

LCD Motion Blur Reduced Using Subgradient Projection Algorithm

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Abstract: Liquid crystal display (LCD) devices are well known for their slow responses due to the physical limitations of liquid Crystals. Therefore, fast moving objects in a scene are often perceived as blurred. This effect is known as the LCD motion blur. In order to reduce LCD motion blur, an accurate LCD model and an efficient de blurring algorithm are needed. There are three main contributions of this paper: modeling, analysis, and algorithm. First, a comprehensive LCD motion blur model is presented, in which human-eye-tracking limits are taken into consideration. Second, a complete analysis of spatiotemporal equivalence is provided and verified using real video sequences. Third, an LCD motion blur reduction algorithm is proposed.

Keywords: LCD, Modeling, Analysis, Algorithm

I. Introduction

Liquid Crystal Display (LCD) devices are known to have slow responses due to the physical limitations of liquid crystals (LC). LC are organic fluids that exhibit both liquid and crystalline like properties. They do not emit light by themselves, but the polarization phase can be changed by electric fields [1]. A common circuit used in LCD to control the electric fields is known as the thin-film transistor (TFT) [2]. Although TFT responds quickly, it takes some time for the LC to change its phase. This latency is known as the fall time if the signal is changing from high to low, or the rise time if the signal is changing from low to high. Since the fall and rise times are not infinitesimal, the step response of an LC exhibits a sample-hold characteristic (see Fig. 1).

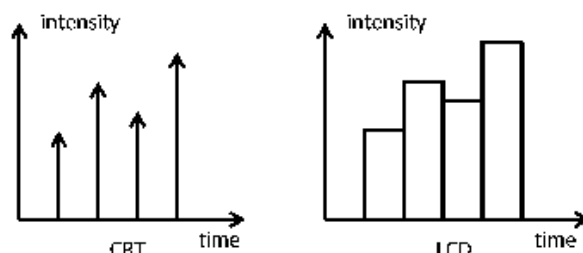


Fig. 1. Signaling characteristics of a cathode ray tube (CRT) and an LCD.

CRT shows spontaneous response, whereas LCD demonstrates a sample-hold response.

Compared to LCD, traditional cathode ray tube (CRT) displays do not have the sample-hold characteristic. When a phosphor is exposed to electrons, it starts to emit light. As soon as the electrons leave, the phosphor stops emitting light. The latency of a phosphor is typically between 20 and 50 ns [2], but the time interval between two frames is 16.67 ms for a 60-frame per second video sequence. In other words, the latency of a phosphor becomes negligible compared to the frame interval. Due to the sample-hold characteristic of LCDs, fast moving scenes displayed on the LCD are often seen blurred. This phenomenon is known as the LCD motion blur. We emphasize the word “motion” because if the scene is stationary, LCD and CRT will give essentially the same degree of sharpness.

II. Existing System

There are a number of methods to reduce LCD motion blur. Backlight flashing presented by Fisekovi *et al.* [3] is one of the earliest methods. In this method, the backlight (typically a cold cathode fluorescent lamp, CCFL) is controlled by a pulse width modulation [4]. Backlight flashing reduces motion blur but it also causes fluctuation in luminance. If the flashing rate is not high enough, the luminance fluctuation can be seen by human eyes, hence, causing eye strains. Therefore, in order to surpass the human eye limit (MPRT 5.7 ms [6]), some advanced CCFL control methods are used, such as the active lamp technique presented by Yoon *et al.* [6].

