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Edge detection Definition, Modelling and Methodologies

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Abstract—**Any significant change in image pixels' intensity can produce the edge that appears as the boundary that isolates various image regions. According to image amplitude changes, edges can be modeled into different types such as; Step, Ramp, Ridge /Line, and Roof Edges. Image edge detection techniques usually reduce the amount of information and ignore the useless data with preserving main image properties, however, Edge detection techniques are mainly grouped into two categories, Gradient and Laplacian edge detection techniques. This paper introduces different concepts related to edges, and discusses essential characteristics of various edge detection techniques.**

***Index Terms*— Digital image processing, Edge detection, Gradient methods, Laplacian methods.**

I. Introduction

During the process of digital image, the image can combine similarity and discontinuity properties, the similarity refers to the region that has the same pixels' intensity while the discontinuities refers to the sharp change in pixel intensity that identifies the objects' boundaries of an image that forms the edges [1][2]. These edges are represented by the boundaries they isolates the objects of an image, however, these boundaries are usually employed in object recognition and segmentation process [3]. Detection of edges plays a major role in various fields such as computer vision and digital image processing [1]. The traditional techniques of edge detection can simply applied by convolving the image with a 2-D filter to build the gradients [4]. The choice of the proper edge detection operator relies basically on the structure and orientation of the edges [4].

The detected edges can be considered as an active feature such as lines, and curves besides other characteristics such as position, direction, and amplitude and remove the useless information [1][5]. Despite its simplicity, it suffers from some essential problems which are; the noise, lightning conditions, and areas with similar intensity [1]. In image segmentation field, the image is partitioning into a specific number of regions in which these regions have the same color or texture [1][3]. However, both edge detection methods and the segmentation process required a suitable selection of thresholding rate to decide the detection process [6]. Edge detection techniques are extremely used in advance applications such as Fuzzy [7], Genetic Algorithm [8] and Neural Network [7].

In this paper, we introduced an overview of the edges, edges modeling types, and edge detection categories as well, edge detection methodologies are also explained in this paper.

II. Edge Definition

Edges can be defined as the significant change of image intensity pixels usually appears at the boundary between different regions [9], sometimes there is a small sudden change in image intensity but it is not an edge, it is a noise in the image which is a local intensity change but not significant [6]. A lot of pixels in the image might have a nonzero gradient value but not all these pixels represent an edge, frequently, thresholding represents the judgment in this case.

The essential problem that arises in the edges is the appearance of the false edge, generating thin or thick lines, and missing true edges, all these problems are caused by the noise in the image [4].

There are a lot of reasons that effects on pixel intensity, some of these events are; different physical changes, geometric events, such as objects and surface boundaries, and Non-geometric events such as shadows [9].

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III. Modeling Edge Discontinuity

Edges usually related with the model according to the image intensity profiles or the image first derivative. Edges can represent various shapes according to the amplitude changes as follows [6][1]:

- Step edge: Image intensity suddenly changes from one value on one discontinuity side to a different value on the other side.
- Ramp edge: Image intensity change not in instantaneous and appears over a finite distance, then the step become a ramp edge.
- Ridge /Line edge: Image intensity abruptly changes value and then returns to the starting value within some short distance.
- Roof Edge: the line edge considered as a roof edge when image intensity changes not in spontaneous manner and arise over a finite distance normally created by surfaces connectivity.

However, step and line edges are rarely seen in real images this back to the smoothing or low-frequency components generated in most sensing devices, step edges become ramp edges and line edges become roof edges when image intensity changes not instantaneous over a limited distance, Figure 1 demonstrates the profiles of edge discontinuity.

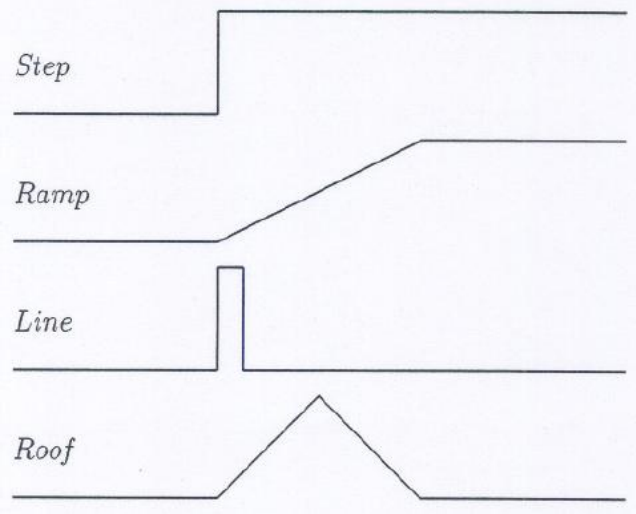

Figure 1: profiles of edge discontinuity [6].

