Autofocus Technologies in Digital Cameras: A Comparative Study

[1]Sumon Dey, [2]Ratnakirti Roy

[1]Department of Computer Applications, Inspiria Knowledge Campus, Siliguri, India.

{sumon.d, ratnakirti.r}@inspiria.edu.in

Abstract - Autofocus technologies have been one of the most important breakthrough achieved in the recent times in the field of digital cameras and digital image processing. Of the many algorithms that exist for the autofocus and object detection in digital cameras, contrast detection and phase detection provide the most reliable results and are hence widely used. However, autofocus technologies are still evolving for better and there exist scopes for development of more efficient and optimal algorithms for scene object detection thereby facilitating the generation of more advanced auto focussing techniques. This paper aims to provide a comparative analysis of the most prevalent auto focus technologies used industrially and commercially with an aim towards further research into development of better object detection and focussing algorithms for digital cameras.

Keywords: Digital image processing, autofocus techniques, contrast detection, phase detection

I. INTRODUCTION

Autofocus technologies are one of the most important breakthroughs in the arena of digital photography and as well as digital image processing. Providing versatility and ease of use, autofocus technologies have put photography on digital cameras to new dimension. However, in the state of the art, there are different focusing systems for digital autofocus in digital cameras. Depending on the camera type, two major classes of autofocus technologies used are contrast detection autofocus and phase detection autofocus or hybrid autofocus is used. In compact cameras, the contrast autofocus is used to ensure proper sharpness. Digital cameras use phase detection or contrast detection autofocus depending on whether the photography is done by using the viewfinder ar the Live-View-Mode (LVM) (Gutierrez et al., 2007). Viewfinder is a device that allows the targeting of a subject. Cameras differentiate between optical, electronic, hybrid and rangefinders. Whereas, for observing the picture or subject, digital cameras offer a Live-View-Mode compared to the optical viewfinder. If the Live-View-Mode is activated, then the subject can be viewed over the camera monitor. To display the image, the incoming light information hitting the sensor is transmitted in real-time to the monitor, so that the light information can pass through the sensor, the mirror is set-up and the shutter is opened. Thus the viewfinder stays dark, while the light is directed to the sensor. In case of an exposure, the shutter will be first closed, so it can open and close again while taking the picture. In comparison to a viewfinder, settings such as filters or a colour effect are directly displayed in the Live-View-Mode. While using a Live-View-Mode with a Digital SLR, the mirror is tilted up, due to which light does not pass to the autofocus module of the phase autofocus system (Śliwiński et al., 2013).

The paper aims to present a detailed comparative study of the contrast and phase detection autofocus technologies with a quest of figuring out possibilities of developing better algorithms for real time object detection and focussing systems for digital cameras.

II. AUTOFOCUSING TECHNIQUES

The basic flow of autofocusing is shown by the following figure. Initially, image is captured by image sensor from light, which is received by the lens from object and then some basic image processing is carried out. The Autofocusing (AF) algorithm is processed on the captured image by the image sensor and decision of movement is given to driver circuit. This decision makes AF actuator to move towards the decided direction moving lens towards focus (Roman et al., 2010).

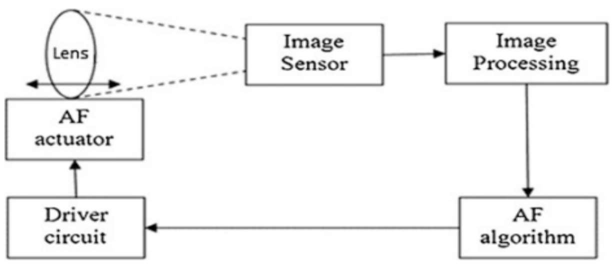


Fig-1

Active Autofocusing

 DOI : 10.18231/2454-9150.2018.0924

Active AF systems identify distance to the image object independently of the optical system and then adjust the optical system to correct the focus of system. The active focusing can also be known as a technique in which a light source is made to be incident on the object and the based on the light reflected by the object, the picture is taken. The more the amount of light reflected, the better the picture quality is. Based on the reflection adjustment of lens can be done (Liao et al., 2003). Distance can be measured using various techniques including ultrasonic sound waves and infrared light.