Signal overdrive [7] is another commonly used method to reduce motion blur. The motivation to overdrive a signal is that the phase change of an LC is faster if the electric field is stronger. This phenomenon is explained in [1] and experimentally verified in [8]. Therefore, if the input signal is changing from 0 to 200 (in grayscale), then instead of sending a signal from 0 to 200, the overdrive circuit produces a signal from 0 to 210 (or a different value, depending on the circuit). Signal overdriving is often implemented

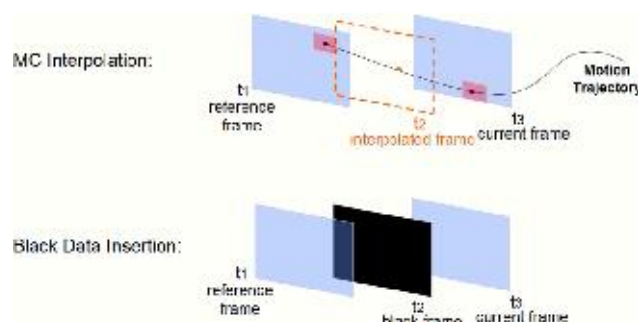


Fig. 2. Two commonly used frame rate up conversion (FRUC) method. Top: full frame insertion method by motion compensation (MC). Bottom: black frame insertion method.

Using a lookup table, and a particular value is determined by the intensity change of a pixel. Image contents such as spatial and temporal consistencies are not considered. Frame rate up conversion (FRUC) schemes is the third class of methods. The motivation of FRUC is that if the LC response can be improved, then the frame rate of LCD should also be increased. There are two major FRUC methods in the market: one is black frame insertion, as presented by Hong *et al.* [9], Fig. 2 illustrates these two FRUC methods. The last class of methods is the signal processing approach, in which the input signal is over sharpened so that it can compensate the motion blur caused by the LCD. Among all the methods, the motion-compensated inverse filtering (MCIF) techniques presented by is the most popular one. MCIF first models motion blur as a finite impulse response (FIR) filter. Then, it finds an approximated inverse of the FIR filter to over sharpen the image. MCIF can also be used together with FRUC scheme. Another signal-processing approach is the de convolution method The de convolution method gives better image quality than MCIF in terms of peak SNR (PSNR) and visual subjective tests.

III. Proposed System

There are three objectives of this paper: modeling, simulation, and algorithm.

First of all, we present a mathematical model for the hold-type LCD motion blur in the spatiotemporal domain. We do not consider the problem in the frequency domain because a video sequence is intrinsically a space-time signal. It is more intuitive to study the motion blur in the spatiotemporal domain directly. The modeling part of this paper is a generalization of a fundamental equation for LCD motion blurs modeling [(7)]. However, they implicitly assume that the human eyes are able to track objects perfectly. This is not true in general because our eyes have only limited range of tracking speed. Do not explain the cause of such a limit and they do not justify their MCIF design from a human visual system point of view. In contrast, our study of the eye-tracking limit is based on literature of cognitive science and verified using subjective tests. The second objective of this paper is to provide a tool for the simulation of motion blur. A limitation of Pan's equation [(7)] is that the integration has to be performed in the temporal domain. To do so, the time step of the integration should be small, for otherwise, the integration cannot be approximated using a finite sum. Since the frame rate of a video sequence is fixed, in order to make the time step small, we need to interpolate intermediate frames. Temporal interpolation is time consuming: if the time step is $1/10$ of the time interval between frames, then ten intermediate frames are needed. Therefore, the simulation of motion blur will be difficult.

The spatiotemporal equivalence has been used extensively in the literature but not proved. It is used the spatiotemporal equivalence to improve LCD image quality; Becker used the spatiotemporal equivalence to show the relation between blur edge width (BEW) and blur edge time for backlight scanning [4]; Tourancheau used the spatiotemporal equivalence to compare four commercially available LCD TVs Klompenhouwer showed the relation between BEW and frequency response of the blur operation Yet, none of these papers attempted to prove the patio temporal equivalence rigorously. The most relevant paper in proving the spatiotemporal equivalence drew a connection between the spatial and temporal apertures in a somewhat different—and very elegant—manner. However, a precise numerical approximation scheme for evaluating the continuous time integration in the discrete spatial domain is not pursued. Also, Klompenhouwer's paper is focused on the unit step input signal (which is a 1-D signal), whereas our study focuses on the general video signals. The third

