Reduced Resolution Driving Scheme for High-Resolution Immersive Displays

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ABSTRACT

To extend line times for high-resolution and wide viewing angle displays in virtual reality applications, we present a novel foveation-based reduced resolution driving scheme. For 4,800x4,800 and 9,600x9,600 resolutions, effective vertical resolutions are reduced to 30.3% and 21.0%. Thus, line times can be extended to 330.0% and 476.2%.

1 INTRODUCTION

For the immersive experience in virtual reality (VR) head mounted display (HMD) systems require high resolution as well as high frame rate. These need high computational power graphic processing unit (GPU) of image rendering and high data bandwidth [1]. Although the computational burden of GPU can be relieved by foveated rendering algorithms, the display should implement the full resolution over the whole area, leading to the insufficient charging time for pixels. This paper proposes the foveation-based reduced resolution driving scheme that realizes the foveated rendering scheme directly in a display panel. The proposed method reduces the vertical resolution of image data transferred to the display panel and extends line times, that is, pixel charging times.

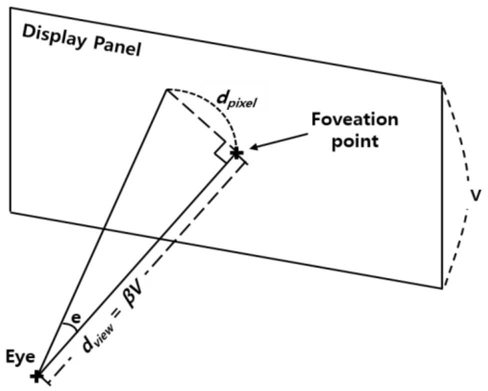

Fig. 1 Viewing geometry for parameters of viewing distance (d_{view}) which is the value of vertical resolution (V), eccentricity (e),and the distance from a foveation point (d_{pixel}).

2 PROPOSED METHOD

2.1 Background

The perceivable spatial frequency of a displayed image is limited by the non-uniform receptor distribution of human visual system (HVS) and the resolution of a display (f_{HVS}, f_{RES}) [2]. The HVS and resolution models in a frequency domain are represented in Eq. (1) and Eq. (2). e is eccentricity, e_2 is half-resolution eccentricity constant, V is a vertical resolution of a display, β is the viewing distance factor, CT_0 is a minimal contrast threshold, and α is a spatial frequency decay constant. The resultant cutoff frequency (f_c) is the maximum perceivable spatial frequency that is the minimum value of f_{HVS} and f_{RES} as described in Eq. (3).

$$f_{HVS}(e) = \frac{-e_2 \ln CT_0}{\alpha(e+e_2)} \quad [cycles/degree] \quad (1)$$

$$f_{RES}(e) = \frac{\pi \beta V}{360 \cdot cos^2\left(\frac{\pi e}{180}\right)} \quad [cycles/degree] \quad (2)$$

$$f_c = \min(f_{HVS}, f_{RES}) \quad (3)$$

$$f_{RES/2^n}(e) = f_{RES}(e) \times 2^{-n}, \; n = 1,2,\ldots \quad (4)$$

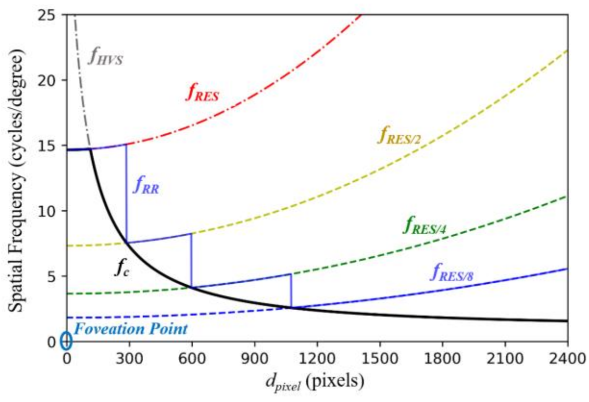

Fig. 2 Spatial frequencies for the distance from a foveation point at the resolution of 4,800x4,800. **β** is 0.35. e_2 , CT_0 and **α** are 2.3, 1/64 and 0.106. The overlapped regions of half Nyquist frequecies are f_{RR}.

