Different Backlight Dimming Algorithms for LCD Backlight Power Reduction with Image quality Enhancement

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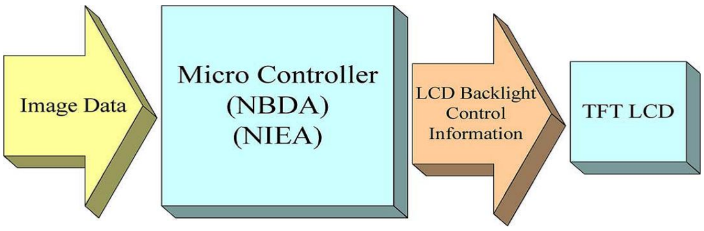
Introduction

Power consumption and image quality both play important role in liquid-crystal display (LCDs). Compare to cathode ray tubes (CRTs), LCDs have the advantages of being light weight, and having thin format, low radiation and high image quality. However, LCD also has certain disadvantages which need to overcome, such as light leakage from the liquid crystals and non-ideal cross polarization. Using a backlight dimming algorithms can minimize these drawbacks. Although LCDs have high dynamic range properties, the complex algorithm and high cost backlight structure are not suitable for small size LCD products, such as mobiles, PDAs, digital photo frame and Car GPSs. Moreover, due to decrease in the driving current of the back light, the display backlight turns dark. Therefore, we proposed the NIEA algorithm to enhance the image contrast ratio and sustain the quality of image. There has been some research on image contrast enhancement. In Raman and Hekstra proposed an architecture and outlined an algorithm using histogram information of the image for the backlight modulation in LDCs. In Sun and Ruan proposed the dynamic histogram specification algorithm to improve the image contrast. Although the above methods could effectively enhance image contrast, they did not considered image quality for the entire system. In cho and kwon proposed backlight dimmining algorithm to reduce power consumption and improve image quality in LCD applications. In Bartolini and Ruggiero adopted the SSIM method to evaluate image quality from the Human Visual System(HVS). Figure shows the block diagram of our proposed display system for backlight control designed to decrease the power consumption of the LCD backlight and enhance the image contrast to compensate for the image brightness. First, the image data are analyzed to determine whether the TFT LCD back light current increases or decreases. After the backlight dimming level is selected, the system enhances the image contrast based on selected current level, and users almost notice no significant changes in image quality. Both of the proposed new algorithms, New Backlight Dimming Algorithm(NBDA) and New Image Enhancement Algorithm(NIEA), not only decreases power consumption, but also increase image contrast to sustain image quality.



BLOCK DIAGRAM OF THE DISPLAY SYSTEM FOR BACKLIGHT CONTOL

The liquid crystal display (LCD) system uses liquid crystal to control the passage of light. The basic structure of a TFT-LCD panel is regarded as two glass substrates sandwiching a liquid crystal layer. The front glass substrate is fitted with a color filter, whereas the back glass substrate has transistors fabricated on it. When voltage is applied to a transistor, the liquid crystal will bend, allowing light to pass through to form a pixel. A light source belongs to a backlight unit and locates at the back of the panel. The front glass substrate combines with a color filter and let each pixel has its own color.

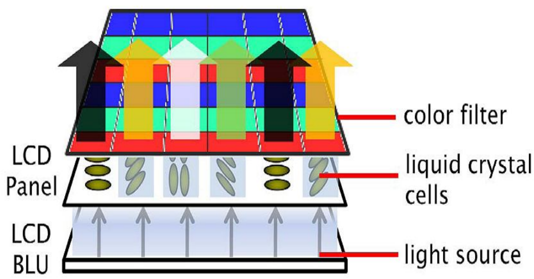


Fig 1. A simplified architecture of a LCD

Liquid crystal displays (LCDs) are used a wide range of consumer products because of light weight, high resolution, good color performance and other advantages. However, there are two major drawbacks that are low image contrast ratio and large power consumption. In conventional LCDs, the image is displayed by controlling the LC transparency with constant backlight luminance. The image contrast ratio is poor because the light is not blocked completely at the lowest gray level. The power consumption is appreciably large because the backlight always operates with the full luminance regardless of input image. Due to this, LCD is also known as the most significant power consumer in a mobile device.