objective of this paper is to propose a de convolution algorithm based on the spatiotemporal equivalence. A limitation of MCIF is that the MCIF cannot take into account of the spatial and temporal consistencies. Spatial consistency means that a pixel should have a value similar to its neighbors, unless it is along an edge in an image. Temporal consistency means that a pixel value should not change abruptly along the time axis, for otherwise; it will be seen as flickering artifacts. In this paper, we use a spatial regularization function to penalize variations in the spatial domain caused by noise. The L1-normed regularization function used in our method is able to suppress the noise while preserving the edges. We also use a temporal regularization function to maintain the smoothness of the images along the time axis. Proposed similar regularization functions in the context of coding artifacts removal. However, their problem setup is easier than ours because there is no blurring operator in their problem.

Organization

The organization of this paper is as follows. We prove the spatiotemporal equivalence. We show by experiments that the spatial approximation to the temporal integration is accurate. we present the findings of human-eye tracking limits. Visual subjective tests are used to determine the optimal length of the FIR motion blur filter. In Section IV, we present the proposed algorithm. Comparisons with MCIF and Lucy–Richardson algorithm are discussed.

IV. Eye Movement Limit

We assume that our eye-tracking system is perfect, i.e., we can track moving objects at any speed. This assumption makes the derivation simpler, but it is not true in reality. A more realistic model is that our eyes have a speed limit. We provide supports to this argument through the literature in cognitive science and visual subjective tests.

A. Eye Tracking

Eye-tracking system, he mentions that when we look at a scene, our eyes are rapidly moving. The rapid movement is known as the saccades, which can be as high as 500. However, at such a high speed, we can hardly see any visual content. This phenomenon is known as the saccade suppression. Therefore; most of the images perceived are obtained during a period of time (typically about 200–300 ms) between saccades. This period is known as the fixation. If an object is moving quickly, then the duration of fixation is shortened, and hence, the perceptual quality reduces. Therefore, even if our eyes may be able to track an object, we may not be able to see what it is. The relation between object speed and perceived sharpness can be concluded from the following findings. In their first experiment, they asked the

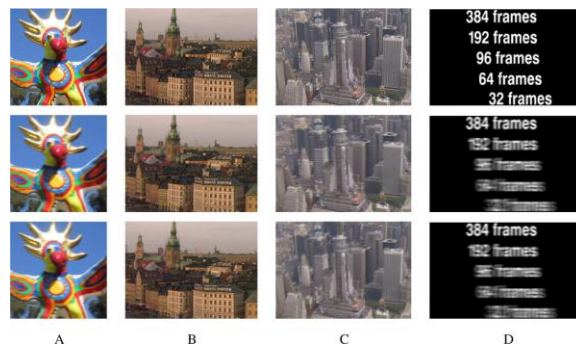


Fig. 3. Simulation results of spatial and temporal integration. Top row: original input image; middle row: simulated blur using spatial integration; and bottom row: simulated blur using temporal integration.

Viewers to track a moving image with their heads stay at a fixed position (referred to as the fixation condition). The conclusion is that the perceived sharpness drops to a minimum score when picture speed is beyond 5 s . In the second experiment by Viewers were allowed to move their heads (referred to as the pursuit condition). The conclusion is that the perceived sharpness drops to a minimum score when picture speed is beyond 35 s studied a mathematical model for temporal sub sampling. They mentioned that there is a maximum Eye-tracking velocity of 5 –50 s, which had been experimentally justified. The discrimination of human eyes on televised moving images of high resolution (300 lines) and low resolution (150 lines). Their results show that it is harder for human eye to discriminate high- from low resolution images if the speed increases.5) Studied the relation between pursuit eye movement and perceptual performance. The viewers were asked to track a moving image of speed 4 s. Results show that the recorded the eye velocities are ranged between 3 and 4.5 s . The conclusion of these findings is that when picture motion increases, the perceptual sharpness decreases. In some

experiments, the maximum picture speed is found to be 5 for fixation condition, and 35 s for pursuit condition. Beyond this threshold, our eyes are unable to capture visual content from the image.

