Content Adaptive LCD Backlight Control

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LCD displays are widely used in cell phones, personal media players, internet tablet PCs, laptops, and large-screen TV sets. These displays account for a major part of the power consumed by these devices. For example, a mobile phone screen may consume upwards of 40% of the system power, while in a large-screen TV, the display may consume 70% or more of the system power. For mobile devices, power consumption negatively affects battery life. For large screen TVs and tethered devices, reducing power consumption results in a green solution and an Energy Star rating. Therefore, reduction of power consumption is of critical importance in such devices. Given the total power budget consumed by the display, targeting LCD power consumption is a natural approach to address this problem.

An LCD display consists of a backlight that shines through a filter. The filter is controlled by the pixel values that are to be displayed and modulates the backlight. The brighter the pixel, the more light that passes through. By controlling the array of pixels in an LCD filter, different images can be shown on the display. The brightness of the entire image can be controlled by the backlight, with typical retail settings being based on a power-brightness tradeoff.

Almost all the power in an LCD display is consumed by the backlight, with the filter itself requiring comparatively little power. Therefore, LCD power control technologies have focused on backlight control. A very common power reduction approach, often used in laptop computers and mobile devices, is to dim or turn off the backlight when the device has not been used for some period of time. However, we are interested in reducing LCD power even when the device is in actual use. For this, we can use content-adaptive backlight control.

