Spatio-Temporal LED Driving for Subjective Super-Resolution of Grayscale Images

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ABSTRACT

We have implemented a novel LED driving circuit to evoke subjective super-resolution effect on grayscale images by use of FPGA. An 8-bit grayscale image is oversampled and coded into multiple subframes, which are shown on an LED panel at a high frame rate. We have confirmed subjective super-resolution.

1 INTRODUCTION

We have developed a system for subjective super-resolution display on FPGA. Fig. 1 shows the principle of subjective super-resolution. Subjective super-resolution means that the pixel data adjacent to a low-density LED element is alternately displayed at a sufficiently high speed, resulting in an illusion that the resolution is higher than the actual LED pixel count [1].

The human eye is constantly moving. However, we do not feel the sight is shaking. This is because our vision unconsciously corrects the eye movements. Subjective super-resolution uses this correction function. By switching sub-frames at a high speed, information that the image on the LED is moving is input to the observer's eyes. In the brain, it is corrected that the image shake is due to the observer's eye movement. Therefore, it looks to the observer with an illusion of resolution close to the original image.

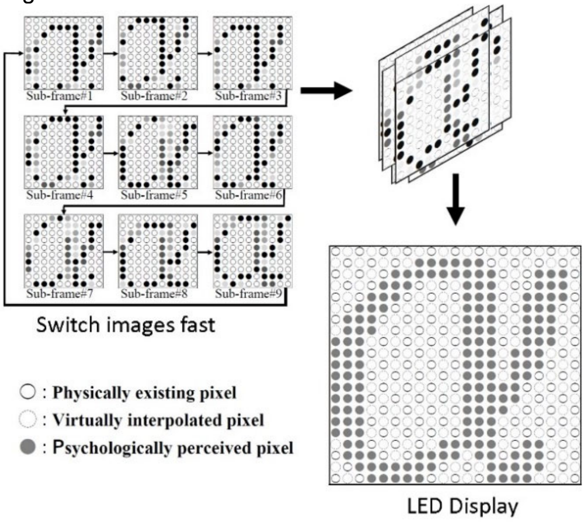


Fig. 1 Principle of subjective super-resolution.

2 EXPERIMENT

In order to evoke subjective super-resolution, it is necessary to divide the original image into sub-frames. In this study, the image was divided into 9 subframes. Fig. 2 shows the division maps, where 9 adjacent pixels correspond to 1 pixel of LED. In other words, 9 subframes are obtained by extracting every other pixel, using the upper left 9 pixels of the original image as a reference. Fig. 2 (a) through Fig. 2 (i) show 6×6 pixels in the upper left of the original image. By extracting pixels that are painted black, subframes used in subjective super-resolution display can be obtained.

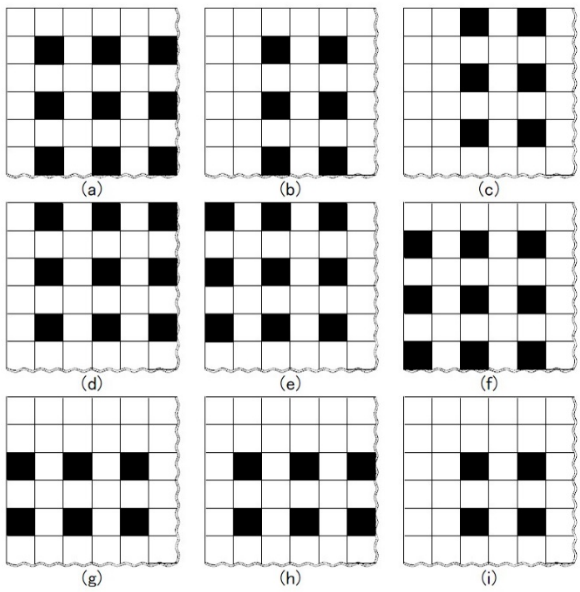


Fig. 2 How to create a subframe from an original image.

Fig. 3 shows the correspondence between the original image and the physical LED pixels. The left part in Fig. 3 shows the actual LED pixels, and the right part shows the original image pixels. For example, the A1 to A9 pixels in the original image are displayed in time division on the pixel A in the actual LED. The displayed order is random, but the subscript numbers must match for all pixels. By alternating subframes at a high speed, the observer can see an image close to the original image before division. As can be seen from Fig. 3, $(2n+1) \times (2n+1)$ image data can be displayed on $n \times n$ LEDs.

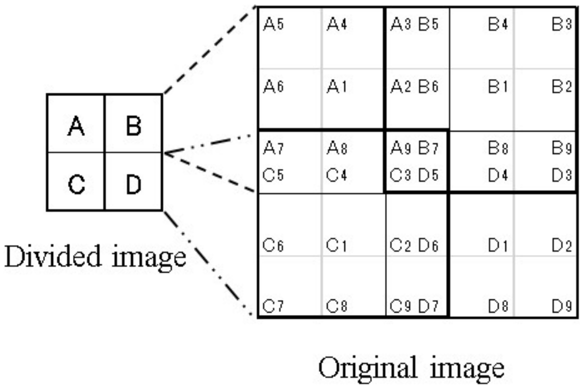


Fig. 3 Correspondence between the original image and the divided image.

