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Focus Assist for 4K Camera -4K/8K Focus Issues and How to Overcome them-

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Abstract

Because of digital technologies, high-definition television (HDTV) has become a common video system. Commercial 4K TV broadcasting has started in Japan in 2015. 8K is also under developing, and the 8K TV broadcasting service is planned in 2020. 4K/8K are prospective media, and their high-resolution video has various possibilities for broadcasting, medical, publishing, and others. With regard to the video system equipment, cameras are very important because they determine the image quality, particularly resolution. However, a fine focus is more important than the capability of a camera. Professional HD/4K/8K cameras are not equipped with auto-focus systems because the focus areas should be controlled manually due to production-making requirements. The image is blurry if the focus is not fine. Because of operability, small and light-weight cameras are preferred. The size of the viewfinders is similar with that of the HDTV cameras. It is extremely difficult to adjust the focus with a small viewfinder even for a professional video camera person. Large bulky LCDs are used to adjust the focus even for outside broadcasting. They reduce the performance and obstruct mobility. Focus aid systems are proposed to cope with the focus issues. They are based on the linear signal processing method. However, these do not have tolerance against noise. Noise always appears if the lighting condition is not sufficient. In this paper, a nonlinear signal processing is proposed to fix the noise issue. The nonlinear focus assist method also shows a more accurate focus and smaller areas than the current systems.

INTRODUCTION

HDTV broadcasting services started at the beginning of this century. At present, analog TV services has been and are being replaced by HDTV in many countries. Although the analog to HDTV switch has not finished, a paradigm shift has begun. It is 4K TV. 8K that has four times higher resolution than 4K is also under developing. 4K/8K are expected to eventually replace HDTV. 4K has been a practical system, and commercial 4K broadcasting has begun in 2015. Experimental 8K broadcasting is commenced to start in 2016, and full-scale 8K broadcasting will start before the Tokyo Olympic in 2020. Cost is one of the most important factors for a broadcasting system. The 4K equipment cost has been approaching reasonable levels, and it accelerates 4K applications for another industries. Although 8K has many technical difficulties in camera, recorder/player, transmission, and related systems, most of them are expected to be fixed by the extended methods used for 4K. Although most issues for 4K have been being fixed, one issue that has proven to be critical even for HDTV has not been resolved, namely the focus. Professional HD/4K/8K cameras are not equipped with auto-focus systems because the focus areas should be controlled manually owing to production-making requirements. The size of the 4K camera viewfinders is almost the same as that of the HDTV ones. Although the viewfinder size of HDTV is not sufficient, it is acceptable for broadcasting image quality. However, the size of the 4K viewfinder is not acceptable for broadcasting usages. It is impossible to adjust the 4K focus even for a professional camera person. A large monitor is required to adjust the focus of 4K cameras. Although a 4K camera with a 4K imaging device and an appropriate lens is used, the focus is out and the video is blurry. The 4K video content that is out of focus does not have high frequency elements and is blurry. Its resolution is the same as or sometimes worse than the resolution of up-converted content from HDTV to 4K. The blurry content is not worth being called the 4K content. Recently, a technology was proposed for the 8K camera. It is the same technology that is now installed in some professional 4K cameras [1][2][3]. It is a very simple idea. Edges are detected in an image and are superimposed in the shot image. The camera person tunes the focus manually by maximizing the edges ’ most visible point.

PREVIOUS WORKS

The basic idea of previous works is based on the similar ideas [1][2][3]. Figure 1 shows the block diagram. It consists of ne focus videos with high-frequency elements and blurry, out of focus videos without them. The high-frequency elements are the key points to determine ne focus or out of focus. The high-frequency elements can be detected with a high pass lter (HPF). However HPFs are vulnerable to noise because noise has high-frequency elements. HPFs detect high-frequency elements from noise as well as the edges.

Figure 2 shows a video frame that was shot on a fine day with a 4K camera. There is a top of the building and the blue sky in the image. Figures 3 and 4 show the processed result with the algorithm shown in Figure 1. Here, the kernel of HPF is (− 0.5, 1, − 0.5). Although noise is not visible in Figure 2 , Figures 3 and 4 are filled with noise on the surface of the building and in the sky area. Here Figure 3 is the out of focus image and Figure 4 is the fine focus image. However both figures are filled with noise and it is not easy to adjust focus because the edges are masked with noise.

