Edge Detection Techniques Based On Soft Computing

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ABSTRACT—Soft Computing is a multidisciplinary field that consists of Fuzzy Logic, Neural Network and Evolutionary computation. These techniques have found various applications in image processing and one such application of image processing is Edge Detection. Edge detection is the process of identifying and searching the sharp discontinuities in an image. As Edge Detection plays a crucial role in the field of image processing because it has been used in various image processing applications such as object recognition, image segmentation, data compression and so on. In this paper, the main aim is to survey the traditional edge detection techniques and soft computing based approaches of edge detection.

KEYWORDS- Edge Detection, Fuzzy Logic, Neural Network, Neuro Fuzzy, Sobel, Roberts, Prewitt, LoG (Laplacian of Gaussian), Canny.

1. INTRODUCTION

Edge detection is a very important area in the field of Computer Vision. Edges define the boundaries between regions in an image, which helps with segmentation and object recognition. They can show where shadows fall in an image or any other distinct change in the intensity of an image. Edge detection is a fundamental of low level image processing and good edges are necessary for higher level processing.

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 [11]. The discontinuities mean the sudden changes in pixel intensity which defines the boundaries of objects in a scene. So, edge detection is an important step in image analysis. It has been used in most image processing applications such as object recognition, image segmentation, data compression and so on. Since it is usually the first operation that is performed before other image processing tasks such as image segmentation, boundary detection, object recognition and classification, image registration and so on.

The fundamental steps performed in edge detection [1]:

1. **Image smoothing**: It 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. Edge thinning and linking are usually required in this step.

2. TRADITIONAL EDGE DETECTION METHODS

2.1 Gradient Edge Detectors (classical)

2.1.1 Sobel
2.1.2 Roberts
2.1.3 Prewitt
2.2 Laplacian of Gaussian(LoG)
2.3 Gaussian Edge Detector
   2.3.1 Canny

2.1 Gradient Edge Detectors (classical)

The Gradient Edge Detectors detect the edges by searching for the maximum and minimum in first derivative of the image. Gradient is a vector which is used to find edge magnitude and direction. It includes Sobel, Roberts and Prewitt Operators.

2.1.1 Sobel Operator

This operator finds the edge magnitude and direction with the help of following 3x3 convolution mask for X and Y direction respectively:

\[
\begin{pmatrix}
-1 & 0 & 1 \\
-2 & 0 & 2 \\
-1 & 0 & 1 \\
\end{pmatrix}
\quad \begin{pmatrix}
1 & 2 & 1 \\
0 & 0 & 0 \\
-1 & -2 & 1 \\
\end{pmatrix}
\]

Fig.1: Sobel [1]

The absolute edge magnitude is calculated as follows [1]:

\[ |\nabla f| = \sqrt{(G_x^2 + G_y^2)} \]  \hspace{1cm} \text{(1)}

Where \( G_x \) and \( G_y \) are the edge magnitude of X and Y direction respectively.

2.1.2 Prewitt Operator

This operator finds the edge magnitude and direction with the help of following 3x3 convolution masks for X and Y direction respectively:

\[
\begin{pmatrix}
-1 & 0 & 1 \\
-1 & 0 & 1 \\
-1 & 0 & 1 \\
\end{pmatrix}
\quad \begin{pmatrix}
1 & 1 & 1 \\
0 & 0 & 0 \\
-1 & -1 & -1 \\
\end{pmatrix}
\]

Fig. 2: Prewitt [1]

2.1.3 Roberts Operator

This operator finds the edge magnitude and direction with the help of following 2x2 convolution mask for X and Y direction respectively:

\[
\begin{pmatrix}
1 & 0 \\
0 & -1 \\
\end{pmatrix}
\quad \begin{pmatrix}
0 & +1 \\
-1 & 0 \\
\end{pmatrix}
\]

Fig. 3: Roberts [1]

Here are some of the advantages and disadvantages of Gradient based Edge Detectors [5]:

\textbf{Advantages:}
1. Simple
2. Detection of edges and their orientations

\textbf{Disadvantages:}
1. Sensitive to noise
2. Inaccurate

2.2 Laplacian of Gaussian(LoG)

This was invented by Marr and Hildreth (1980) who combined Gaussian filtering with the Laplacian [8].

\[ \nabla^2 f = (\partial^2 f / \partial x^2) + (\partial^2 f / \partial y^2) \] \hspace{1cm} \text{(2)}

Fig. 4: Laplacian of Gaussian [1]

Here are some of the advantages and disadvantages of LoG Edge Detector [5]:

