Characterization of Motion Interpolation in 120Hz Systems

Byung Hyuk Shin, Kyungwoo Kim, Minkyu Park, Brian H. Berkeley

LCD Technology Center, LCD Business, SAMSUNG ELECTRONICS CO., LTD

Asan-Si, ChungKorea

TEL:82-41-535-5442, e-mail: bh04.shin@samsung.com

Keywords : 120Hz, motion estimation, motion compensation, artifact, text

Abstract

Motion interpolation is adopted and has been spread widely into market since it is effective in reducing motion blur, which is considered as weak characteristic due to slow response time of liquid crystal and hold-type display. 120Hz driving using interpolated frames achieves better moving picture quality with less motion blur and less motion judder. However, errors in the interpolated frames can cause visual artifacts such as static text breakup, halos, and occlusions. This paper focuses on categorizing characteristics of visual artifacts and on reducing side-effects by using information from original frames in special cases.

1. Introduction

120Hz double speed driving of liquid crystal displays (LCD) has been implemented to overcome motion blur due to hold-type driving in LCD panels [1]. The basic concept of 120Hz driving is to insert an interpolated image, which is calculated based on motion vectors (MV), between incoming 60Hz frames [2] [3]. By using motion interpolation and double speed driving in this way, LCDs can cut hold time in half, thereby theoretically cutting motion picture response time (MPRT) in half as well. However, the interpolated frames are not always ideal because of errors in estimating MVs and in generation of the interpolated images. Interpolated images are calculated based on MVs of original frames with a motion compensation algorithm. Because visual artifacts are algorithm dependent, the same visual artifact is repeated under similar conditions. For this reason, one 120Hz display system may show a corrupted subtitle or a broken on-screen display (OSD) when overlaid on a fast moving object, while another system may show almost no breakup in text information when displaying the same image sequence.

In particular, in order to eliminate judder in case of a 3-2 pull-down film source, a 120Hz display system extracts MVs from the incoming 24Hz original film frames, and then inserts 4 different interpolated images between the original frames to form the 120Hz image sequence. This kind of 120Hz display system can achieve smooth movement of objects in film mode with this dejudder feature. However, in this case visual artifacts are even more perceivable because there are four times as many interpolated images compared to the original 24Hz images, and some approaches use recursive algorithms to create the motion interpolated images, which can cause even more errors.

2. 120Hz Technology

This paper categorizes visual artifacts as a side-effect of 120Hz driving technologies. Movie judder, spatially or temporarily perceivable artifacts, text artifacts and object flashing artifacts are categorized according to symptoms in table 1. Because current ME/MC technology is imperfect, evaluation of a 120Hz display system should consider all of these artifacts, which are not necessarily observable in conventional 60Hz driving systems.

Due to interpolation artifacts, text information in a 120Hz display system can easily be corrupted. This paper focuses on achieving better legibility in 120Hz display systems. A driving scheme is proposed to minimize visual artifacts especially in content with scrolling or static text. Other artifacts are categorized as well in this paper. Scrolling text and static text visual artifacts are shown in figures 1 and 2, respectively.

2.1. Scrolling Text

Scrolling text commonly appears in video input and is often used as a good criterion to evaluate performance of 120Hz display systems compared to their 60Hz counterparts. Scrolling text in a liquid crystal display (LCD) is often used to show the benefit of deblurring in 120Hz display systems. However, breakup of scrolling text can reduce legibility. To improve performance of scrolling text, smooth movement and legibility of text without visual artifacts should be achieved. Text can scroll horizontally or vertically. To extract MV information of vertically scrolling text, larger line memory is required as the algorithm requires MV information over a larger vertical range. Scrolling text sometimes moves too fast for MV information to be captured. In this case, some 120Hz display systems will disable the motion interpolation (MI) function in order to prevent visual artifacts that may be even more objectionable than the blurring itself. Hence it is helpful to extract information about moving text and to calculate motion vectors of that text. Another case is often called "mixed mode", which has scrolling video-rate text overlaid on film contents. If the entire screen is handled as film content, scrolling text will show broken movement. Alternatively, film content will show judder if video handling is applied to the entire screen contents. To prevent this side-effect, the driving scheme proposed in this paper recommends disabling motion judder compensation (MJC) within the scrolling text area as will be described in Figure 3.

Fig. 1. ME/MC artifact in scrolling Text

2.2. Halo and Occlusion

Halos and occlusions are considered as common side-effects of ME/MC systems and can be seen in most 120Hz display systems on the market today. Halo is observed as smearing along the contour of a moving object against a complex background. Occlusions result in a similar visual artifact, but occur at an object boundary when different MVs meet and cross. Halos or occlusions usually depend on the object size, complexity of background image and on the magnitude of the MV. Therefore, various test contents are needed to evaluate halo and occlusion performance. To prevent halos and occlusions, it is required that the system have a metric that measures complexity in calculating the interpolated frame. With this information, the MI engine can apply global fallback, in which case interpolation is disabled and the original frame is repeated instead.