PROPOSED METHOD

NONLINEAR SIGNAL PROCESSING (NLSP)

4K/8K cameras have four or 16 times larger pixels than HDTV. Imaging cells of 4K/8K cameras becomes smaller in inverse proportion to the number of pixels. The signal-to-noise ratio (S/N) of 4K/8K is lower than that of HDTV because the size of imaging cells of 4K/8K is smaller than that of HDTV. Noise is an essential problem for the previous algorithms to adjust 4K/8K

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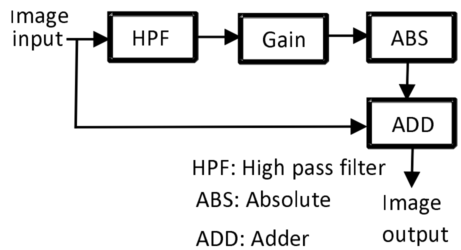

Figure 1. *Previous method*

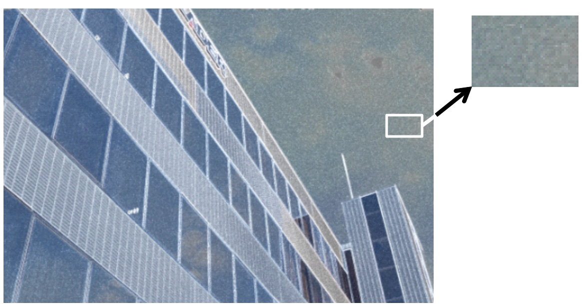

Figure 3. *Out of focus image*

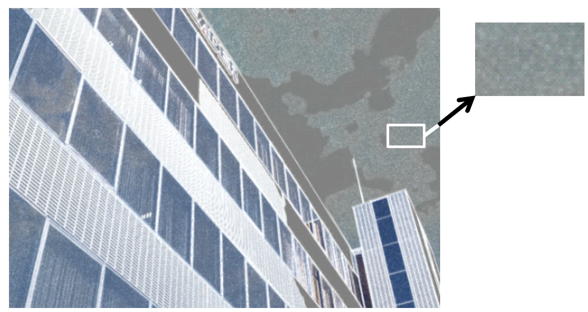

Figure 4. *Fine focus image*

Figure 2. *Building and sky*

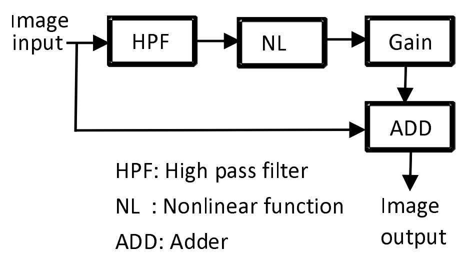

Figure 5. *NLSP*

camera focus. Some new technologies that cope with the noise issue are awaited.

If we just enhance high-frequency elements to improve video resolution, noise is also enhanced and it degrades the image quality. NLSP has been recently proposed to improve the resolution of videos in real time [4]. NLSP has high tolerance against noise and does not amplify noise. Figure 5 shows the signal flow of NLSP. The upper path comprises an HPF, a nonlinear function (NLF), and the LMT. The edges in the video are detected with the HPF and then processed with the NLF, which generates harmonic waves from the edges. These harmonic waves have higher-frequency elements than what the original video has and are generated only from the edges detected with the HPF. There are no harmonic waves in flat areas, because there are no edges in flat areas. An example of an NLF is a cubic function. The range of the input of the NLF is from -255 to 255 if the depth of the video is 8 bits. The output of the NLF becomes very large, because the cubic function generates the pixels from -255^3 to 255^3. The LMT saturates these large values to fit the harmonic waves to the video. NLF amplifies both the edges and noise. However the level of NLSP processed edges is larger than that of noise. Noise can be eliminated by the level differences. The details are discussed in the next subsection.

EDGE DETECTION

Here, we discuss the edge detection method with conventional HPF [1] and with NLSP. Figure 6(a) shows the graphical image of edges created by conventional HPF and Figure 6(b) shows the edges created by NLSP. The edges created by NLSP are stronger and sharper than those created using conventional HPF. Moreover, the edges are also thinner and higher because the harmonic high-frequency elements with NLF are added to the original edges. The edges created with NLSP show the focus point with strong edges, which helps in focus adjustment.