Passive Autofocusing

In Passive AF systems, correct focus is determined by performing passive analysis of the image that is entering the imaging system. They generally do not direct any energy, such as ultrasonic sound or infrared light waves, as in active autofocusing system toward the subject. Study suggests that Passive autofocus must have light and image contrast in order to do its job. The image needs to have some detail in it that provides contrast. Passive autofocusing can be achieved by contrast measurement or phase detection.

- **Contrast Detection Autofocus**

Compact digital cameras use a contrast detection autofocus system for automatic focusing. The system first analyses the contrast of the image sensor for different focal positions and thereby looks for the point at which the maximum contrast can be found. When it is found, the optical system is adjusted accordingly and the image can be captured sharply. There are some particular steps while an image is to be captured using the contrast detection autofocus.

When shooting a subject, light enters through the lens onto the sensor. This sensor image's contrast is then analyzed by the autofocus Naoto Nakahara, Saitama (JP) system. One value is not sufficient, because only with comparative values can the maximum contrast be determined. According to that, the focus system determines the contrast for further focus positions. Because it is not clear in which direction the optimal distance setting is present on the lens, a direction is tried blindly.


Fig-2

As long as the measured contrast increases, the direction is maintained. If a lower contrast is detected, the AF-system proceeds in the opposite direction based on an algorithm. This determination takes place until the maximum value is found. This process takes a little more time, however it ensures a more precise result accordingly and consequently. The more contrast the subject has the better the contrast autofocus system can work. If an object has little contrast, the search for the maximum value becomes more difficult. Therefore, the autofocus system could behave cumbersomely with low contrast scenes or low light conditions and may lead to focusing errors.

The following is the graphical representation for finding the maximum contrast when the contrast detection autofocus is taken into consideration.

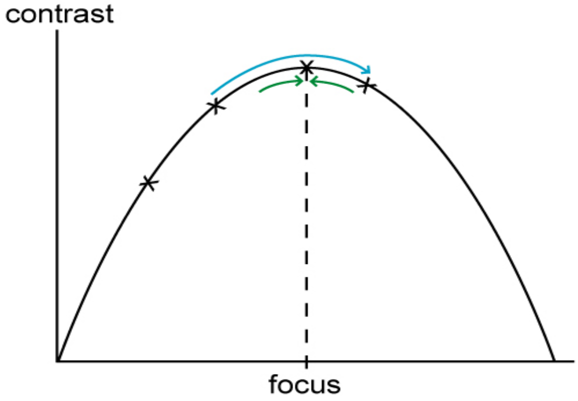


Fig-3

The contrast detection autofocus system includes algorithms based on an image histogram or its gradient analysis. It does not require any additional equipment and hence can be implemented in virtually all digital cameras. Its well-known issue, however, is that a single image does not provide information about either:

- the distance between the sensor and the image plane, or
- the direction toward the sensor should be shifted in order to attain a focused image,

and subsequently contrast detection algorithms seek the focus iteratively, in the back-and-forth manner (shifting the lens accordingly), and require capturing an image in each position determined by the algorithm. The contrast detection autofocus algorithms are usually derivatives of the stochastic approximation routines (like e.g. the golden-section search (if a noise is negligible) or the Kiefer-Wolfowitz algorithm (if the noise impact cannot be ignored) (Kiefer et al. 1953, Kushner et al., 2003). In consequence, they are rather slow and not directly applicable in e.g. object tracking or video applications.

- **Phase Detection Autofocus**

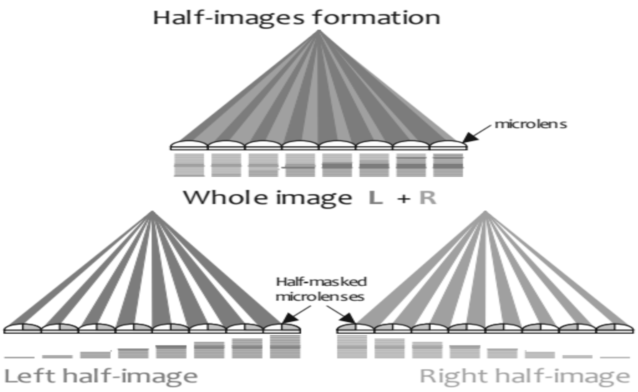
In order to overcome these deficiencies in contrast detection autofocus system, phase-detection autofocus system is used. In comparison to the contrast detection autofocus system, the phase detection autofocus system knows exactly in which direction settings need to be changed. Consequently , this approach saves time and the system works faster as compared to the contrast detection

