Study on Definition Evaluation Function Based on Image Contrast Variation

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Abstract: - The definition evaluation function of digital image plays a key role in the auto-focus technology based on image, and it not only determines the auto-focus validity of a whole system, but its algorithm determines the real time characteristic of the whole hardware. This paper analyses the imaging principle, and brings forward that the focusing characteristic curves should meet no-bias, single peak, high defocusing sensitivity, enough signal-to-noise ratio and little calculation quantity. In the paper the preprocessing methods of CMOS image are discussed, the evaluation method based on the image contrast variation is presented in accordance with the existing problems of common image definition functions. From the result of emulation experiments, the focusing curves of the definition evaluation function based on contrast variation are good in focusing characteristics, strong in anti-jamming ability and excellent in real time.

Key-Words: - image, auto-focus, definition, evaluation function, CMOS, contrast variation

1 Introduction

Auto-focusing is a broad domain. After development of several decades, many focusing methods appear. Compared to manual focusing, auto-focusing has higher precision, higher efficiency, better real time characteristic, but its structure is more complex and its cost is more enormous. The auto-focusing method based on image processing judges basically the imaging quality by whether imaging is an ideal imaging position. Compared to the defocus image, the focus image has more information and details. By the principle, the imaging system collects a series of digital images from camera lens and CMOS (CCD) sensors and processes every frame image in real time, at the same time judges whether focusing is correct and imaging is clear, then emits a feedback signal to control the movement of the camera lens until collected images accord with the request. The method not only improves focus precision, but also decreases the request for machining and assembling an imaging system. Hence, now it becomes an important aspect of studies on the auto-focusing technology.

The definition function plays an important role in the auto-focusing technology based on image, and it not only determines the auto-focus validity of a whole system, but its algorithm determines the real time characteristic of the whole hardware. The scholars at home and abroad have regarded the recognition technology based on image definition in several years, have done lots of researches and experiments on the method, and have gained definite success. This paper brings forward a definition evaluation function based on image contrast variation according to existing problems in the common evaluation methods of image definition. The studying results show that the focusing curves of the definition evaluation function based on contrast variation are good in focusing characteristics, strong in anti-jamming ability and excellent in real time.

2 Focusing Characteristic Curve

From the Newton imaging equation xx'=ff', it can be seen that when the object focus f and the imaging focus f' of an optical system is fixed, there is the hyperbolic relation between an object distance x and an imaging distance x' and they correspond one by one, which is called the conjugate relation of object and imaging. When the absolute value of x increases, the absolute value of x' will be decreases, vice versa. When an object distance is changed, and the new conjugate relation between object and imaging is constituted, the focus of the optical system must be adjusted, which is called focusing. At this time a focusing criterion is needed to judge whether to meet the conjugate relation between object and image. The optical imaging principle is as follows.

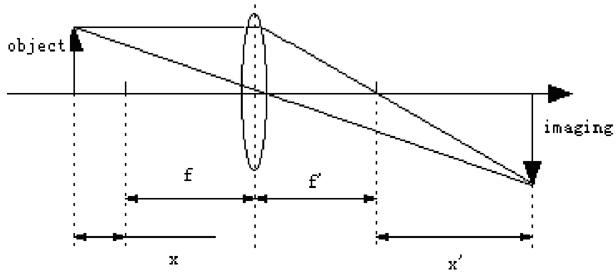


Fig.1 The graph of optical imaging

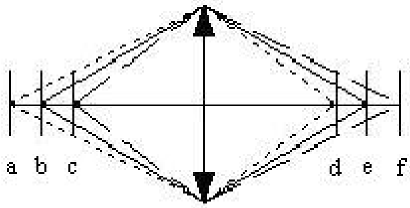


Fig.2 Relation between object and image in optical system

From the imaging equation, various object imaging can be educed. In Figure 2, b and e are the conjugate surfaces of object and imaging under the real imaging, the sensitization surface is on Surface e, an object on Surface a, images on Surface d. An object is on Surface c, images on Surface f. The object's image on Surface e is a dispersion circle. At the same reason, the image of Surface a on Surface e is also a dispersion circle. So the object that is not on b Surface b images on Surface e, the image is the convolution of the dispersion circle that is formed on Surface e by every point of the object. That makes the image blurred. Hence the quantitative token of image definition should be searched from image for a focusing criterion. By careful analysis, it can be known that in the imaging process, the b and e imaging couple is the clearest state. However, if deviating Position b towards the right or the left, clearer image can be not obtained on a sensitization surface and the blurred degree is increased with increase of deviation. So the focusing curve of an imaging system can be got qualitatively as shown in Fig.3.