In general, noise is smaller than the edges in images and videos. Figures 7(a) shows an example of edges detected in video by the conventional method and Figure 7(b) shows an example of edges detected in video by NLSP. A threshold level is selected to separate the true edges in a video from the edges created by noise. However, in Figure 7(a) the true edges detected by HPF are not sufficiently larger from the noise edges. The edges detected by conventional HPF have levels similar to the noise. If

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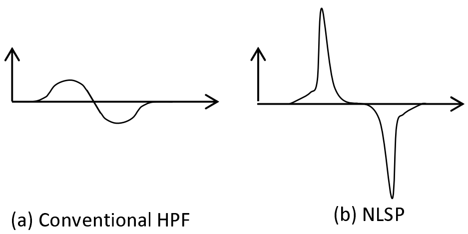

Figure 6. *Created edges*

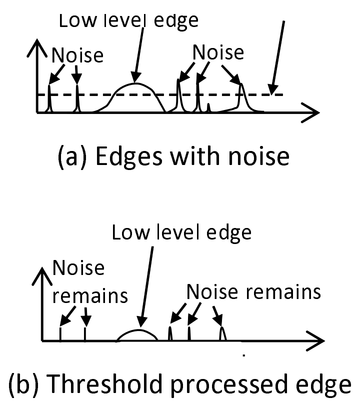

Figure 7. *Threshold process for HPF*

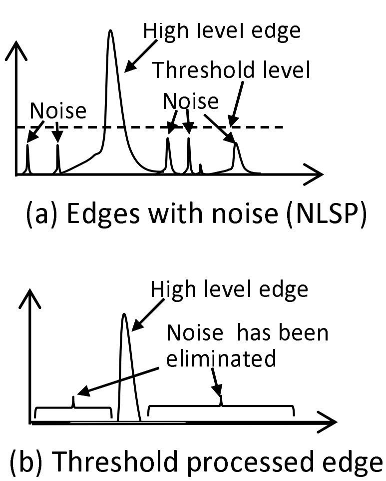

Figure 8. *Threshold process for NLSP*

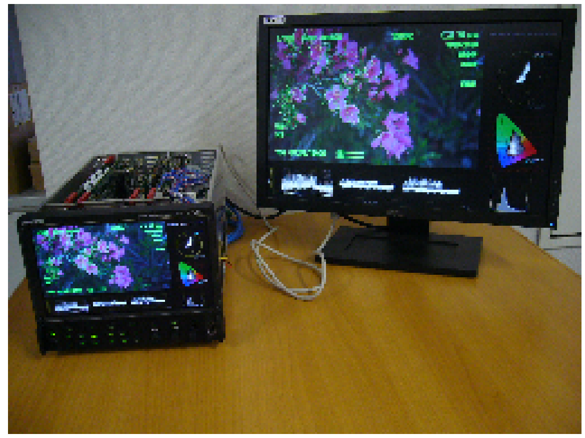

Figure 9. *Real-time hardware*

we define a threshold level to differentiate the edges in an image from noise, the allowance for the level is narrow, as shown in Figure 7(a). If we detect the true edges in the video, we have to lower the threshold level. Although the characteristic of HPF is deliberately selected, it is very difficult to separate the true edges in the image from those detected by noise. In this case as shown in Figure 7(b) the appropriate threshold level does not exist and edges cannot be separated from the noise. The edges created by noise are also detected in video and it is impossible to adjust the focus. This is exactly what happened in Figures 3 and 4. Conversely if we higher the threshold level to remove the edges caused by noise, the true edges in video are also removed.

The edges detected by NLSP are larger than those detected with HPF and noise can be suppressed by the nonlinear function shown in Figure 8(a). Edges in the image are amplified by NLSP and it becomes the high level edge (HLE) in Figure 8(a). The edges detected by noise (EN) are small. As shown in Figure 8, the levels of HLE and EN can be separated with an appropriate threshold level. By controlling the threshold level, noise can be suppressed so that only edges are detected, as shown in Figure 8(b). The edge shown in Figure 8(b) is thinner and larger than that shown in Figure 7(b). The edges amplified by NL are much more visible than the edges detected by conventional HPF. The edges detected by NLSP are sufficiently large to adjust the focus.

EXPERIMENT with REAL-TIME HARDWARE

The field rate of TV systems including 4K/8K is 50 Hz/60 Hz. Video systems including cinema, security cameras and digital sinages work in real time. Real-time functionality is a fundamental requirement for video equipment, and adjusting the lens focus is no different: it must be able to be done in real time. Furthermore, the focus adjusting system should be installed in a small device. If the system is in a bulky device, it will be impractical for daily use. There are many super resolution (SR) technologies that can amplify the edges. However they do not have tolerance against noise and cannot work in real time [5][6][7][8][9][10][11]. The proposed NLSP algorithm meets these requirements because NLSP has been successfully implemented in an field programmable gate array and has worked as SR equipment for both 4K and 8K [4].