In Table I, we notice that an LCD backlight unit (BLU) on a modern laptop consumes up to 26% of the total power while an LCD panel consumes 8% of the total power in its idle state with full brightness. This laptop employs a cold cathode fluorescent light (CCFL) bulb as a light source in the LCD BLU. In a typical smartphone, an LCD BLU consumes up to 60% of the total power while an LCD panel consumes only 7% of the total power in its idle mode. The latter device is supported by LED in the BLU. This indicates that there may be much room to reduce LCD BLU's power consumption by decreasing the brightness of light sources in an LCD BLU (a.k.a. backlight dimming), obtaining the whole LCD's power saving consequently.

TABLE 1

Modules	Power consumption in a	
	Modern Laptop [1]	Typical Smartphone [2]
CPU	15%	6%
Memory	3%	1%
Graphics	8%	12%
LCD Panel	8%	7%
LCD BLU	26%	60%
Others	40%	14%

POWER CONSUMPTION IN LCD- BASED DEVICES

To solve these problems, backlight dimming algorithms have been studied by many researchers. The backlight dimming algorithm is defined as the dynamic control of backlight luminance according to input image.

The process of backlight dimming algorithm is shown in Fig. 2. Firstly, the input image is stored in memory and characteristic data of input image, such as average luminance, maximum luminance, gray histogram and etc., are extracted.

Secondly, the backlight luminance is determined by using characteristic data of input image. Thirdly, the pixel data of input image are compensated according to the backlight data. At last, the mixture of backlight and compensated image is displayed on the panel.

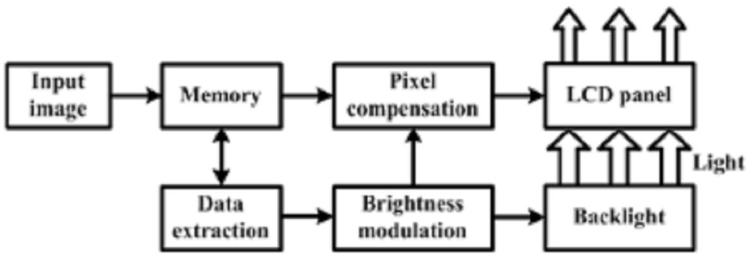


Fig 2. The process of Backlight Dimming Algorithm

Brightness modulation of the backlight

To reduce the power consumption of backlight, the brightness of the backlight is modulated according to input image. The brightness modulation reduces not only the power consumption of backlight but also the quality of displayed image. So, the determination of backlight luminance satisfying backlight power and image quality simultaneously is important work. The backlight luminance is determined by using characteristic data of input image. To analyze characteristic data, characteristic parameter and gray histogram of image are used.

In parameter based brightness modulation, fixed parameters of input image are used for brightness modulation. In average algorithm, the backlight luminance is determined by average luminance of input image. In square root algorithm, the backlight luminance is determined by square root of average luminance of input image. In max algorithm, the backlight luminance is determined by maximum luminance of input image. Parameter based brightness modulation operates simply, but it is not suitable to reduce power consumption for various images.

For more adaptive brightness modulation for various images, histogram based brightness modulation were proposed. In these algorithms, the backlight luminance is determined by using gray histogram of input image. In IMF (Inverse of Mapping Function) algorithm, the inverse of the cumulative distribution function of input image is used for mapping function. In backlight dimming algorithm, the backlight luminance which minimizes total image distortion is used. In BDG (Backlight Dimming Gray) algorithm, the gray level at 75% histogram is defined as the representative value of input image. The histogram based brightness modulation is adaptive for various images but its operation is complex and it needs a lot of memory for storing the gray histogram.

Pixel compensation

After brightness modulation of the backlight, the luminance of displayed image is reduced because backlight luminance is reduced than full luminance of the backlight. To compensate the luminance reduction of displayed image, the pixel data of input image must be changed according to backlight luminance. After pixel data are compensated, displayed image and input image are exactly not same because the luminance of displayed image cannot exceed backlight luminance. Therefore, the luminance of high gray pixels is same as shown in Fig. 3. This is called “clipping artifact”.