It can be known by further analysis that focusing evaluation curves should have the following important characteristics.

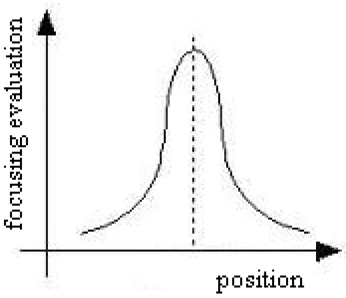


Fig.3 Focusing characteristics

①no-bias
②single peak
③high defocusing sensitivity
④high signal-to-noise ratio
⑤little calculation

3 CMOS Image Pretreatment

Image pretreatment consists chiefly of data format transform, the removal of noise and ray disturbance, and image transform from color space to gray space. The flow chart is shown in Fig.4.

① Transforming data format: Digital image has various file formats. Sampling and quantifying can also make bits of image data different. Image format and bit are important to image processing. By the data transform, data quantity of image procession is decreased and real time character will be strengthened.

② Transforming color space: The output signals of COMS image sensors are RGB format in color space. During analyzing definition, gray signals are used practically, the calculation quantity of which will be decreased and the real time character of focusing systems will be stronger. So the data transform from color space to gray space is needed.

③ Removing noise: Some noise may be produced after COMS sensors transform ray signal into electronic signal. The noise comes generally from imaging system's devices. At the same time the sequent procession will import some noise, such as positive noise, multiple noise. The noise makes images to have lower contrast, dimmer edge and worse definition, so it affects image definition evaluation finally. For improving the signal-to-noise ratio of an imaging system and decreasing noise, the relevant methods of removing noise will be used according to different noise characters. The methods of removing noise have the neighborhood mean filter, the median filter and the homomorphic filter.

④ Removing ray disturbance: Ray will affect shooting process. The imaging effect is bad when COMS sensors are used in dark environment. Hence under the condition, gray value emendation is needed to improve image contrast and remove ray disturbance. The linear transform or subsection linear transform of gray values can be used for images equilibrium.

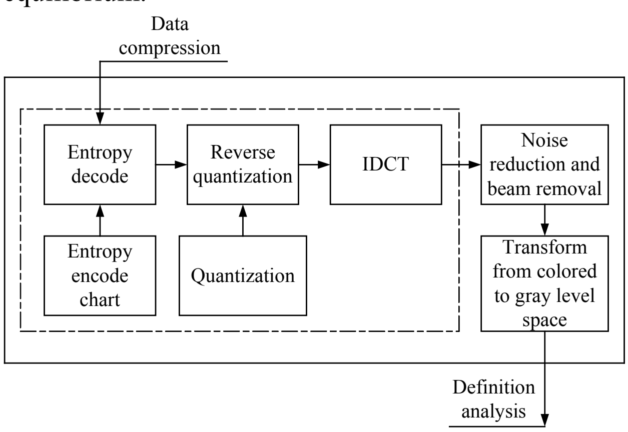


Fig.4 The flow chart of image pretreatment

4 Contrast Variation Method

Now, the usual focusing evaluation methods have image energy entropy method, image gray variance method and image gray grads method. The image energy entropy method and image gray variance method are only fit to judging specific images, such as a medicinal image and an image with simple texture. Commonly, the evaluation effect is very bad and calculation quantity is enormous for complicated images so that the response to focusing is not good. The calculation quantity for image gray grads method is small, but sometimes there are partial peaks because of noise disturbance, which makes easily focusing search to be immersed in partial peak values and results in misfocus phenomena. This paper brings forward a method between the two methods, which gives consideration to focus precision and response speed.