IV. Edge Detection Using Derivatives

In Calculus, the variance of continuous functions is described using derivatives [9]. An image is represented by a 2D function, and the representation of edges is described using derivatives, however, to detect the pixels that lie on an edge area, different edge detection techniques can be grouped into two main categories: [9][10]:

- The Gradient method: Finds the edges by searching for the local maximum and minimum in the first derivative, such as Prewitt, Sobel, etc.
- The Laplacian method: Finds the edges by searches for zero crossing in the second derivative of the image, such as Marr-Hildreth, Laplacian, etc.

Figure 2 shows the representation of the edges detected as the gradient of the signal described by the first derivative of t;

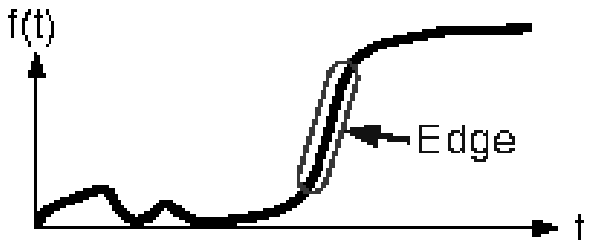

Figure 2: The gradient of a signal; the first derivative [11].

In Figure 3, the gradient with a large peak is centered on the edge, when comparing the gradient with the threshold, the threshold is exceeded and the edge is determined. Since the edge is determined at the peak, one dimension Laplacian operation can be applied, which can be defined as the second derivative with considering the t and achieve the zero crossings.

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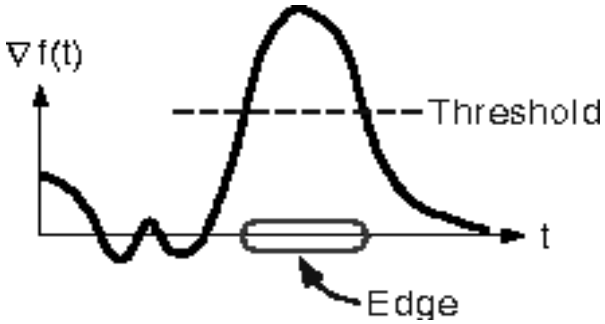

Figure 3: Second derivative [11].

Figure 4 explains the application of Laplacian operation on one dimensional signal where the edge corresponds zero crossing, as seen in Figure 3 there is a small ripples in the signal can be detected which corresponding to a zero crossings [11].

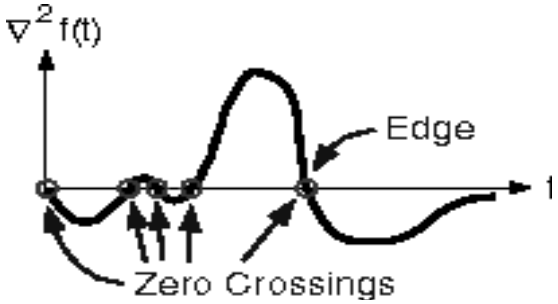

Figure 4: Zero crossing representation [11].