 DOI : 10.18231/2454-9150.2018.0924

autofocus system. Phase detection system is predominantly found on DSLR cameras. They have a separate autofocus module mounted at the bottom of the camera. The focus is set by the autofocus sensor, which evaluates the incoming light. The calculated information is then passed on to the lens. Finally, the lens motor ensures the necessary distance setting. There is a particular way by which the light reaches the autofocus sensor. In this autofocus system, the image is split into two halves, namely left-hand side and right-hand side halves. The splitting of an image is accomplished with the help of a separate optical path consisting of semi-transparent/pellicle mirrors and dedicated line sensors and such an implementation is often met in digital SLRs (Ray et al., 2004). If the subject/scene is out of focus, then the two half-images are shifted with respect to each other, which is referred to as "phase-shift", which maintains information about both-

• the distance between the sensor and the image plane, and
• the direction towards the sensor should be moved.

This property makes the Phase Detection Autofocus system faster than that of the Contrast Detection Autofocus. DSLR cameras have an oscillating mirror, pointed down when looking at the subject through the viewfinder so that the light information can reach the viewer's eye. In autofocus mode, the phase detection autofocus is active at the same time, which means that the light must reach the separate autofocus module. This reason is that, a part of the oscillating mirror is partially transparent, which allows a small amount of light to pass through. On the way the light passed through the transparent oscillating mirror, hits a second mirror or sub-mirror, resulting in the redirection of the light information into the autofocus module. The module has multiple autofocus sensors, whereby every focus fields of the camera is assigned of two sensors, a so called sensor pair. A typical autofocus sensor is a **charge-coupled device** (CCD) that provides input to algorithms that compute the contrast of the actual picture elements. The CCD is typically a single strip of 100 or 200 pixels. Light from the scene hits this strip and the microprocessor looks at the values from each pixel (Kang et al. 2015).With the help of the micro-lenses, the edge rays of measurement area are divided an directed to the corresponding sensor pair. The resulting sub-images, more precisely their intensity of light, test patterns are compared with each other. The autofocus system calculates their necessary corrections due to the position and deviation that the sub-images have, to each other. The corrected information then are passed onto the lens. The distance is corrected so that the subject is in focus. In the phase-difference detecting method, a light bundle of an object image, which is passed through a photographing optical system to be formed on a reference focal plane in a predetermined focus detection area thereon, is separated into two light bundles by the phase- difference detecting method to be formed as two object images on a line sensor (which includes an array of photo electric converting elements) to detect a phase difference between the two object images on the line sensor, and an amount of defocus is determined through a predetermined defocus operation in accordance with the detected phase difference. The focusing lens group is moved to a position at which the amount of defocus becomes minimal. The phase difference detecting method has the advantage of having a long distance measuring range. However, the focus detection area is Small and fixed (Nakahara et al. 2003).



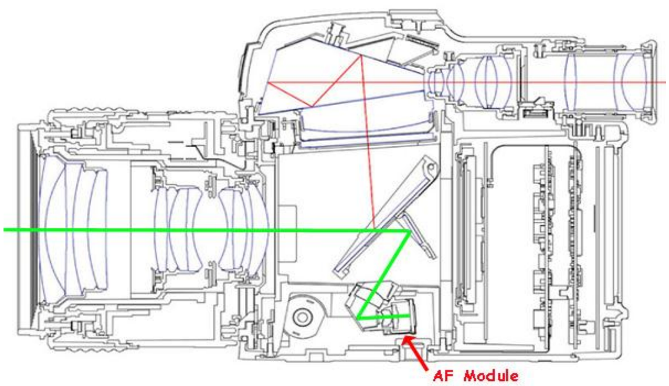


Fig-4 Fig-5**Comparison between Contrast Detection and Phase Detection**

Whether to go for Contrast detection or phase detection, depends on the photographer himself/herself, as both of these autofocus system have their own advantages and disadvantages (Shih et al., 2007). There are certain situations or circumstances where the Contrast detection and phase detection autofocus system plays their own expertise.

