26.3: Motion Interpolation Performance of 120Hz Display Systems

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Abstract

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 described 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, halos/occlusions, and static text visual artifacts are shown in figures 1, 2, and 3, respectively.

Figure 1. Scrolling text

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 4.

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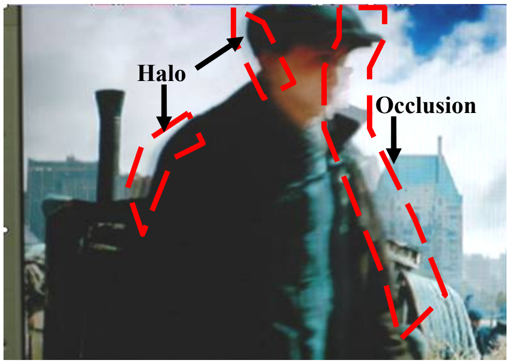

Figure 2. Halo and occlusion

2.2 Halo and Occlusions

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. As shown in Fig.2, a 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. It is also a requirement to have seamless transitions as the MI engine switches between interpolation and global fallback modes.

Figure 3. OSD breakup

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.

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.

3. Proposed Driving Scheme

The scheme used to reduce artifacts in 120Hz display systems is proposed in Figure 4. 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 (F_n). 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 (F_{n-1}) and current images (F_n); 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 4 shows a simplified diagram of this scheme. This approach can utilize various MV search windows in order to achieve optimized performance.

4. Summary and Future Work

This paper focuses mainly on categorizing visual artifacts in 120Hz display systems and on reducing their impact by applying frame doubling or other handling when appropriate. Having a categorized list of the various artifacts will provide better criteria for evaluation of 120Hz display systems. Many contents are used for evaluation, but there is no standardized evaluation clip for 120Hz display system. Future work is needed to develop standard evaluation content for 120Hz display systems.

Special care must be taken in 120Hz display systems to ensure legibility. 120Hz interpolation systems can reduce visual artifacts from interpolation errors as well as achieve better moving picture quality with a well-organized frame doubling scheme and by the method proposed in figure 4, which is based on text information in the source signal. A determination of whether to apply frame doubling depends on the interpolation system performance. This determination should be based on specific error-prone patterns so that motion blur reduction can be maximized while minimizing any corresponding increase in interpolation-related visual artifacts.

Table 1. Artifacts in 120Hz display systems

Category	Artifacts in 120Hz Display Systems	Description
Film Judder	Motion Judder	120Hz technology eliminates motion judder by inserting interpolated frames between original frames. There are cases for which 120Hz display systems show motion judder due to an absence of motion compensation for film contents or inferior motion compensation.
Spatially Perceivable Artifact	Halo and Occlusion	As depicted in Figure 2, a 120Hz display system shows an unexpected translucent contour along a moving object with a complicated background. A halo in the occlusion area is one of the most common artifacts in 120Hz display systems.
	Repetitive Pattern	Repetitive patterns have a high component of constant spatial frequency. Artifacts occur when the ME/MC algorithm errs in matching an object comprised of this content in the previous and current frames. Artifacts may be easily observed when a moving object is overlaid on a repetitive pattern, or when repetitive patterns are in motion.
	Color Breakup	120Hz display system shows color distortion in a moving object due to the fact that some ME/MC algorithms only consider luminance information to calculate the motion vector.
	Block Breakup	Due to motion interpolation calculation errors, algorithm-dependent block breakup occurs. It is often related to the search range of the algorithm, and may also be observed as smearing around a moving object. If the artifact is due to MVs being too large or outside of the search range, this artifact will be most easily observed with large objects moving at high speed.
Temporarily Perceivable Artifact	Image Dependent Flicker	The combination of deinterlacing and the interpolation algorithm can cause flickering in a 120Hz display system depending on source signals. Flicker may also be seen when the ME/MC algorithm has errors in generating an interpolated image from source signals with small, repetitive patterns.
Text Artifact	Scrolling Text Breakup	Breakup in scrolling text is shown in Figure 1. Breakup in scrolling text is more easily observed when text is scrolling over a complex background. Scrolling direction can be horizontal or vertical, and the breakup can be both direction and speed dependent.
	Static Text Breakup	Breakup in static text is shown in Figure 3. Static text includes closed captions, logos, subtitles and OSDs. When large motion vectors overlap static text, static text breakup may be observed.
	Mixed Mode	Mixed mode refers to video-rate scrolling text overlaid on film-rate contents. In this case, the algorithm should detect the scrolling text and movie background separately, and different handling should be applied. Otherwise, the scrolling text will appear to shake, causing deterioration of the text legibility.
Flashing Object Artifact	Thin Line Error	Due to interpolation errors, a thin line or small object may disappear in the interpolated frame. Hence, small artifacts or thin lines may be perceived as blinking in the 120Hz display system.
	Small Object Error	

