White Paper

Improving Visibility in Dark Areas with Smart Insight

CONTENTS

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1. Introduction

We have been striving to create high quality image technology such as high precision gamma correction, brightness stability control and digital uniformity equalizer technology, aiming for "monitor display that is faithful to the original image source".

We have implemented this concept of high quality image technology into FORIS, our line of home entertainment monitors. Thus, we have developed FORIS based on the concept of "natural comfort", in which monitors express the color tone and smoothness of an image source accurately and naturally.

However, while "natural comfort" is certainly an essential concept to accurately reproducing the intention of image creators, depending on diverse user environments and preferences as well as image source, accurate reproduction of the image source itself does not necessarily result in user satisfaction. When viewing low tones and dark areas, on the monitor visibility changes significantly in response to the environment in which it is viewed (surrounding luminance) and monitor brightness. Therefore, the concept of natural comfort could make areas we want to see, harder to view.

To solve this problem, we developed Smart Insight, which improves visibility in dark areas and suits user preferences (details described in this document.) This function improves visibility in dark areas while retaining the original texture of the image source and provides visibility that emulates how things appear in the real world. In addition, Smart Insight includes the concept of “natural comfort” and provides newly added value based on the concept, “make the scene come alive” which means to accurately reproduce real-world images on the monitor.

FORIS FS2333 monitor equipped with Smart Insight

2. Technology to improve visibility in dark areas

2-1. Conventional technology to improve visibility in dark areas

Conventional monitors apply gamma correction across the screen as a means of improving visibility in low tone areas. The essential purpose of gamma correction is to linearize optical input-output relation by adjusting gamma value in response to the input image source. Since gamma correction allows the output value of low tone areas to rise, users can use gamma correction to brighten those areas.

However, using gamma correction to improve visibility in dark areas can brighten light areas excessively and result in a loss of tonality.

2-2. PowerGamma

We developed the FORIS FS2331 in November 2010 which provides Power1 and Power2 gamma correction settings to improve visibility in dark areas of game images. In particular, Power2 enhances visibility in dark areas without sacrificing tone display.

However, since gamma correction applies tone conversions to all tones equally, the local contrast of outlines and textures may decrease. This can cause gamma correction to create an impression differing from the texture of the original image. Also, as gamma correction is not suitable for some kinds of images, we provide the PowerGamma setting for games only.

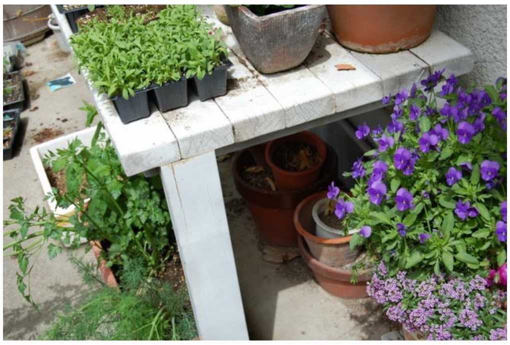
FORIS FS2331 monitor equipped with PowerGamma

3. Smart Insight Technology

Smart Insight extracts local contrast information of an image from each pixel and corrects and brightens the image while preserving the original texture. In addition, Smart Insight detects the overall brightness of the whole image and the tone bias within the frame, and then adjusts the parameters in response to the scenes automatically. This section describes the visual differences between original, real images and those produced by conventional monitors, as well as the reasoning behind the development of Smart Insight.

3-1. Visual differences between real-life and monitor images

When we photograph subjects with a significant difference between backlighting and shadow, images shown on the monitor could sometimes be dark and hardly visible. We can prevent this type of phenomenon to some extent by adjusting the exposure on the camera. However, exposure adjustment usually applies to the whole screen so lengthening exposure time may cause the saturation of bright areas, making the images hardly visible.



Original image with a camera
The shadow of the table looks darker than its actual color.

Image corrected by Smart Insight
The shadow of table is close to its actual color.