V. Edge Detection Methodologies

Edge detection techniques can be divided into two main categories, Gradient (first derivative) edge detection techniques which contains canny, Sobel and Brewitt methods, and Laplacian (second derivative) edge detection techniques such as; Marr-Hilderth, and Gaussian methods shown in Figure 5 [12][3]:

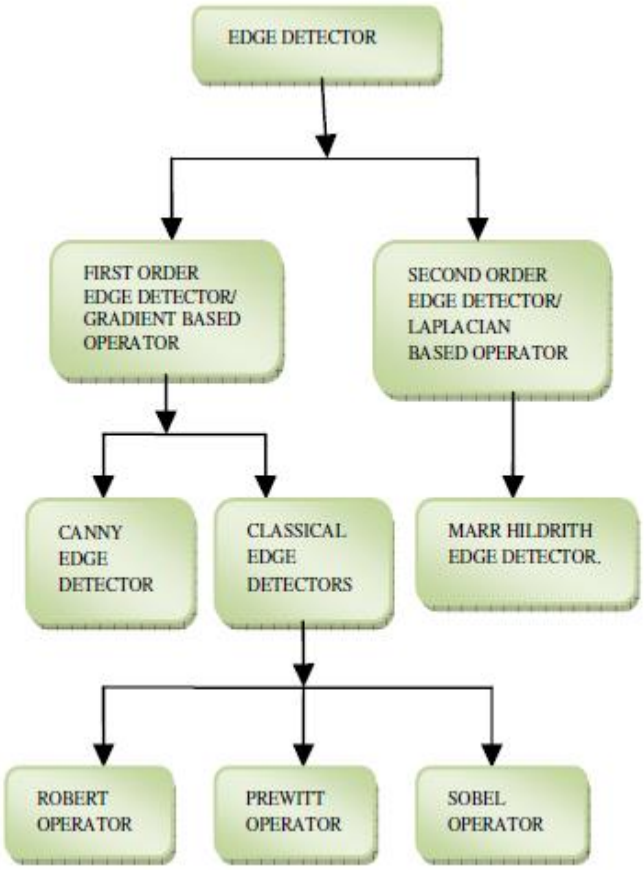

Figure 5: Types of edges detector [12].

However, a portray representation of the explained edge detection methods are shown in Figure 6, where the first derivative technique using Prewitt operator is shown in Figure 6(b), second derivative technique using Marr-Hilderth operator as seen in Figure 6(c), and finally applied Gaussian method in Figure 3(d).

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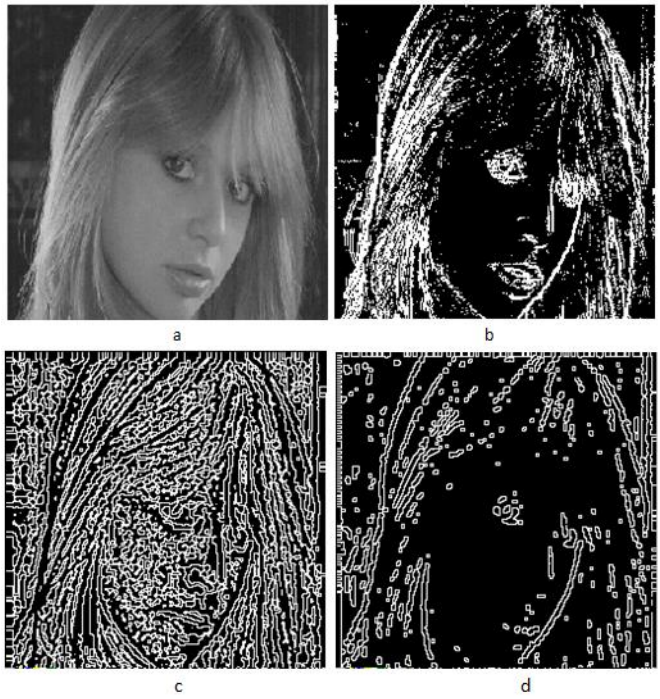

a. Original Image, b. First derivative technique (Prewitt operator), c. Second derivative technique (Marr-Hilderth operator), d. Gaussian operator

Figure 6: Applying various edge detection techniques.

VI. Conclusions

A set of connected points that consists the boundary between two separated areas can be identified as an edge. Edge detection plays an active part in most image processing applications such as pattern recognition and movement analysis. In this paper we explained the commonly utilized edge detection methods of Gradient and Laplacian techniques. The Gradient techniques are easy to implement and calculate using simple mask that convolve the image while Laplacian methods requires more computational efforts but introduces butter results than Gradient methods, however these methods are sensitive to noise and hardly identify a suitable parameters and kernel's size regarding the input image. To experience the efficiency of any technique some performance evaluation should be calculated to analyze the results correctly.

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