The sampled image is divided into a few of focus areas, as shown in Fig.5.

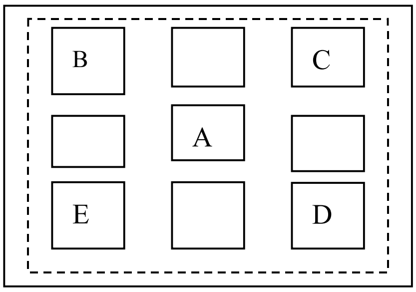


Fig.5 Focusing areas

$n \times n$ pixels are chosen in every area, marked as W. In the area W ($n \times n$), array distribution is as follow.

$$\begin{matrix} f(0,0) & \cdots\cdots\cdots & f(0,n-1) \\ \cdots\cdots\cdots & f(x,y) & \cdots\cdots\cdots \\ f(n-1,0) & \cdots\cdots\cdots & f(n-1,n-1) \end{matrix}$$

Fig.6 Array in focusing area

The gray value on every image point of an object is different, the gray value of Point (x,y) is $f(x,y)$. The relative contrast variation for $f(0,0)$, ······, $f(n-1,n-1)$ is expressed as

$$f_{(x,y)} = \frac{|\, f(x,y) - \overline{f}\,|}{f(x,y)} \quad (x,y) \in W \tag{1}$$

The value of $\overline{f}$ is the gray mean value of the same four $n \times n$ neighborhoods in the area W. Its expression is as follows.

$$\overline{f} = \sum_{(x,y)\in B,C,D,E} f(x,y) \Big/ 4 \times n \times n \tag{2}$$

The sum of their variety rates can be calculated for every gray value of the area A (16×16) in Fig.5, as shown in the next expression.

$$F_k = \sum_{(x,y)\in A} f_{(x,y)} = \sum_{(x,y)\in A} \frac{|\, f(x,y) - \overline{f}\,|}{f(x,y)} \tag{3}$$

It is called the whole summation of image contrast variety. When image is clear, the variety rate among image pixels is high and the value of F_k is maximal. When image is blurred, the variety rate among image pixels is low and the value of F_k is smaller. In the simulation experiment, $f(x,y)$ is calculated for all pixels of a 16×16 area and every image has 256 values of $f(x,y)$. F_k is gained by summing all values. The corresponding F_k value is big for clear image. On the contrary, its value is small. Whether image is clear can be judged by the F_k value.

5 Simulation Analysis

During the simulation calculation procession of image auto-focusing, F_k expresses an image definition function. For 50 pieces of image arranged in a defocus → focus → defocus order, the F_k value is calculated. While the image is clearer, the F_k value is bigger. When the F_k value is maximal, the image is in a correct focusing position.

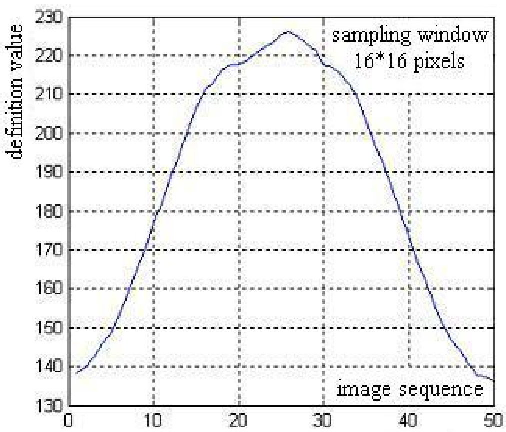
By calculation and simulation for many images, a 16×16 rectangular image area is chosen for calculation. The image definition values are gained in Figure 7 and the focusing curves is also gained in Figure 8.

From Figure 8, it can be seen that when a sampling window is 16×16 pixels, an ideal focusing curve can be gained. But near the focusing area, the variety rate of definition is very low, which is unfavorable for finishing search rapidly and correctly. So the sampling area should be enlarged. When the area is 32×32 pixels, the focusing curve has the character of signal peak and no-bias. The time complexity for computing an image by the evaluation function based on image contrast variety is $T(n) = O^2(n)$.