2.3. Static Text

Subtitles in movies, closed captions and overlaid menus in TV are all examples of static text. These are enabled by end users, and their legibility is a very important feature for display systems. Some 120Hz display systems show serious breakup in static text due to interference by MVs of overlaid objects. Preserving visual quality requires special signal processing because static text has a zero MV that can easily be corrupted by a non-zero MV, especially large MVs associated with fast moving objects.

To minimize side-effects on static text, the area information for static text can be helpful because location of the static text does not change. For example, subtitles in movies are usually located at the bottom of the scene and OSD menus are typically at the center of the screen. With a priori knowledge of the static text location information, an ME/MC algorithm can generate interpolated images with fewer static text artifacts.

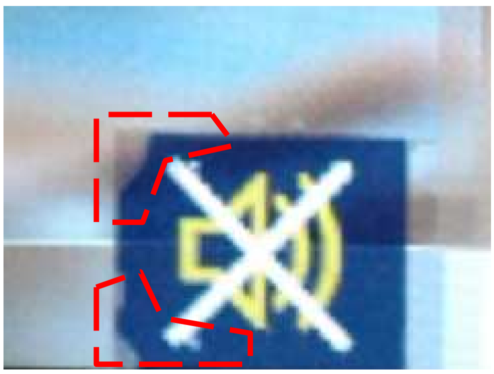

Fig. 2. ME/MC artifact in static text

2.4. Frame Doubling on Text Information

120Hz display systems are now widely considered to be an effective countermeasure for hold-type driving induced motion blur. But most current 120Hz solutions have a disadvantage in terms of image breakup or interpolation noise. To reduce these side effects, 120Hz display systems can use frame doubling when there is a high probability of image breakup. MV matching is a good criterion to use for deciding whether to interpolate or to revert to frame doubling. The MV map can also be used to detect static text by analyzing distribution of MVs in previous and current frames. In particular, subtitles in film should have zero MVs, usually with the same luminance. If it is determined that there is a region which contains subtitles, the 120Hz display system may apply frame doubling specifically to the subtitle region.

TABLE 1. Artifacts in 120Hz systems

<table>
<tr><th>Category</th><th>ME/MC artifacts</th></tr>
<tr><td>Film Judder</td><td>Motion Judder</td></tr>
<tr><td rowspan="4">Spatially perceivable artifact</td><td>Halo and Occlusion</td></tr>
<tr><td>Repetitive Pattern</td></tr>
<tr><td>Color Breakup</td></tr>
<tr><td>Block Breakup</td></tr>
<tr><td>Temporarily perceivable artifact</td><td>Flicker
(Image Dependent)</td></tr>
<tr><td rowspan="3">Text artifact</td><td>Scrolling Text Breakup</td></tr>
<tr><td>Static Text Breakup</td></tr>
<tr><td>Mixed Mode</td></tr>
<tr><td rowspan="2">Flashing object artifact</td><td>Thin Line Error</td></tr>
<tr><td>Small Object Error</td></tr>
</table>

3. Proposed Driving Scheme

The scheme used to reduce artifacts in 120Hz display systems is proposed in Figure 3. The sequence of this scheme is as follows:

1) Calculate edges within the image by applying a high pass filter (HPF) to the current frame image (Fn). Usually HPF enables extraction of sharper edge information.

2) Match calculated MVs to image edges.

3) Calculate MV distributions at the edges of objects in the image; it can be assumed that there is static text or scrolling text if zero-MVs or the same MVs comprise a large portion of the MV distribution at the object edge.

4) Calculate luminance distribution in the previous (Fn-1) and current images (Fn); luminance distribution can indicate static text information because constant color or constant luminance dominates the distribution when there is static text or scrolling text. For better image quality, information from the color domain should also be considered to extract static text information.

5) Extract static/scrolling text area from 1), 2), 3) and 4).

6) When scrolling text is detected, it is recommended that the ME/MC algorithm not apply MJC to the scrolling text area.

7) If static text is detected, the ME/MC algorithm extracts static text information and the frame image without static text is sent to the ME/MC block for generation of the motion interpolated image.

8) ME/MC block generates a motion interpolated image (F'n-0.5) between the original frames. Various approaches, such as block matching and phase plane correlation, have been reported for use in motion estimation and compensation.

9) Extracted static text from step 7 is overlaid on the interpolated frame (F''n-0.5).

10) ME/MC algorithm calculates error for incoming source signal, detecting if there is a need for fallback. In case of fallback, the ME/MC block repeats the original frame to hide the artifact.

