator consisting on the convolution of the image with the Laplacian of the Gaussian function. The final form of the filters, known as LOG with scale σ , which should be convolved with the image is as

follows:

$$f_\sigma(x,y) = \nabla^2 G_\sigma = -\frac{1}{\pi\sigma^4}\left(1-\frac{x^2+y^2}{2\sigma^2}\right)e^{-\frac{x^2+y^2}{2\sigma^2}} \quad \ldots(5)$$

There are advantages for the Gaussian filter that make it unique and so important in edge detection. The first concerns to its output. It is proven that when an image is smoothed by a Gaussian filter, the existing zero-crossings (i.e. detected edges) disappear as moving from fine-to-coarse scale, but new ones are never created . This unique property makes it possible to track zero-crossings (i.e. edges) over a range of scales, and also gives the ability to recover them at sufficiently small scales. Yuille and Poggio proved that with the Laplacian, the Gaussian function is the only filter in a wide category that does not create zero crossings as the scale increases. They also showed that for second derivatives, there is no filter that does not create zero-crossings as the scale increases. This implies the importance of combination made by Laplacian and Gaussian. Another issue concerns to the filters' conflicting goals of localization in spatial and frequency domains. The —optimall smoothing filter should obey to two conditions: (1) the filter should be smooth in the frequency domain and approximately frequency limited, to be able to reduce the scale range where intensity changes occur (well-posed); (2) the filter should be localized in the spatial domain, since the influence of a given point only makes sense in a relatively small neighbourhood. The LOG filter is a linear filter that is able to simultaneously minimize the (product of the) spread in space and frequency domains. Canny showed that for a 1D step edge the derived optimal filter can be approximated by the first derivative of a Gaussian function with variance σ as follow:

$$f_\sigma(x) = \frac{dG_\sigma(x)}{dx} = -k\frac{x}{\sigma^2}e^{-\frac{x^2}{\sigma^2}} \quad \ldots(6)$$

In 2D, Canny assumed the image affected by white noise, and proposed the use of two filters representing derivatives along the horizontal and vertical directions. In other word, the edge detection is performed through the calculation of derivative along two directions of the image

filtered by Gaussian function. The separability feature of the 2D Gaussian function allows us to decompose it into two 1D filters.

$$f_\sigma(x,y) = \left[f_\sigma(x)G_\sigma(y) \quad G_\sigma(x)f_\sigma(y)\right] \quad \ldots(7)$$

Where $G_\sigma(.)$ and $f_\sigma(.)$ denotes the 1Dimensional Gaussian function and its derivative respectively and $f_\sigma(\ldots)$ denote 2 Dimensional optimal filter.

This is not surprising since the Gaussian has been emerging as a very important function in several areas of image analysis and processing and, specially, in multi-resolution analysis. Our goal is not to give an inventory of algorithms and merely review significant works that attempt to achieve high performance edge detectors using multi-resolution analysis.

4.3 Multi-Resolution Methods

Multi-resolution methods incorporate repeating edge detection for several scales of the Gaussian filter to achieve a quality performance. The main challenges in these methods includes selection a proper range for the scales, combination of the outputs corresponding to

different scales, and adaptation to level of noise in the image. There are plenty publications in this area, we just content few sample works in this sub-section. Schunck introduces an algorithm for the detection of step edges using Gaussian filters at multiple scales. The initial steps of Schunck's algorithm are based on Canny's method. The algorithm begins by convolving an image with a Gaussian function. The gradient magnitude and gradient angle are then computed for each point in the resulting smoothed data array. Next, the gradient ridges in the results of the convolution are thinned using non maxima suppression (NMS). Then, the thinned gradient magnitudes are thresholded to produce the edge map. The gradient magnitude data at the largest scale will contain large ridges which correspond to the major edges in the image. As the scale decreases, the gradient magnitude data will contain an increasing number of ridges, both large and small. Some of these correspond to major edges, some to weaker edges, and the rest are due to noise and unwanted details. The gradient magnitudes over the chosen range of scales are multiplied to produce a composite magnitude image. Ridges that appear at the smallest scale and correspond to major edges will be reinforced by the ridges at larger scales. Those that do not will be attenuated by the absence of ridges at larger scales. Therefore, in the combined magnitude image, the ridges that correspond to major edges are much higher than the ridges that do not. NMS is then performed using sectors obtained from the gradient angle of the largest filter. Schunck's algorithm chooses the width of the smallest Gaussian filter, and the filters that are used differ in width by a factor of two. However, he did not discuss how to determine the number of filters to use. In addition, by choosing such a large size for the smallest filter, Schunck's technique loses a lot of important details which may exist at smaller scales.

Lacroix detects edges using the Canny method of NMS of the magnitude of the gradient in the gradient direction. His method then considers three scales: σ0, σ1, and σ2.

The smallest scale, σ0, is the detection scale, and is the finest resolution at which a group of edges appears. The largest scale, σ2, is the blurring scale, and is the coarsest resolution at which the first appeared edges still remains. The intermediate resolution is computed as :

$$\sigma_2 = \sigma_0 + \frac{\sigma_2 - \sigma_0}{3} \quad \ldots(8)$$

The first appeared edges are validated as long as they are local maxima in the Gaussian gradient and the two recent regions are homogeneous and significantly different from one another. Only validated edges are then tracked through the scales.

Deng and Cahill also use an adaptive Gaussian filtering algorithm for edge detection. Their method is based on adapting the variance of the Gaussian filter to the noise characteristics

and the local variance of the image data. Based on observations of how the human eye perceives edges in different images, they concluded that in areas with sharp edges, the filter variance should be small to preserve the sharp edges and keep the distortion small. In smooth areas, the variance should be large so as to filter out noise. They proposed that the variance of a 1D Gaussian filter as follows:

$$\sigma^2(x) = \frac{k\sigma_n^2}{\sigma_f^2(x) + \sigma_n^2} \quad \ldots(9)$$

where k is scaling factor, σ_n is the noise variance, and σ_f local variance of the signal. The major drawback of this algorithm is that it assumes the noise is Gaussian with known variance. In practical situations, however, the noise variance has to be estimated. The algorithm is also very computationally intensive.

Conclusion And Future Work :

This paper is a review over the published articles on edge detection. At first, it provides theoretical background, and then reviews wide range of methods of edge detection in different categorizes. We had a small discussion on all the linear methods of edge detection. Since nobody is perfect and everything needs some modification so in our future work we will be evaluation the each of the method discussed in this paper and try to implement the result in Mathematica so that all the result can be compared easily and we can tell that which approach is better one.

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