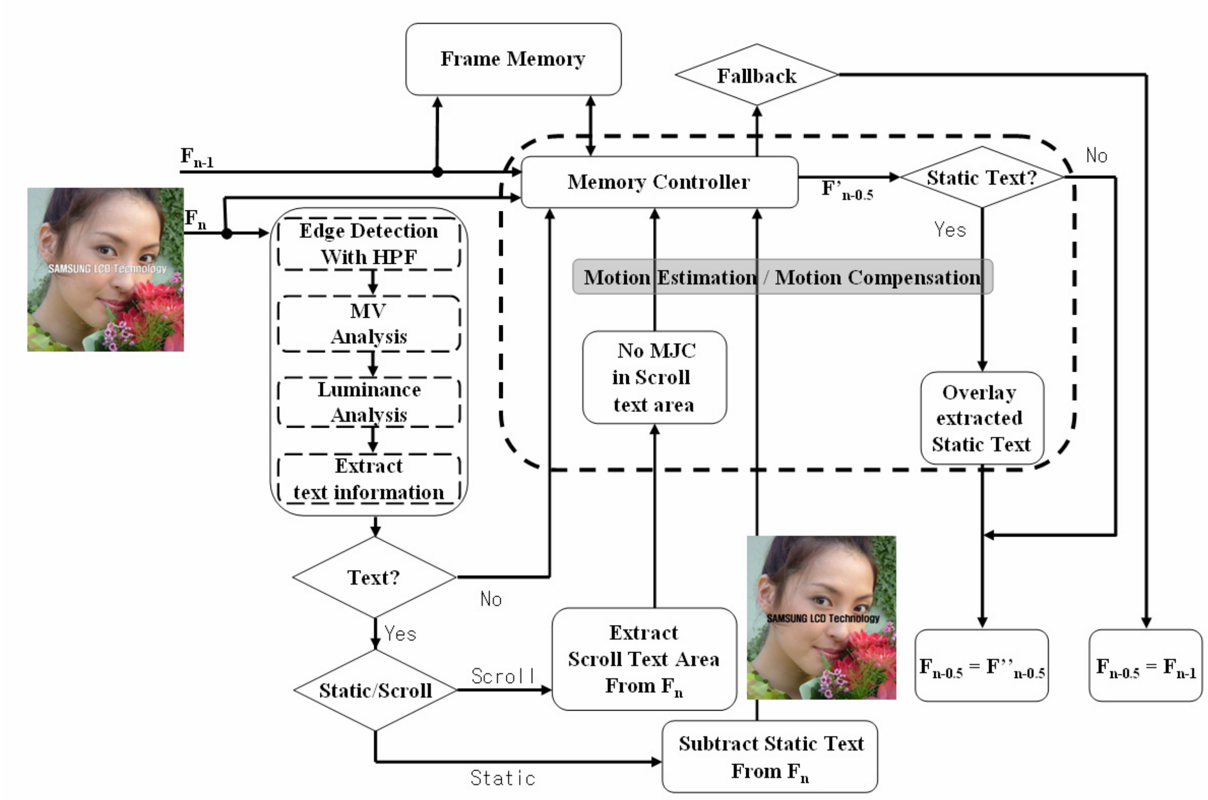

Figure 4. Proposed driving scheme for improved 120Hz display system

5. 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 line 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.

6. References

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