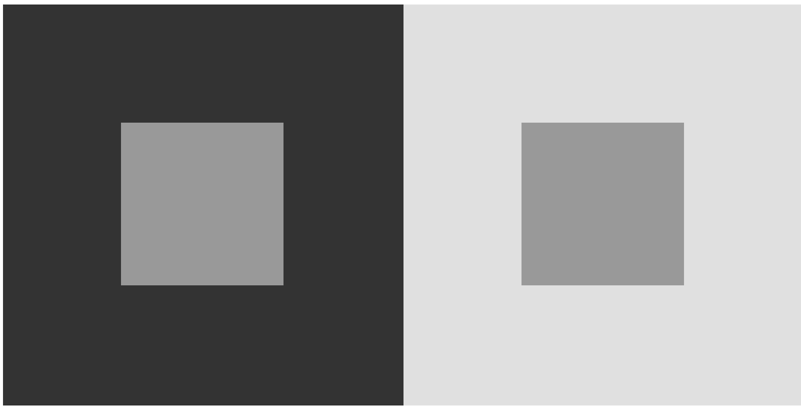
The reason for such low visibility in the dark area is because the brightness of the monitor output is significantly darker than real-life. For example, the luminance in mid-summer is approximately 100,000 lx in the sun and 10,000 lx in the shade. However, the maximum luminance of general monitors is several hundred cd/m² and the minimum is close to zero. Although the units between the luminescent and illuminated sides differ, the brightness of what we see is significantly different between the monitor and the real thing. In short, the monitor can brighten the low tone areas (a few cd/m² on the screen) in the photograph of a subject that is 10,000 lx luminance in the shade.

The human eye optimizes a dynamic range of brightness perception by adapting to the brightness of its surroundings. However, eyes have to acclimate to a dark environment to recognize a few cd/m² of luminance. We can not easily adapt to a dark environment each time when looking at an image on the monitor. Therefore, it is harder to see the dark areas of the picture compared to what we see in real-life.

3-2. Visual reproduction using the human eye

A monitor's luminance range is lower than in the real world so the monitor can not reproduce a perfect optical representation of a real subject. However, the perception of the human eye adapted to its surrounding brightness (dynamic range of perception) is said to be at about an order of 10^2 (approximately 100:1 – 1000:1). Although the optical absolute value is inaccurate, with perception representation, the dynamic range (approximately 400:1 – 1000:1) of a monitor can reproduce visibility that emulates the real subject.

The images below describe an optical illusion. Although the gray square on the right looks darker than the left, both squares have same level of brightness. This optical illusion is mainly caused by the cone cells, photoreceptor cells which identify color and brightness with photopic vision; concentrating near the center of the eye's viewpoint. This is known as "lightness constancy."



Both gray squares have the same level of brightness.

This optical illusion indicates that brightness and color that humans perceive, depends on the relative change between their surroundings rather than absolute optical representation within the image. The Retinex theory expresses this phenomenon through a physical model. We developed Smart Insight on the basis of this theory. The Retinex theory describes the intensity of the light that enters the eye I as a product of the reflectance of an object R and light L as shown in the following formula.