\textbf{Advantages:}
1. Finding the correct places of edges
2. Testing wider area around the pixel

\textbf{Disadvantages:}
1. Malfunctioning at corners, curves and where the gray level intensity function varies
2. Not finding the orientation of edge because of using the Laplacian filter
2.3 Gaussian Edge Detector (Canny)

The steps for Canny Edge Detector are as follows:

1. The first step in this detector is to filter out noise in the image by using a Gaussian smoothing filter.
2. The second step in this edge detector is to locate the edge strength in the smoothed image by computing the image gradient, which helps to indicate where the actual edge is located.
3. The last step is to thin down the edges by tracking along the edge in the edge direction and set any pixel that is not at the maximum to be 0, which is called non-maximum suppression. And finally edges are detected and link using pixel connectivity and double thresholding that is, if the magnitude is above the high threshold, it is considered as an edge. If the magnitude is below the low threshold, it is considered as a non-edge. This edge detector has the advantage that maximum edges get detected by using this edge detector [10].

Here are some of the advantages and disadvantages of Gaussian based Edge Detector (Canny)[5]:

**Advantages:**
1) Better detection specially in noise conditions
2) Localization and response
3) Improving signal to noise ratio

**Disadvantages:**
1) Complex Computations
2) Time consuming

3. SOFT COMPUTING BASED APPROACHES

3.1 Fuzzy Logic Based Edge Detection

Fuzzy image processing has three main stages: image fuzzification, modification of membership values, and, if necessary, image defuzzification. The fuzzification and defuzzification steps are due to the fact that we do not possess fuzzy hardware. Therefore, the coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step (modification of membership values).

After the image data are transformed from gray-level plane to the membership plane (fuzzification), appropriate fuzzy techniques modify the membership values. This can be a fuzzy clustering, a fuzzy rule-based approach, a fuzzy integration approach and so on [2].

A.A. Alshennawy et. al.[2] have proposed a new method based on fuzzy logic reasoning for edge detection in digital images without determining the threshold value. The proposed method begins by segmenting the images into regions using floating 3x3 binary matrix. A direct fuzzy inference system mapped a distinct range of values in the floating matrix to detect the edge by using 8 proposed rules.

3.2 Neural Network Based Edge Detection

Neural networks are nothing but the computer algorithms contend with how the way the information is processed in nervous system. Neural network diversifies from other artificial intelligence technique by means of the learning capacity. Generally, the neural network consists of three layers such as input layer, hidden layer and output layer each layer consists of fixed number of neurons equal to the number of pixels in the image. The activation function of neuron is
a multisigmoid. The major advantage of this technique is that, it does not require a priori information of the image. The number of objects in the image is found out automatically [7].

Hamed Mehrara et al., [3] have proposed a new edge detection technique based on the BP neural network. They classified the edge patterns of binary images into 16 possible types of visual patterns. In the following, after training the pre-defined edge patterns, the BP neural network is applied to correspond any type of edges with its related visual pattern.

3.3 Neuro-Fuzzy Based Edge Detection

In the last few years, the image edge detection based on the neural networks and fuzzy logic systems have attracted attention of many researchers. This is due mainly to the fact that Neuro-Fuzzy (NF) systems are very suitable tools to deal with uncertainty encountered in the process of extracting useful information from images since NF systems combine the ability of neural networks to learn from examples and the capability of fuzzy logic systems to model the uncertainty and imprecision. Hence, NF systems may be employed as powerful tools for edge detection provided that appropriate network topologies and training strategies are chosen [4].

Lei Zhang et al., [4] have presented a novel adaptive neuro-fuzzy inference system (ANFIS) for edge detection in digital images. The internal parameters of the proposed ANFIS edge detector are optimized by training using very simple artificial images. The edges are directly determined by ANFIS network.

4. CONCLUSION

This paper mainly focuses on the study of traditional edge detection techniques and soft computing based approaches for edge detection. As mentioned earlier there are few disadvantages of traditional edge detectors. So the soft computing based approaches are fuzzy logic based approach, Neural Network based approach and Neuro-Fuzzy based approaches for edge detection are discussed in this paper. Fuzzy logic based edge detection is a tiring process because there is a problem of finding membership function and their corresponding values. Neural Network based edge detection also has difficulty in determining the number of layers and number of neurons. So it has been concluded that Neuro-fuzzy based approach is considered to be the best method for detecting edges, because NF (Neuro-Fuzzy) systems combine the ability of neural networks to learn from examples and the capability of fuzzy logic systems to model the uncertainty and imprecision.

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