V. Deblurring Algorithm

The objective of this section is to propose a de blurring algorithm for LCD motion blur reduction.

A. Optimization Formulation

First, by spatiotemporal equivalence, we know that the observed (blurred) image is related to the original (sharp) image by a linear convolution.

B. Spatial Regularization

The spatial regularization function is defined by the gradients of the image. Specifically, we define the directional gradient operators

C. Temporal Regularization

Although the spatial regularization function can be applied to each frame of a video individually, the temporal consistency of the video is not guaranteed. Temporal consistency describes whether two adjacent frames have a smooth transition. If a pixel has a sudden increase/decrease in brightness along the time axis, then it is said to have temporal inconsistency. Note that pixels around the edges of the window have different intensities in the two adjacent frames, although they are at the same location. To enhance the temporal consistency, we introduce regularization function along the temporal direction.

VI. Simulation & Synthesis Results



Fig.4 Blurred video

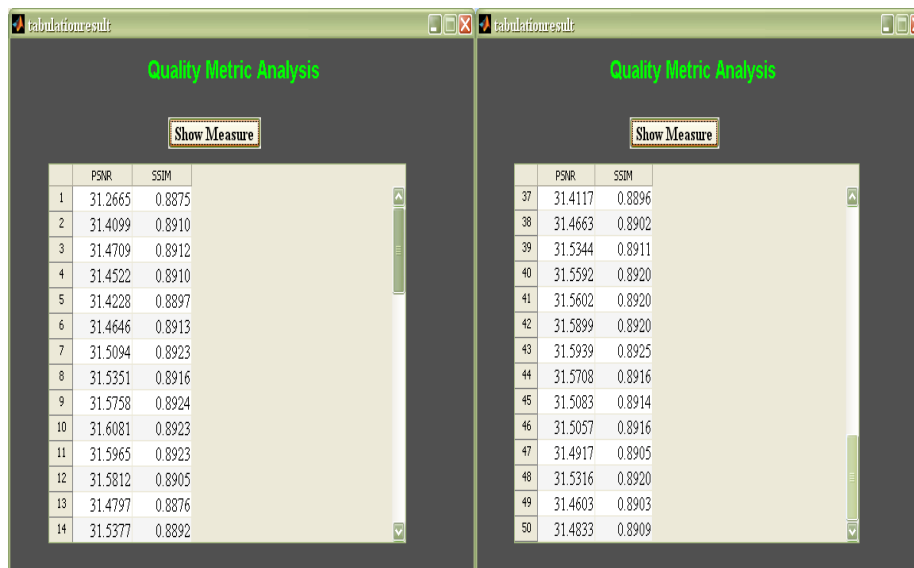
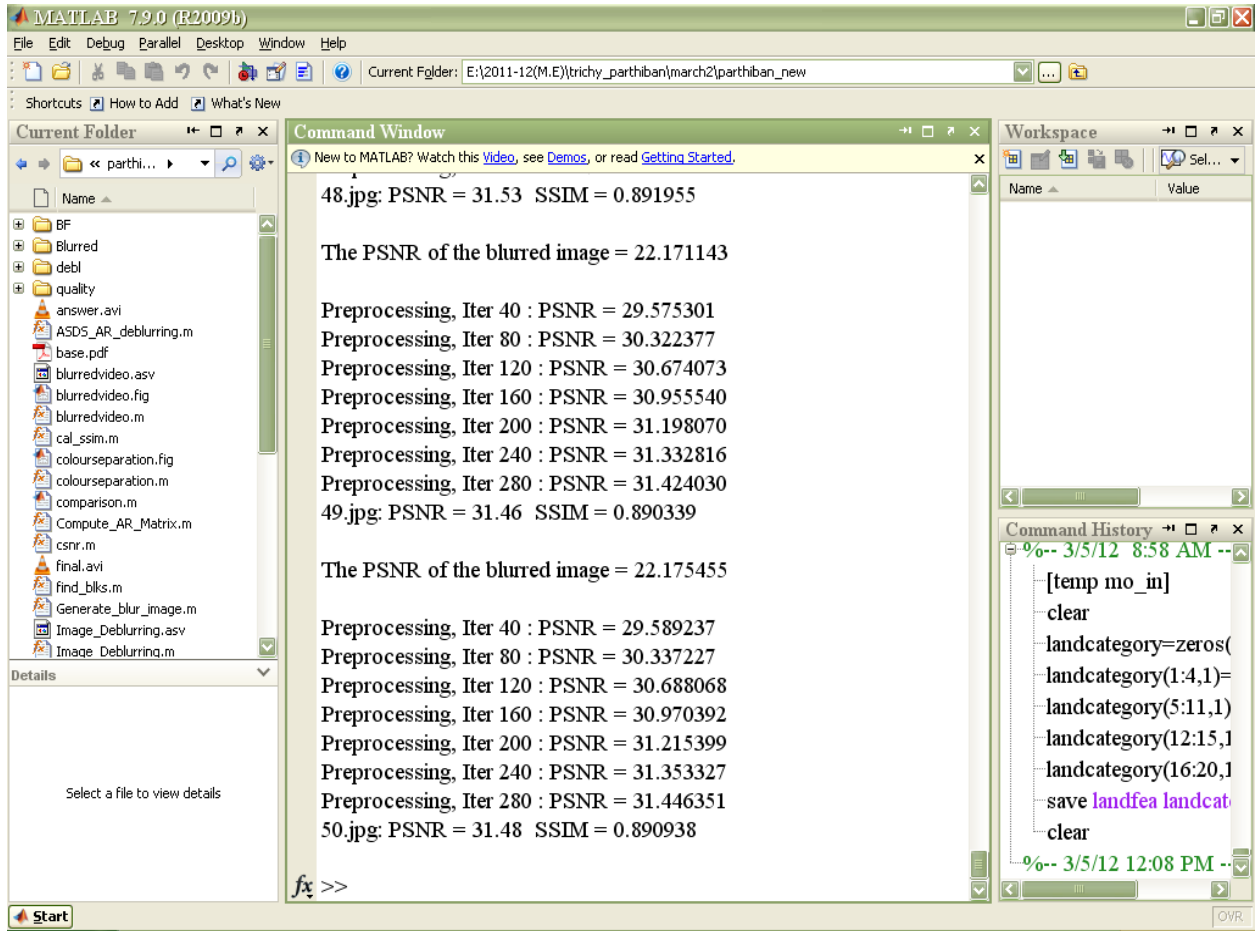


