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Development of autofocusing algorithm based on fuzzy transforms

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Abstract

In this paper, we propose a new passive auto focusing algorithm to acquire images with enhanced quality through a digital camera. The focus measure operations play a key role in a passive auto focusing method. The proposed focus measure operation is based on a localized version of image variance method. The localization of the image variance focus measure operation can be implemented with the use of fuzzy partition and Fuzzy Transform. In order to validate our approach, experimental comparative studies are conducted on test images with the use of different focus measure operators. The selected operators have been chosen from an extensive review of the state-of-the-art approaches. A comparative analysis demonstrates that the proposed algorithm is superior to the conventional methods.

Keywords: Passive auto focusing algorithm; Fuzzy transforms; Conditional fuzzy C-means clustering; Fuzzy C-means clustering

1. Introduction

With the rapid development of digital image processing techniques, they are widely available to provide an easy way to produce high quality imaging with minimal user intervention in tasks such as autofocusing. The basic idea of autofocus is to enable automatic adjustment of the lens of the camera to the right position, ensuring the image is well positioned at the focal plane. Autofocus is a key factor affecting the sharpness of a final captured image. It is based on the fact that an object on the image appears the sharpest when it is in focus. Otherwise, image will be blurry in an out-of-focus position. Thus the highest quality imaging depends on how the lens is adjusted by camera's autofocus system to bring an image into focus where sharpness is maximized.

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Autofocus mechanisms are divided into two categories: active autofocus and passive autofocus [1,2,11]. In general, in case of an active autofocus method, additional equipment is needed to measure the distance between an image sensor and a target object. These additional devices emit an ultrasonic wave or laser light and receive the reflective signal. The distance between an emitting device and the target object is calculated by determining the difference between emission time and the time the signal has been received. This kind of autofocus mechanism is not preferred as additional devices increase the production cost and take up more space [3]. Therefore most consumer-level digital cameras deploy a passive autofocus. Passive autofocus mechanisms require focus measure operations to evaluate the quality of an acquired image through an image sensor.

Various types of focus measure operations have been proposed to enhance the quality of an image. Especially, the passive auto-focusing mechanisms based on contrast or sharpness of images are more popular due to their simplicity [1].

For image variance focus measure operation, the output value of the focus measure operation is the variance of the entire collection of image intensities. We propose the localized version of the image variance focus measure operation by using Fuzzy Partition Techniques [10] and Fuzzy Transform [9]. Nowadays, Fuzzy Transform has been used in various fields such as image processing [12,13], and data analysis [14–16].

In the proposed focus measure approach, we are not interested in the intensities of all pixels but our interest is in the intensities determined over the sub-space defined by using fuzzy partition techniques such as Fuzzy C-means clustering and conditional Fuzzy C-means clustering technique. For each sub-space, the local mean value is calculated in the form of a weighted sum. In the following test the local variance is obtained by determining the sum of square of the difference between intensities and local mean value.

We use the obtained local variance to evaluate the quality of the acquired image. The higher the obtained local variance is, the higher the quality of an image becomes. In order to evaluate the proposed autofocus operation, we apply the proposed operation to various images.

2. Passive auto focusing algorithms

Passive auto focusing technique uses the image processing algorithm to measure the sharpness of the image acquired through a camera [3]. Several focus measuring operators have been proposed in the literature to assess the degree of focus of either an entire image or a part of it. A brief description of each family is presented in this section.

2.1. *Tenenbaum gradient [4,5]*

It is a representative focus measure operator of derivative-based focus measure operators. This focus measure operator realizes a convolution of an image using Sobel operators, and then implements a summation of the square of the gradient vector components.

$$F_{TG} = \sum_{y=1}^{H}\sum_{x=1}^{W}\left[\left(I_{S_x}(x,y)\right)^2 + \left(I_{S_y}(x,y)\right)^2\right] \tag{1a}$$

$$I_{S_x}(x,y) = \sum_{s=-1}^{1}\sum_{t=-1}^{1} S_x(s,t)\cdot P(x+s, y+t) \tag{1b}$$

$$I_{S_y}(x,y) = \sum_{s=-1}^{1}\sum_{t=-1}^{1} S_y(s,t)\cdot P(x+s, y+t) \tag{1c}$$

where H and W denote the height and the width of an image, respectively and $I_{S_x}(x,y)$ and $I_{S_y}(x,y)$ represent the images resulting from convolution with the Sobel operator. Sobel operators such as S_x and S_y are described as follows. These operators are considered as discrete differentiation operators which approximate the gradient of the image intensity function.

$$S_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, \qquad S_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \tag{2}$$