$$I = R \times L$$

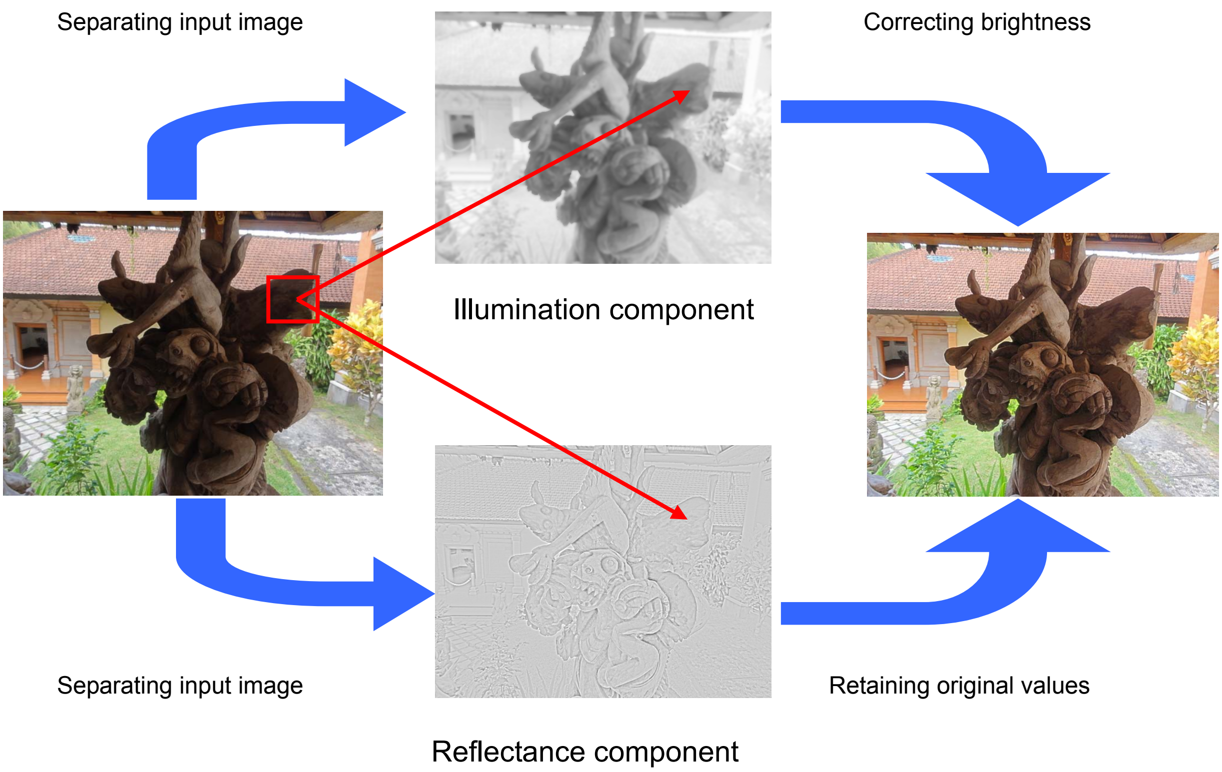
From the view of image processing, the Retinex theory is simply expressed as "the perception of the brightness and color of pixels is more influenced by the relative change between the surrounding area and the point of observation over the absolute values of the optics." The relative optical amount here is the reflectance R from the above formula, and corresponds to the detail of the image outline component i.e. the local contrast component.

Thus, to improve the visibility in low tone areas of a monitor using the Retinex theory, the monitor needs to extract reflectance components from an input image R, and then adjust the light component L. Then, it becomes possible for the monitor to implement visibility emulating real-world values.

3-3. Improving visibility in dark areas with Smart Insight

The figures below describe the image correction process with Smart Insight.

- First, our original process separates the input image's illumination component and reflectance component. Then, Smart Insight calculates the value of the illumination component and the reflectance component by analyzing the local image area centering on a certain pixel as shown outlined in the red square below.
- Next, it corrects the brightness of the dark areas of the illumination component and recombines it with the reflectance component.
- Now Smart Insight has produced the image with the correct brightness while retaining local contrast.



Through these measures, Smart Insight brightens low tone areas and converts the image to an accurate representation of the real subject. Moreover, Smart Insight corrects the dark areas of the illumination component, as well as overall screen brightness and tone bias with our original dynamic control. The amount of correction is dependant on illumination. For example, Smart Insight actively corrects dark scenes and carefully corrects bright scenes. Therefore, we can always see various moving images with the appropriate amount of correction.

3-4. Effect of Smart Insight

The figures below show the differences between correction by conventional gamma and Smart Insight.

Original image

Image corrected by Smart Insight

Gamma correction γ=1.6

Gamma correction can improve visibility of the dark area, however, since gamma correction converts all tones equally, local contrast decreases and outlines becomes blurred. Also, the entire image becomes whitish from the loss of vividness.

Smart Insight corrects the brightness in dark details while retaining the original local contrast and details, like the outline, remain clear. Moreover, Smart Insight corrects only illumination while retaining hue and saturation so images don't fade in color and the corrected areas appear more vivid. This phenomenon is caused by the Hunt effect, a visual trait where vibrancy increases with luminance.

4. Summary

Our new Smart Insight technology improves visibility in dark areas while retaining visual naturalness. This technology provides not only visual improvement but also brightness adjustment in response to contents or user preferences without increasing the light volume of backlights allowing for lower power consumption.

Moreover, since the delay of this process is only a few lines, Smart Insight is ideal for games which require real-time responsiveness as well as watching movies, pictures and more.