An Examination of a Gradation Number for High-Gradation Displays Based on Luminance-Differences

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1 Introduction

With recent advances in high dynamic range displays, high-gradation displays have been actively studied. High-gradation displays have more than 256 gradations. When a luminance range of a display is very wide, a luminance-difference between each pixel value becomes small by increasing a gradation number. If this luminance-difference is larger than just noticeable difference (JND), the viewer may see contours on changes in gradation. Therefore, the number of gradations must be set up so that the luminance-difference between each pixel value is smaller than JND [Toshiyuki et al. 2008]. On the other hand, in usual high-gradation studies [Seetzen et al. 2004], the number of recognizable gradations is treated as one of the performance metrics because medical use high-gradation displays are based on DICOM GSDF and have recognizable gradations. Therefore, we must examine what kind of luminance-difference is appropriate for the outside of the medical field because high-gradation displays will be used there as well.

This study compares impressions of images displayed with the recognizable luminance-difference and with the unrecognizable luminance-difference, in order to examine the luminance-difference that is suitable for high-gradation displays. In addition, we examine the necessary gradation number based on results of impression assessment.

2 Our Approach

First, we examined the JND in our experimental environment. We measured the numbers of recognizable gradations along the response characteristics of the gamma values 3.33 and 2.20 with our high-gradation display. Following the previous studies [Michimi et al. 2012], we constructed an experimental environment for our high-gradation display that had 1024 gradations. Our measurement was performed in a darkroom using our high-gradations display with a luminance range of 1.85–1841.40 cd/m^2. We examined the ratio of subjects that could distinguish the difference between each pixel value. Then, by multiplying the luminance-difference of each gradation-difference by each ratio value, we calculated the JND in our experimental environment. Figure 1 shows our JND, which is larger than the existing JND.

Second, we performed an impression assessment experiment with differences of gradation number. We first carried out the experiment that was limited to a dark luminance range because the JND is different by luminance and human eyes are sensitive to luminance-difference in a dark environment. Our measurement was performed in a darkroom and the luminance range of our experiment was 6.82–62.27 cd/m^2. We prepared seven gradation numbers (8, 12, 16, 32, 64, 128, 256 gradations). The 64, 128 and 256 gradations had luminance-differences that could not be discriminated. For the assessed images, we used RAW images that could be obtained by a single-lens reflex camera. In addition, we converted RAW images to gray scale images in order to focus on the luminance-difference. We used six words as assessment terms and five-step Likert scales. Using correspondence analysis, we analyzed our experiment's results. We found that the larger the number of gradations, the more

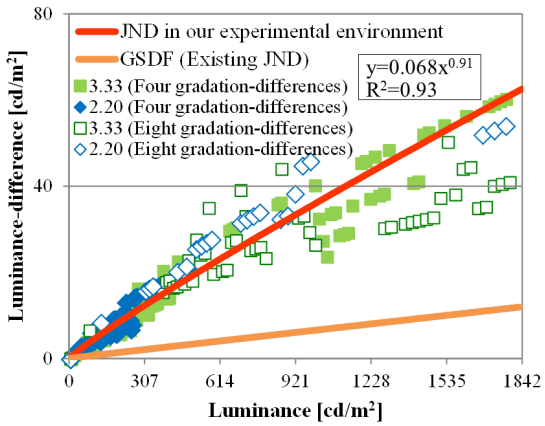

Figure 1: *Our JND.*

we felt a good impression. However, the impression of the image became constant above 64 gradations. Hence, the impression of the image might not improve, even if we increased the number of gradations.

In conclusion, we consider that the necessary gradation number is 64 in our experimental luminance range. In addition, luminance-difference of 64 gradations is less than our JND. Therefore, we think that a good impression is felt when the luminance-difference is less than our JND. It is said that the necessary gradation number in a dark luminance range is less than a usual gradation number (256 gradations). In the future, we will perform the experiment on a wide luminance range including bright luminance. In addition, if we assess a display by the existing JND, the impression of the image may not improve because the existing JND is less than the luminance-difference of 64 gradations where the impression of the image becomes constant. Consequently, by continuing our study, we can propose a new indicator to assess the high-gradation displays.

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