Fig 5. Quality metric analysis

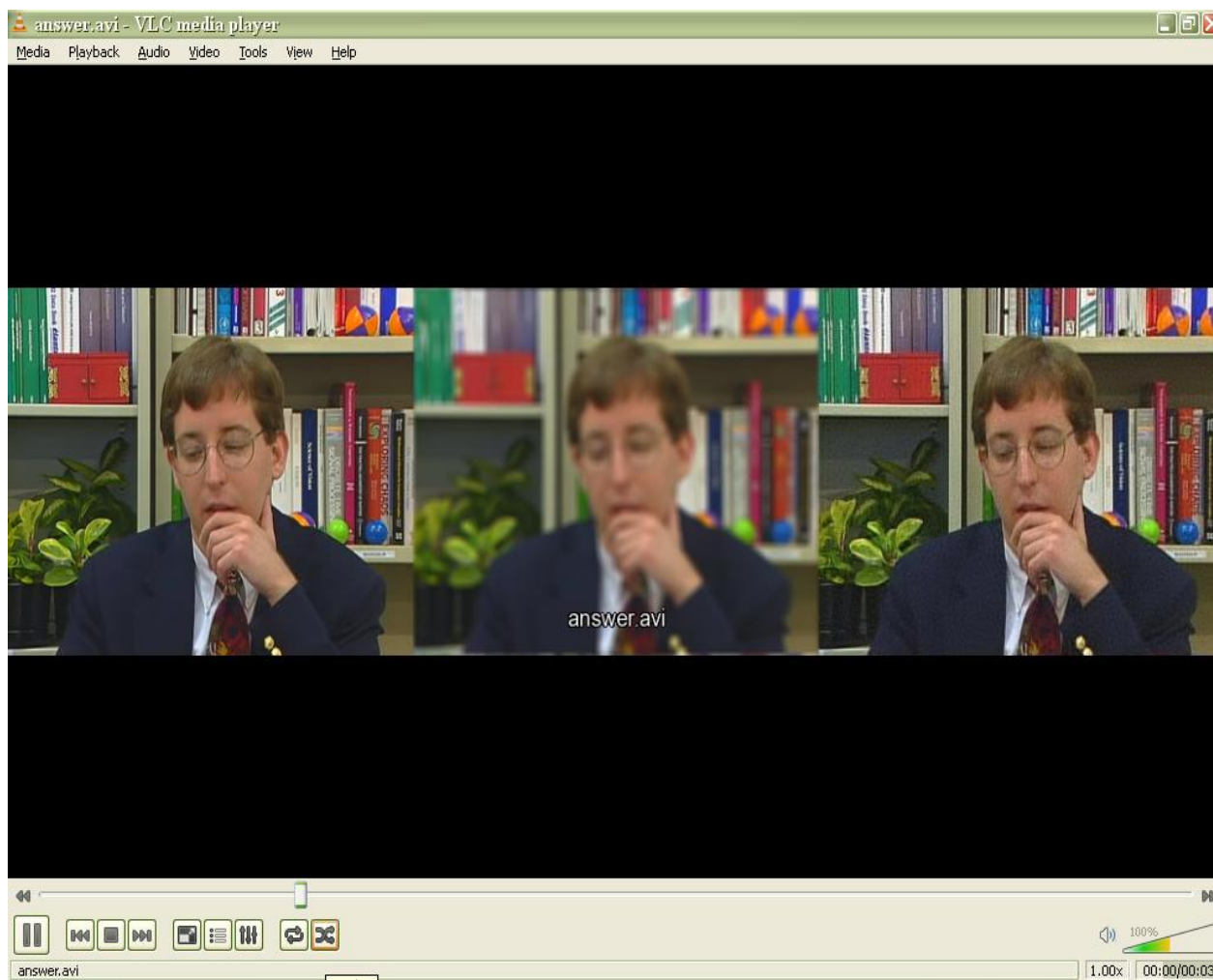


Fig 6. Input, Output Video Comparison.

VII. Conclusion

This paper has three contributions. First, we proved the equivalence between temporal and spatial integration. The equivalence allows us to simulate the LCD blur efficiently in the spatial domain, instead of a time-consuming integration in the temporal domain. Second, we studied the limit of eye movement speed. Based on a number of papers in the cognitive science literature, we showed that perceptual quality reduces as picture motion increases. Beyond certain speed limit, human eyes cannot retrieve any useful content from the picture. Consequently, we showed that the size of the LCD motion blur filter should be limited, and the optimal size can be determined using a visual subjective test. Third, we proposed an optimization framework to preprocess the LCD signal so that it can compensate the motion blur. In order to maintain the spatial and temporal consistencies, we introduced an ℓ_1 -norm regularization function on the directional derivatives and an ℓ_2 -norm regularization function on difference between current and previous solutions. Experimental results showed that our proposed method has relatively higher PSNR, and lower spatial and temporal error than state-of-art algorithms. Future research directions include the robustness of the algorithm toward the errors introduced by motion estimation algorithms, and methods to restore texture areas.

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