Figure 3 shows a simplified diagram of this scheme. This approach can utilize various MV search windows in order to achieve optimized performance.

4. Conclusion

High speed driving is gaining mainstream acceptance as a means of motion blur reduction for LCD-TV systems. However, various interpolation artifacts can degrade image quality. This paper categorizes the various artifacts to serve as a roadmap for system evaluation and future improvement. Although ME/MC algorithms have not yet achieved perfection, better solutions can be expected to improve performance of each of the categorized items.

This list should be updated as high speed driving systems undergo further improvement.

This paper also provides a driving scheme which can improve performance, especially text legibility, of high speed LCD-TV systems. Future work will focus on elimination of other artifacts, such as repetitive patterns, thin line artifacts and halos.

5. Reference

1. Taesung Kim, Bongim Park, Byunghyuk Shin, Brian H. Berkeley, Sang Soo Kim, *SID`06 Symposium Digest*, Vol. 37, p1793, (2006).
2. Sang Soo Kim, Nam Deog Kim, Brian H. Berkeley, Bong Hyun You, Hyoungsik Nam, Jae-Hyeung Park and Junpyo Lee, *SID`07 Symposium Digest*, Vol. 38, p1003, (2007).
3. Sunkwang Hong, Jae-Hyeung Park, and Brian H. Berkeley, SID`06 Symposium Digest, Vol. 37, p1892, (2006).

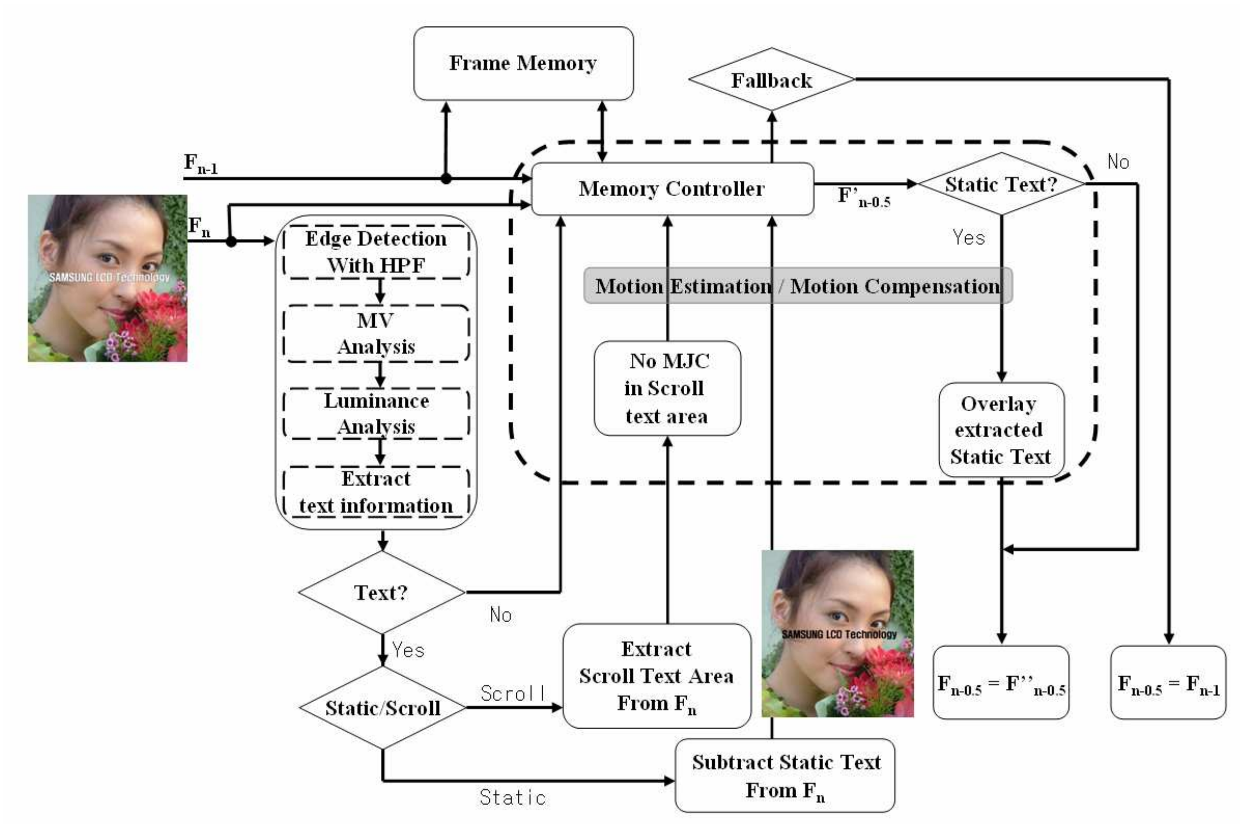

Fig. 3. Driving scheme for legibility improvement