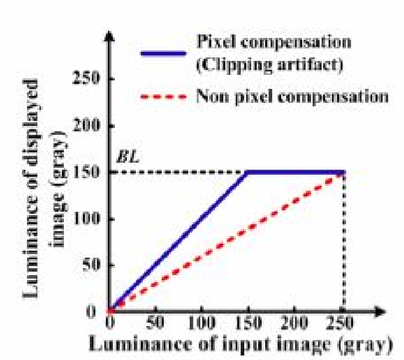


Fig 3. Pixel Compensation

To solve clipping artifact, “roll-off” method was proposed. In this method, smooth tone scale function is used from MFP (Maximum Fidelity Point) to 2_n gray to solve the closed gray level as shown in Fig. 4. However, because gray level that is over the maximum luminance of input image is not existed unnecessary luminance reduction occurs at displayed image. And, this method needs complex operation for smooth mapping.

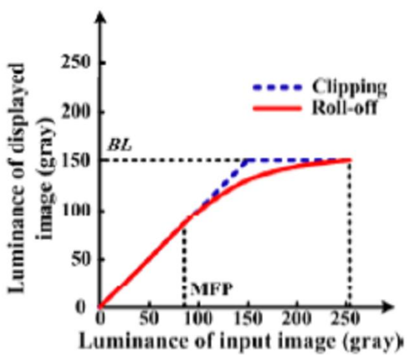


Fig 4. Pixel compensation using roll-off method

DIFFERENT BACKLIGHT DIMMING ALGORITHMS

Various researchers has derived different Backlight dimming algorithm with their pros-cons. Some of the best are explained below:

Backlight power reduction and image contrast enhancement using Adaptive Dimming for global backlight applications by Chih-Chang Lai and Ching-Chih Tsai

An adaptive dimming technique is simultaneously enhancing the image contrast ratio, reduce image distortion and save backlight power for global backlight applications.

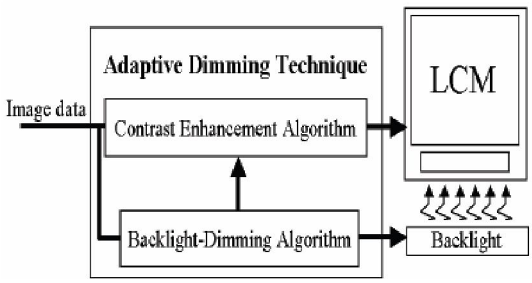


Fig 5. Block diagram of the proposed adaptive dimming technique.

The proposed technique is composed of the two parallel algorithms: backlight-dimming and contrast enhancement. The backlight-dimming algorithm has been shown useful in obtaining backlight saving ratio, while the contrast enhancement algorithm has been confirmed to improve the image contrast ratio and reduce the image distortion. From the simulation results, the backlight power saving is more than 31% and the contrast ratio improvement is approximately up to 20.75%.

A Backlight Dimming Algorithm for low power and high image quality LCD applications by Hyunsuk Cho This backlight dimming algorithm is proposed for low power and high image quality LCD applications. The proposed algorithm is consisted of two techniques: brightness modulation of the backlight and pixel compensation. The proposed brightness modulation operates simply and it is well adaptive for various images using relationship of characteristic parameters. The proposed pixel compensation removes clipping artifact and unnecessary luminance reduction.

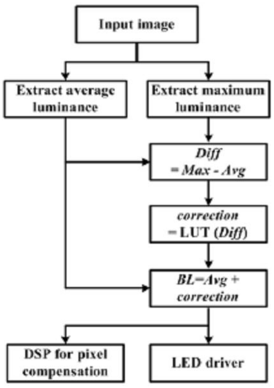


Fig 6. The flow chart of the proposed brightness modulation

By using proposed backlight dimming algorithm, low power consumption and high image quality are achieved simultaneously.