2.2 Proposed Reduced Resolution Driving Scheme

In Fig.2 that is the plot of f_c, the region effected by f_{HVS} around the foveation point is called f_{HVS}-dominant and the other region is called f_{RES}-dominant. If the resolution is reduced by 2^n (n=1,2,...) according to Eq. (4), the f_{RES}-dominant region is extended, however, there still exist the f_{HVS}-dominant regions. Therefore, when reduced resolutions (f_{RR}) is applied to the image, the resultant low-resolution image is perceived equivalently to that of the original resolution image without any visible artifacts.

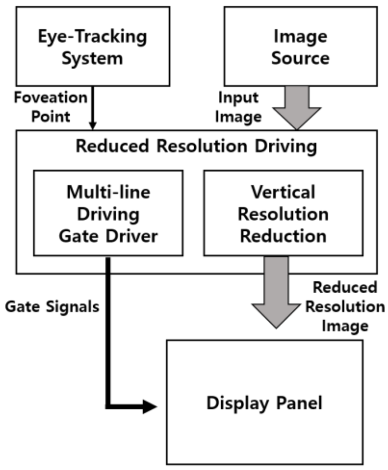

Fig. 3 Block diagram of the foveation-based reduced resolution driving scheme.

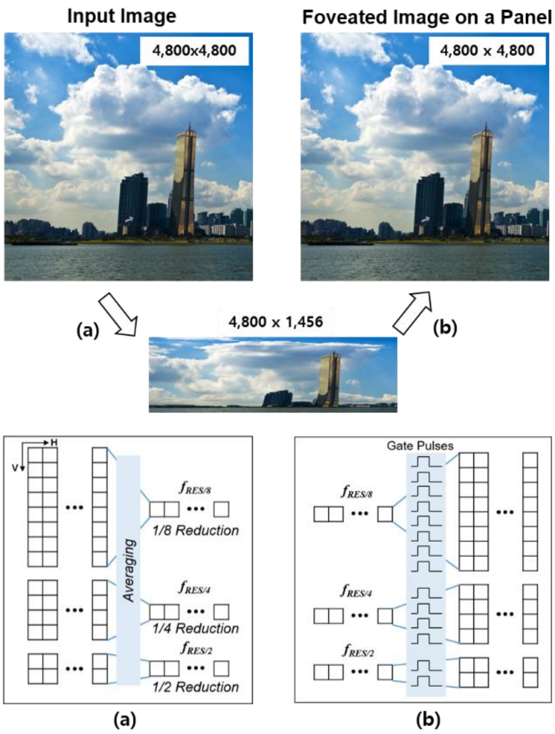

Fig. 4 The proposed driving scheme. (a) Vertical resolution reduction (b) Foveated-rendering image construction of original resolution on a panel by multi-output driving.

The proposed method can be implemented by means of vertical resolution reduction and multi-line driving gate circuit [3] with the foveation point data received from the eye-tracking system as illustrated in Fig.3.

When foveation point and viewing distance are determined, the vertical resolution reduction is performed in GPU which gives rise to the image with the smaller number of lines by squeezing multiple-line pixels into one-line pixels with their average values according to pre-defined f_{RR} regions. Then the compressed pixel data are simultaneously programmed to pixels of corresponding lines in a panel by the multi-line gate driving circuit. This scheme can reduce data bandwidth and extend the pixel charging time. The proposed method is explained in more details in Fig.4. When the resolution can be reduced up to 1/8, reduced vertical resolutions for displays of 4,800 and 9,600 lines are 1,456 and 2,008 lines, respectively. The ratios of reduced resolution to original resolution in these two resolutions are 30.3% and 21.0%. Therefore, their line times are extended to 330.0% and 476.2%.

3 CONCLUSIONS

In this paper, we demonstrate how a display panel can directly realize the foveated imaging algorithm that is widely used for the image rendering in wide-viewing-angle and high-resolution HMD applications. The proposed foveation driving scheme reduces the effective number of lines of a display by a multi-output shift registers that drives multiple lines with the same pulses, therefore, it enables the pixel charging time extension as well as the data bandwidth reduction. The proposed scheme will be a key technology to pave the way to the immersive VR/AR solutions.

ACKNOWLEDGMENTS

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