The real-time hardware was developed to prove the validity

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and practicality of the proposed method. The proposed focus adjustment system is built in a circuit board and embedded in the left-side monitor. The left-side 9-inch monitor is equipped with 4K multi-signal generators and 4K wave monitor functions. The 200-inch LCD is set to show the size of the system.

The typical difference between the proposed method and the conventional method is shown in Figures 10 and 11. Both of them are fine-focused 4K video frames. Figure 10 shows the edges detected by the proposed method, and Figure 11 shows the edges detected by the conventional method. Both of them are fine-focused images. The white rectangles in the sky areas are enlarged and showed at the right side of each images. The contrast is modified to check the noise level. Although the contrast is modified, noise is not visible in Figure 10. In contrast noise appears in the sky areas in Figure 11.

The edges shown in Figure 10 are added to the input image according to the algorithm shown in Figure 5 and Figure 12 is produced. On comparing Figures 12 (the proposed method) with Figure 4 (the conventional method), the conventional method, the edges are clear and noise is negligible. Other 4K frame examples are shown from Figures 13 to 21. Figures 13, 16, and 19 are the input video frames. Figures 14, 17, and 20 are processed by the conventional method, and Figures 15, 18, and 21 are processed by the proposed method. All of them were shot outside on a fine day. Although the 4K videos were shot under good lighting conditions, noise appeared with the edges in the conventional focus-adjusting systems. The proposed method provide better focus.

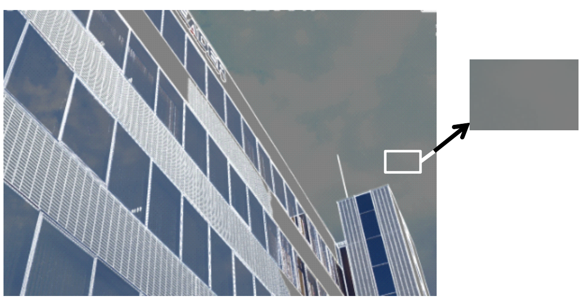

Figure 12. *Proposed method*

Conclusion

Professional HD/4K/8K cameras are not equipped with autofocus systems because the focus areas should be controlled manually owing to production-making requirements. The image is blurry if the focus is not fine. Because of operability, small and lightweight cameras are preferred. The size of the viewnders is similar to that of the HDTV cameras. It is extremely difcult to adjust the focus with a small viewnder even for a professional video camera person. Although focus aid systems were developed, noise affects their operations for 4K/8K. A real-time focus adjustment system for 4K is proposed. It uses a nonlinear signal processing method and is more tolerant to noise than the conventional focus aid systems.

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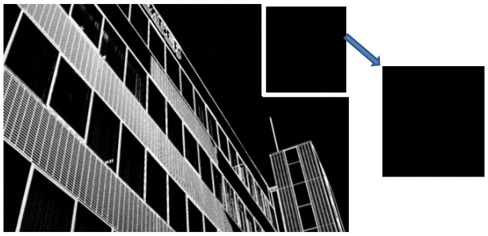

Figure 10. *Edges of building and sky*

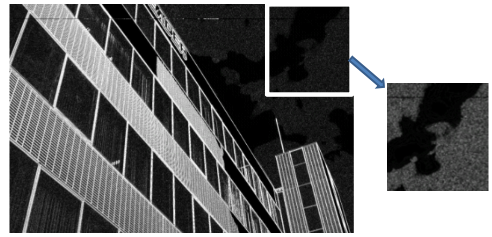

Figure 11. *Edges of building and sky([1])*

Figure 13. *Entrance of building*

Figure 14. *Entrance of building ([1])*

Figure 15. *Entrance of building (proposed)*

Figure 16. *Flower*

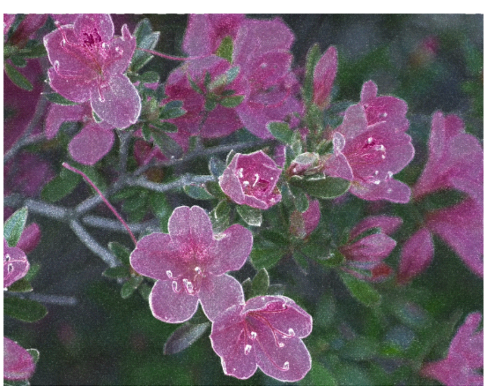

Figure 17. *Flower ([1])*

Figure 18. *Flower (proposed)*

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Figure 19. *Car*

Figure 20. *Car ([1])*

Figure 21. *Car (proposed)*