• For ***Still subjects and high contrast***, Contrast detection will give the most accurate focus when shooting single shot autofocus with a still subject. There are less chances of the camera focusing in front of or behind the subject as sometimes happens with the phase detection. Being called as front or back focus, one should still be aware of it with contrast detection. One disadvantage of contrast detection is that, the lens motor moves more in case of contrast detection. Consequently it will consume more power and energy (Chan et al., 2017). Further the lens motor will move slowly with larger lenses with multiple glass elements, so the contrast detection autofocus system works

 DOI : 10.18231/2454-9150.2018.0924

slower as compared to the phase detection autofocus system.

• For ***Moving objects***, the phase detection will be more likely to give the fastest and the most accurate autofocus, as there is a notion of splitting the image into two halves and then combine them with proper focusing (Vuong et al., 2013). In comparison contrast detection is not good enough with moving objects as it takes more time to find the maximum contrast. It may also happen that by the time maximum contrast is detected, the subject would have already moved to a different distance, and the camera must find the position again to make the frame ready for capture (Nguyen et al. 2010).

• For both, contrast and phase detection autofocus system, require enough light to focus on the subject. If the image has no contrast or a little light, the camera may not have enough data to use the either of the focus methods discussed above. The following are the ways that may be followed when one tries to shot a picture in low light and low contrast.

•• Some cameras will increase the ISO when the focus bottom is hit, which allows enough light in to focus, and after that the ISO will drop what is set previously.

•• Lights and autofocus assist beams. Cameras and flash units will emit beams of light in attempt to illuminate the subject. If the subject is too far away, then a high flash light can be used.

• The back button focus can be used so that the camera won't try to autofocus every time the shutter button is hit, especially with the still scenes. One needs to point the focus-point to an area of high contrast or higher luminance, hit the focus button and then response, so that the focus is set and locked for the distance.

III. FUTURE SCOPE AND CONCLUSION

The above is related to the study of different autofocus technology that is/are being used by the DSLR cameras now a days. This study can be taken forward to object identification in the image, depending on the Contrast or Phase detection autofocus, whichever is applicable or used. This can be implemented as a base to judge the aesthetic quality and standards of the picture (Incorporating the composition rules).

REFERENCES

[1] Chan, C.C., Huang, S.K., Homer, H., (2017), "Enhancement of Phase Detection for Autofocus", National Taiwan University, Taipei, Taiwan.

[2] Gutierrez, R C., Fossum, E.R., Tang,T.K., (2007) "Auto-focus technology," in Proc. International Image Sensor Workshop, pp. 20-25

[3] Kang, P.C., Lin, H.Y., (2015), "Intelligent Autofocus with Adaptive Depth of Field", 14th IAPR International Conference on Machine Vision Applications (MVA), Tokyo, Japan

[4] Kiefer, J.(1953), "Sequential Minimax Search for a Maximum," Proceedings of the American Mathematical Society, Vol. 4, No. 3, pp. 502-506

[5] Kushner, H.J., Yin, G.G., (2003), "Stochastic Approximation and Recursive Algorithms and Applications," 2nd Edition, Springer, New York. Liao, W.-S., (2003) Fuh, C.-S. "Auto-focus", CSIE

[6] Nakahara. N., Saitama. J.P., (2003), "Passive Autofocus System for a Camera", 2003/0081137 A1 5/2003 Yamazaki 348,354

[7] Nguyen, T.; Jeon, J., (2010) "Camera Auto-Exposing and Auto-Focusing for Edge-Related Applications using a Particle Filter". Proceedings of the IEEE International Conference on Intelligent Robots and Systems, Taipei, Taiwan, pp. 1177-1182.

[8] Ray, S.J., (2004), "Applied Photographic Optics", 3rd Edition, Focal Press, Oxford.

[9] Roman, G. (2010): "MEMS Focus on Cell Phone Camera Market", MEMS Investor Journal Inc.

[10] Śliwiński, P., Wachel, P., (2013) "A Simple Model for On-Sensor Phase-Detection Autofocusing Algorithm", Journal of Computer and Communications, pp 11-17

[11] Shih, L. (2007), "Autofocus survey: A comparison of algorithms Loren Shih Cypress Semiconductor", 10 Wilson Rd. Floor 3, Cambridge, MA 02138

[12] Vuong, Q.; Lee, J. (2013) "Initial Direction and Speed Decision system for Auto Focus Based on Blur Detection", Proceedings of the IEEE International Conference on Consumer Electronics, Las Vegas, NV, USA, pp. 222-223.

 DOI : 10.18231/2454-9150.2018.0924