The comparison of the definition functions based on gray contrast variety, gray variance and Laplacian neighborhood is shown in Fig.9. The same degree of spiced salt noise is added to test and evaluate the capability for resisting noise disturbance in Fig.9. It can be seen from Figure 9 that the definition evaluation method based on gray contrast variety is better than the one based on gray variance as a whole, the monotony of its curve is good and its descendant direction is not obvious, compared to Laplacian neighborhood method, but it keeps the monotony character and is not sensitive to noise, has no phenomenon of partial peaks. These will be in favor of searching rapidly and steadily. The mean $\overline{f}$ is used in equation (3), which will eliminates the aberrance phenomenon of image definition produced by high frequent noise.

138.40	139.67	142.56	145.74	148.61
153.27	159.03	164.62	170.47	176.82
182.56	188.73	193.91	200.67	206.13
211.15	212.94	216.09	217.74	217.49
218.49	220.56	221.97	223.32	225.34
226.13	224.56	222.88	221.22	217.46
216.93	215.26	212.31	209.03	202.68
197.29	191.69	185.92	180.01	173.40
167.41	161.67	155.91	150.62	146.90
143.95	140.60	137.69	137.15	136.45

Fig.7 Emulation data of image contrast variety



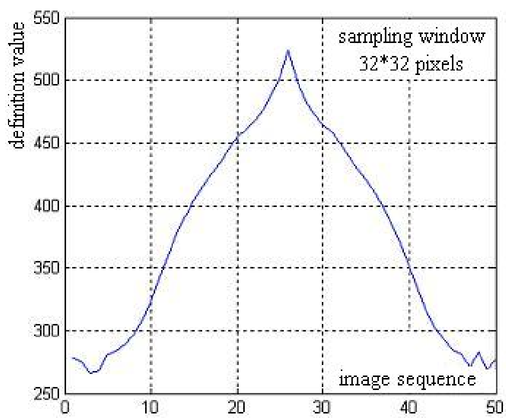
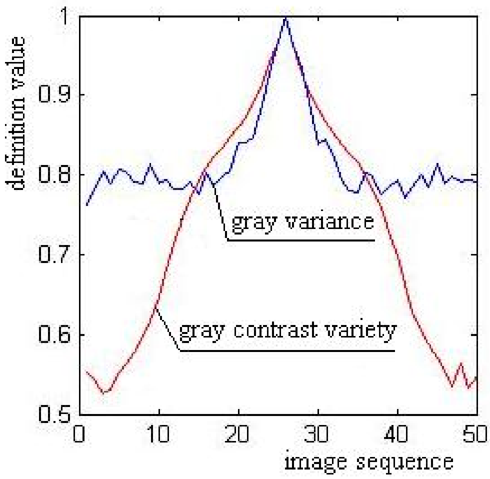


Fig.8 Focusing curves of 16×16 and 32×32 sampling windows



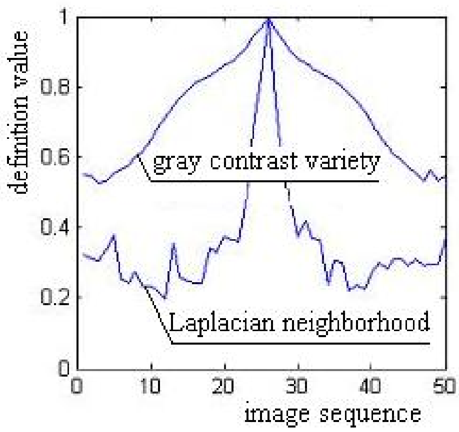


Fig.9 Comparative curves of image contrast variety

6 Conclusion

(1) The focusing curve of image definition function based on contrast variety has a single peak. It has only an obvious single peak, besides a few of false peaks produced by little noise. The corresponding image to the point is the clearest, that is to say that the position is a correct focus point.

(2) The varying trend of the definition function curve based on image contrast variety is obvious and the curve can keep ascending or descending monotonously beside a peak point. The character is favorable for searching rapidly and correctly and can also improve the real time and reliable capability of the whole system.

Acknowledgements:

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