We have developed an FPGA circuit to display subframes at a high speed. In this experiment, the original image is a grayscale image with a size of 65 × 65 and a bit depth of 5 bits. In each 32 × 32 subframe after division, blank lines are added every other line to make it 64 × 64 size and displayed on the LED. In addition, BW-PWM (Binary Weighted Pulse Width Modulation) control was used for gradation expression with LED. PWM control is a control method that adjusts the brightness by changing the lighting time per unit time of the LED. LED is suitable for PWM control because of its high-speed response. BW-PWM is weighted by lighting for a power of 2 for the minimum lighting time [2]. For example, when the brightness sequence is “10101”, the LED lights as shown in Fig. 4. In this system, the image data divided into nine images is stored on the FPGA in advance. In addition, the switching speed of image data can be switched by 8 switches from 1Hz, 16Hz, 32Hz, 40Hz, 50Hz, 64HZ, 80Hz and 100Hz.

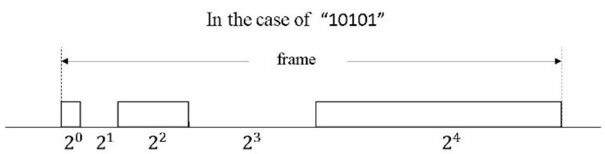


Fig. 4 Example of BW-PWM.

P2.5-LED was used as the display device. The P2.5-LED performs 1/32 scans at the top to the bottom. The scan time for one line is about 6.3 μs. Therefore, the scan time for 64 lines is about 200 μs. Furthermore, since BW-PWN control is used for gradation expression, 5 scans are required to update one screen. From the above, it takes about 6.4 ms to update one screen.

3 RESULTS

The original image used in this experiment is shown in Fig. 5. In order to compare the difference in the appearance of subjective super-resolution depending on the size of characters, two types of samples were prepared.

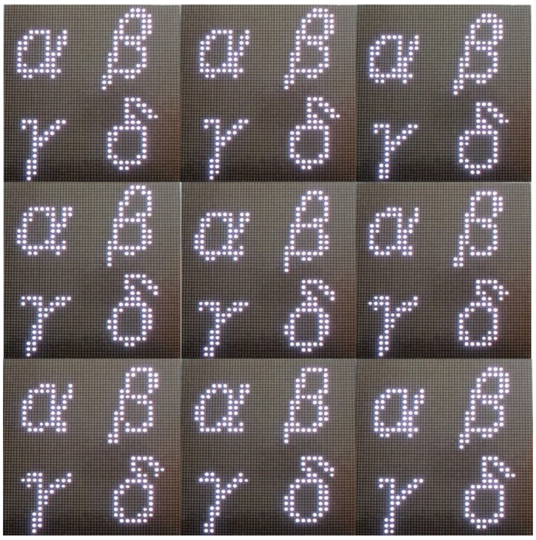
(a) Sample 1

(b) Sample 2

Fig. 5 Original images.

Fig. 6 shows these original images divided into 9 subframes. These subframes are displayed at a high speed on our developed system. Then, the effect of subjective super-resolution is verified. The average image of the subframe in Fig. 7 is used as the resolution comparison target. In this experiment, the LED display interval was increased so that it was easy to see if there was an improvement in resolution. Since there is a blank line after each division, the displayed pitch is 5 mm.

(a) Sample 1

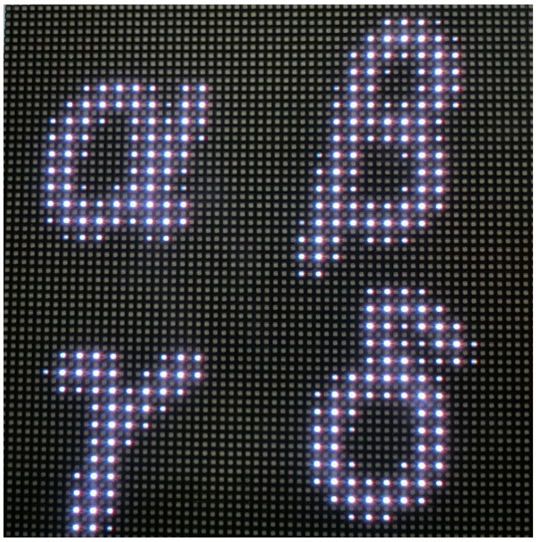


(b) Sample 2

Fig. 6 Divided subframes.

As a result of comparing the average image and the subjective super-resolution display, it was confirmed that the resolution of the subjective super-resolution display seems to be improved in both Sample1 and Sample2. Of the frequencies set this time, the resolution improved most when the subframe was switched at 50 Hz. However, since subjective super-resolution uses a human visual system, the optimal frequency is considered to vary among individuals.

(a) Sample 1



(b) Sample 2

Fig. 7 Averaged images.

4 CONCLUSIONS

A system to display subjective super-resolution corresponding to grayscale images was developed on FPGA, and it was confirmed that the resolution was improved.

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