Object based local dimming for LCD Systems with LED BLUs by Aldhino Anggorosesar and Young-Jin Kim

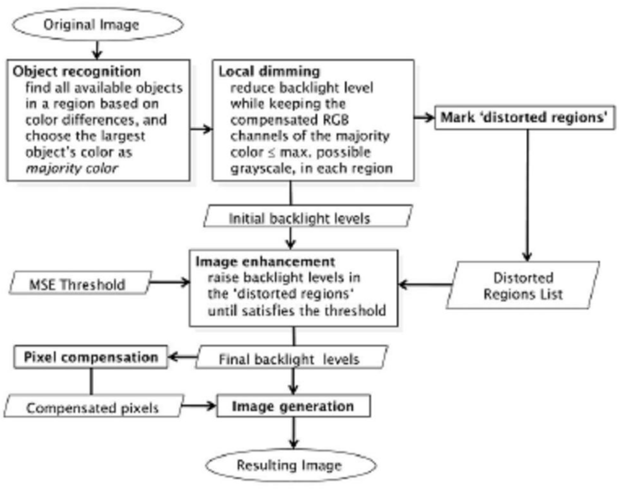


Fig 7. Overall flow of object-based local dimming

This proposed a local dimming technique which employs an object-based approach. The proposed technique successfully adopts MSE (Mean squared Error) as a human visual system-aware metric to suppress visible artifacts remarkably. Since the iterative image enhancement process after dimming only occurs in some regions in a given image and is based on MSE, the proposed technique gets the benefit of low complexity compared to HVS (human visual System) global dimming. Compared to PCBD (Pixel-Compensated Backlight Dimming), object-based dimming shows better dimmed image quality with no visible blocking artifacts. With a similar HVS-aware image quality level, it also produces higher power saving than HVS-aware global dimming and PCBD with negligible image distortion. Experiments showed the proposed technique achieved power saving up to 54% compared to no dimming and up to 12 and 5.5 times higher than HVS-aware global dimming and PCBD local dimming techniques, respectively.

Content based LCD backlight power reduction with image contrast enhancement using Histrogram anlysis by Yeong-Kang Lai , Yu-Fan Lai & Peng-Yu Chen

In this study, the new backlight-dimming adopts the current image histogram to calculate mean and median value to select backlight current, and the new image enhancement algorithm enhances image by index formula.

Here, proposed two algorithms to realize the power saving and image enhancement: one is the back dimming algorithm; the other is the new image enhancement algorithm.

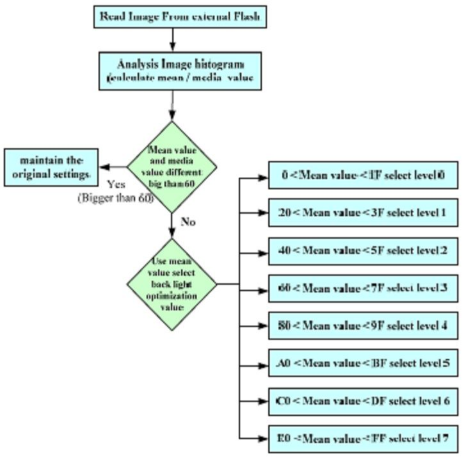


Fig 8. Flow chart of NBDA

The NBDA (New Backlight Dimming Algorithm) technique uses the mean and median value of the image histogram to select the TFT LCD backlight current. Moreover, the NIEA (New Image Enhancement Algorithm) technique maintains the image quality; the consumer cannot notice changes of the system. The experimental result shows that the proposed algorithm can save more than 40% backlight power and sustain the image quality.

conclusion

By the study of all above different techniques of Backlight dimming for reduction of power consumption by LCD, the best solution is given by Object-based Local Dimming, but the drawbacks of its is the elapsed processing time of these techniques for real time implementation. Therefore, although the Content-based LCD power reduction is less than object-based local dimming, its gives faster processing for real time implementation.

Hence, I conclude from my study, Content-based NBDA and NIEA are best solution for power reduction of LCD with enhancement of image quality.

I. References

01. *Modern Television Practice 3rd Edition by R.R. Gulati*

02. *Backlight power reduction and image contrast enhancement using Adaptive Dimming for global backlight applications by Chih-Chang Lai and Ching-Chih Tsai*

03. *A Backlight Dimming Algorithm for low power and high image quality LCD applications by Hyunsuk Cho*

04. *Object based local dimming for LCD Systems with LED BLUs by Aldhino Anggorosesar and Young-Jin Kim*

05. *Content based LCD backlight power reduction with image contrast enhancement using Histrogram anlysis by Yeong-Kang Lai, Yu-Fan Lai & Peng-Yu Chen*