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Automatic focus and fusion image algorithm using nonlinear correlation: Image quality evaluation

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ABSTRACT

We propose a new autofocus and fusion algorithm to enhance the characteristics of the image in less run-time. The autofocus method selects the best-focused image (BFI) in a stack of images captured at different distances from the object. A vector is defined for each image in the stack, which contains elements selected by spiral scanning of the image. The spectrum of each vector is calculated using the Fourier transform then applying non-linear correlation to the reference vector spectrum and those of each of the corresponding to the images in the stack the BFI is determined. The fusion is carried out with a subset of images that have a focus measure value close to the BFI ones. The parabolic filter is applied to determine the relevant elements of the images that will be included in the fusion. The results evaluation is conducted using a multi-image metric, a quality measure that represents the percentage improvement of the fused image. The comparison was made with other fusion methods such as standard wavelets, resulting in that the autofocus and fusion algorithm (AFA) method obtained the highest quality indices. It is concluded that the AFA improves the quality of the images in less time than the conventional fusion methods.

1. Introduction

Today, most imaging systems have automatic focus and fusion functions that minimize manual processes for obtaining high-quality images. Autofocus allows obtaining the best focal plane of an object or scene automatically. Fusion consists of taking the most characteristic visual features in different focal planes and merging them into a single image of higher quality. Both techniques play an essential role in digital image processing. The aim is to obtain a high-quality image that enhances the main features of the image object for further analysis, identification, or classification.

Most autofocus and fusion functions provide quality images, but this quality can be improved as well as the runtime. Most of the algorithms include only two pictures for fusion; in this work, a quality image obtained was enhanced by comprising more than two images for the fusion, achieving to fuse at less eight images in less time than are fused two by other methods. In this work, we propose an autofocus and fusion algorithm (AFA). The algorithm implements Fourier transform and non-linear correlation to find a best-focused image, as well as applies a parabolic filter to select the significant features of each picture.

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AFA also, improves the data acquisition from the image, using a spiral scanning of the picture, that is, only pixels that pass through the coordinates of the spiral path are included in the vector taking enough information in the sample to process the autofocus, and allowing the processing of data in an optimal time.

This paper begins with a brief overview of the central concepts used in the algorithm such as autofocus, fusion, and image quality assessment in Section 2. Section 3 presents a description of the process and methodology. An evaluation and comparison of the results are in Section 4. Finally, we conclude the paper in Section 5.

2. Background

2.1. Autofocus

Autofocus refers to the ability of a camera or optical system to focus automatically. Focusing aims is to find the best focal plane of an image by either classical or automated method. Autofocus methods may be active, passive or hybrid. A classic dynamic system emits sound or light waves (ultrasound, microwaves, infrared) to detect the distance of the subject from the camera. Typical active systems that use infrared systems might use a variety of techniques to judge the distance as triangulation, the amount of infrared light reflected from the subject or lapse of time. Passive autofocusing can be achieved by phase detection or contrast measurement. Phase detection is based on the triangulation of the subject distance, by using two sensors that evaluate the light passing through two end sides of the lens through the same objective. The length is determined by the difference in the images captured by both sensors.

To compute the contrast of the image, this is analyzed comparing the values from each element in a pixel strip provided by the charge-coupled device (CCD). Algorithms that automatically control these processes are based on various theoretical aspects of traditional auto-focus, some of the different search strategies to find the maximum focus is based on a Fibonacci search or a "coarse to fine" search. There are various methods for measuring focus; some revisions and comparisons can be found in [1–5] and more recently [6–8]. Some of the new investigations in autofocus and image fusion develop systems for remote viewing, using microwave or radar imaging, to merge different signals to form a sharp image [9,10].

In this work ten different standard autofocus methods were analyzed, energy of Laplacian [1,11], Tenengrad [2,11], absolute Tenengrad [3], variance [4], normalized variance [4,11], Vollath's F4 [12], Vollath's F5 [12], Gaussian filter [13], Logarithmic histogram [14] and Multi-focus fusion algorithm based on Fourier Transform and Pearson's Correlation [15]; they are briefly described below.

2.1.1. Energy of Laplacian

This model makes use of the discrete convolution of the image with the Laplace mask [1,11]. The following equation writes it

$$F_L = \sum_{i,j} \left[g(i-1,j) + g(i+1,j) + g(i,j-1) + g(i,j+1) - 4g(i,j) \right]^2, \tag{1}$$

where $g(i,j)$ is the gray level at a pixel (i,j) on the image g.

2.1.2. Tenengrad

The algorithm convolves an image with Sobel operators and sums the square of all magnitudes greater than a threshold [2,11]. The convolution mask is given by

$$S = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, S' = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}, \tag{2}$$

where S is the convolution mask Sobel and S' its respective transposed, the Tenengrad measurement function F_T is provided by

$$F_T = \sum_{i,j} \left[g(i,j) \otimes S \right]^2 + \left[g(i,j) \otimes S' \right]^2, \tag{3}$$

where $\otimes$ represents convolution operator.

2.1.3. Absolute tenengrad

This measurement function is similar to the above, but in this case, the absolute values of gradient coefficients are taken to reduce the computational cost [3]. The full Tenengrad function F_{AT} is given by

$$F_{AT} = \sum_{i,j} \left[g(i,j) \otimes S \right] + \left[g(i,j) \otimes S' \right]. \tag{4}$$