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Image Edge Orientation Estimation via Fuzzy Logic

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Abstract

This paper proposes a novel image edge orientation estimation using fuzzy logic approach. The idea behind orientation estimation is to design edge directed image interpolation for image super resolution enhancement. The calculation of image edge pixel orientation is based on different types of gradients measured across different angles from particular edge pixel. Orientation of edge pixel is classified in to nine angles to ensure the quality of orientation estimation. The advantage of proposed fuzzy based method is that, orientation calculation is done in human language with the help of simple fuzzy rules. Use of simple membership function and rules helps to design an efficient orientation estimation frame work. The experimental results show that fuzzy based orientation estimation outperforms even if the image is affected by noise.

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Keywords: fuzzy logic; image interpolation; orientation estimation; pixel gradients

1. Introduction

Edge is one of the prominent image feature that help in human perception and computer vision applications such as feature extraction, pattern recognition, image segmentation, and texture and edge analysis. Nowadays, super resolution enhancement is becoming a challenging area of image processing which requires detailed analysis on edge pixel. Image pixel characteristics such as edge, texture and orientation must be identified properly to design different image resolution enhancement algorithms. This work proposes to design an edge based orientation estimation approach in fuzzy domain which has the ability to map uncertainty. There are enormous image edge and line detection methods proposed by researchers in the field of image processing [1]-[3]. Since edge pixel is defined on the basis of pixel illumination variation, compared to its neighbouring pixels, one simple way to identify edge

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pixel is through pixel gradients. In this paper we propose to use the idea of finding maximum gradient from a set of gradients calculated in different directions to detect edge pixels. Orientation is calculated from these edges using fuzzy inference frame work.

There are different types of edge detectors available which are sensitive to certain types of edges. We have considered only few of them. In [4]-[9] different gradient based edge detection methods such as Robert, Sobel, Prewitt and Canny is discussed to have an idea on existing techniques. The simple and quick cross gradient operator, Robert, is designed to detect edges running 45º to the pixel grid. Whereas, Sobel [5] and Prewitt operators help to identify horizontal and vertical edge line, in which later is highly sensitive to noise. Canny [8] and [9] edge operator performs even better and known as optimum edge detector. But it is computationally more expensive compared other gradient approach. In addition, the performance of canny edge operator can be improved even better by thresholding but it tries to exhibits hysteresis. Furthermore, Gaussian based Laplacian operator even outperforms but is sensitive to noise. A comparative study on different edge detection method [10] states that all these methods are limited by precision.

Many of these edge detection methods can be used for orientation estimation too. But only precise edge detection leads to accurate orientation estimation. The usual way of finding orientation is from horizontal and vertical edge gradients as illustrated below:

$$\theta = \tan^{-1}\left(\frac{Gy}{Gx}\right) \tag{1}$$

Where, Gx and Gy are the horizontal and vertical pixel gradients mentioned in the edge detection operation. Most of the orientation estimation technique is designed on spatial domain. In [11], a spatial domain approach, gradients are generated by applying Gaussian orientation filter separately on both coherence and angle image obtained from texture image. Bigun *et al*. in [12] proposed a frequency domain approach of least square estimation based orientation estimation. Double orientation estimation frame work is introduced in [13]. In [14], to divide image gradients, a clustering based approach is employed. PCA based approach along with SVD is proposed in [15]. All these methods fail if the image is affected by noise. In addition, it is a common practice to use fuzzy logic based design methodology if the system is affected by noise.

An image is said to uncertain if it is affected by any kind of noise. It is necessary to identify these uncertainties properly to design an efficient processing algorithm. The well known uncertainty mapping tool available is the fuzzy inference logic system [16]. The main advantage of using fuzzy based approach is the ability to design a system in human language using simple mathematical descriptions.

The motivation of proposed work is to use fuzzy logic technique in the field of image processing for image edge orientation estimation. Furthermore, orientation can be defined clearly, linguistically (using human language), using fuzzy inference technique rather than mathematically. The use of human kind language and simple rule help to design an efficient algorithm for orientation estimation. To implement the idea of proposed method, orientation is classified in to nine different angles, represented using nine membership functions in fuzzy domain that helps to improve accuracy of designed system. The experimental results show that the use of fuzzy based gradient approach performs better than both spatial and frequency domain approaches even the system is affected by noise.

The rest of the paper is organized as follows. Section 2 describes existing edge detection methods. The concept of fuzzy based orientation estimation method is presented in Section 3. Section 4 gives description on experimental results and conclusion is drawn in Section 5.

2. Edge detection methods

This section describes existing and fuzzy inference based edge detection methods. It should be noted that orientation is calculated only for identified edge pixels. So the first step is to apply an edge detection method that leads to orientation estimation.

Edge detection is a critical step in orientation estimation because; the inaccurate detection may lead to design inefficient orientation estimation algorithm. A pixel is identified as *edge* if the difference in intensities between