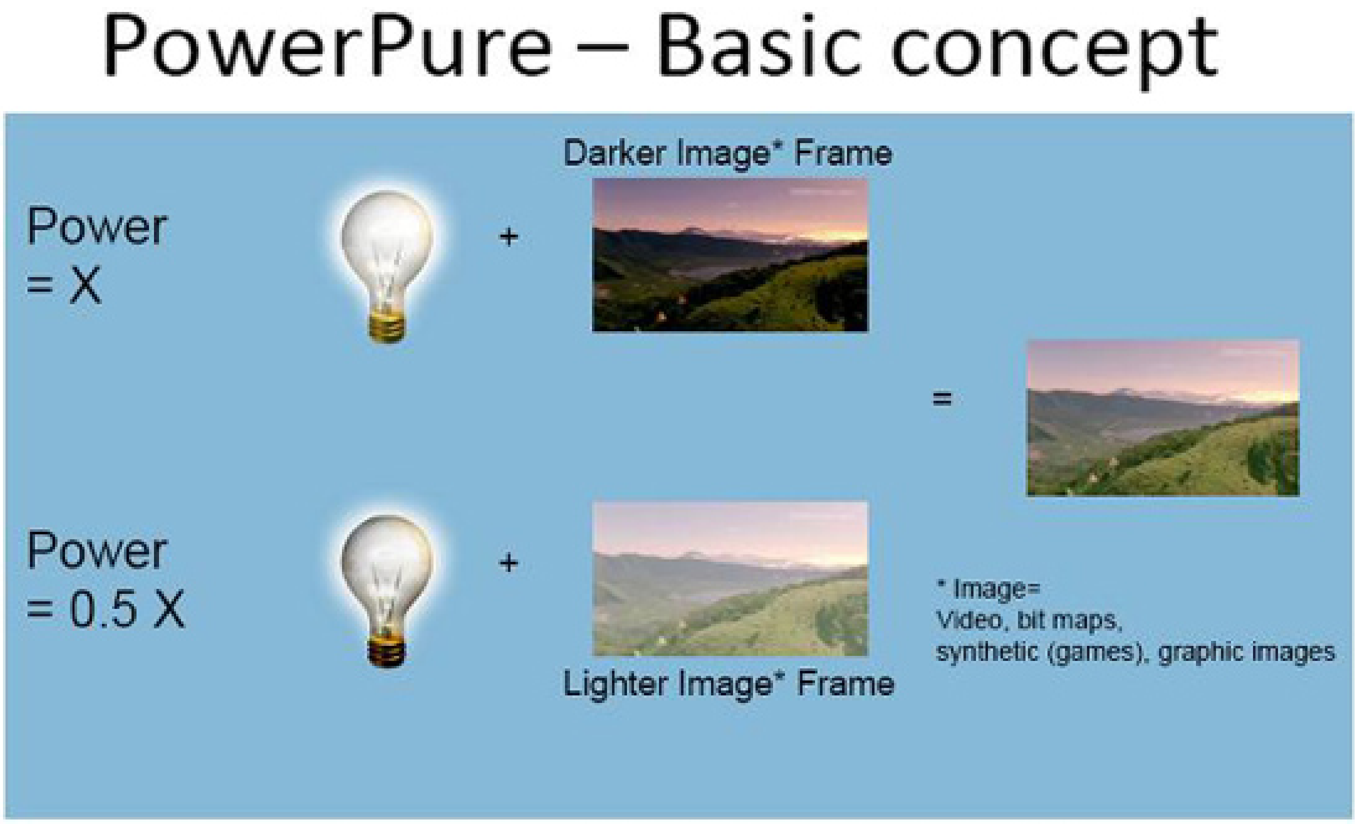

Figure 1: Basic Concept of PowerPure Dynamic Content Adpative Backlight Control

Content-Adaptive Backlight Control

Content-adaptive backlight control (CABC) takes advantage of the fact that the perceived brightness is due to the backlight being modulated by the filter, which in turn is controlled by the image. A dark image appears dark because the filter does not allow much of the light to shine through. However, the same effect can be achieved by using a dimmer backlight, and controlling the filter to allow more light to shine through. In other words, the backlight is dimmed and the image is boosted, resulting in the same perceived brightness. Typically, some kind of histogram analysis is done on the image to determine the maximum brightness than needs to be displayed.

This decides the required backlight brightness. Finally, the image is boosted by the appropriate amount depending on the backlight brightness. Several types of boosting methods are in use, though some result in artifacts like clipping of bright pixels.

Several types of backlight control are possible. For example the lighting of the entire display can be uniformly changed, also known as 0-dimensional control. Alternately, it may be possible to control the brightness of different horizontal display sections separately (1-dimensional). Finally, it may be possible to control different sections of the display independently of each other (2-dimensional). Smaller displays, such as those used in mobile devices typically offer 0-dimensional control, though 1- and 2-dimensional control is possible in some larger displays. Because the light in one physical section of the display affects neighboring sections, 1- and 2-dimensional control can be more challenging. However, because control is region-specific, greater power savings are possible. In this article, we focus on 0-dimensional control. The ideas we discuss can be adapted to 1- and 2-dimensional control as well.

Challenges with CABC

Reducing the brightness of the backlight decreases the available dynamic range. If there are any pixels that require a higher range, they could be clipped, an artifact called “washout”. When the backlight is changed dynamically, it is possible that the target backlight brightness varies greatly from frame to frame, aggressively changing the backlight by such large amounts is often perceived by the user as flickering in the image.

Flickering is an artifact that is visible even to a novice user, and it must be avoided at all costs. The perception of washout, on the other hand, depends on its severity, and most systems trade off washout for power savings. A good system makes sure that the washout, if any, is not perceptible to the end user. It is possible to use knowledge about the human visual system to reduce such perceived artifacts. Finally, CABC affects not just brightness, but color as well. For example, if we decided backlight brightness based on luminance alone, color components would not be faithfully rendered.

Original frame displayed at full backlight (level 127) on a Nokia N810 device.

Frame processed with Moxair PowerPure™ displayed at backlight level of 36 on a Nokia N810 device.

Figure2: Moxair PowerPure Algorithm Software Implementation on Nokia N810 Internet Tablet

Solutions

To get the best performance, histogram analysis is done separately for each color component. For each color, the desired brightness is determined. Then the maximum of these is chosen as the target backlight. This ensures that all colors are accurately rendered.

As described before, reducing the backlight always has the potential to cause washout. Washout can be controlled in several ways. One approach is to determine what fraction of pixels can be clipped without the user perceiving the artifact. Another approach is to use a smooth roll-off of the image transform so that there is no clipping. Yet another way is to use human-visual system based constraints that make optimal use of the dynamic range. By combining these techniques, washout can be minimized.

Flicker is, by far, the most irritating and unacceptable artifact. It is also very difficult to control while at the same time minimizing power consumption. Several approaches have been presented to solve this problem, and most of them focus on smoothly changing the backlight so that the change is not perceived. For example, if the target backlight for frame N is much lower than that of frame N-1, then the actual target value used is a smoothed version of the two values. Unfortunately, this approach is necessarily conservative, and the power reduction is small. At Moxair, we use scene-based backlight control, where backlight changes ride on scene discontinuities.

Because the user is conditioned to accepting the drastic scene change, large changes in the backlight synchronized with scene changes are not perceived. An important challenge for this approach is to determine what backlight value to use at the beginning of a scene. This is difficult because the brightness can change considerably during a scene, requiring the backlight to track these changes. An important innovation of our method is to predict the target backlight for the entire upcoming scene based on the first frame of the scene and previous scene information.

Most current CABC techniques reduce the display power on average by about 20% while maintaining image quality. However, using advanced techniques like human-visual system based constraints, and predictive scene-based backlight control, we can achieve greater than 50% display power savings while maintaining identical image quality.

Summary

CABC is a very important technology for reducing power consumed by LCD display devices. The challenge with CABC is to get the best tradeoff of power and image quality. In particular, there are artifacts, such as flicker, that are very difficult to control while still giving a high reduction in power consumed. The advanced techniques used by us at Moxair give over 50% power reduction while maintaining image quality. While the methods described here have been used mainly for 0-dimensional control, we envision these being adapted to 1- and 2-dimensional control in the near future.

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