Advanced Frame Rate Conversion without Halo and judder effect for 120Hz LCD Displays

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Abstract

Frame rate conversion became key technology due to recent advances in LCD panel refresh rates. Although many FRC algorithms have been developed and applied for LCD TV sets, they still suffer from well-known halo artifact. This paper discusses about the artifacts and method to handle them.

1. Introduction

LCD TV market is moving rapidly to 120Hz LCD TV. In the worldwide market for 40" or larger screen LCD TV, the market volume for 120Hz LCD TV is estimated to grow from 14.8% of 2008 to 75.4% by 2012 [1]. The 120Hz driving technology has been initially motivated by the need to overcome motion blur of LCD TV. A key technical challenge for 120Hz driving is generating new image frames between original frames to support faster display frame rate from low rate sources. Typical source frame rate is 24/25 or 60/50Hz.

Until now, many FRC algorithms [2, 3] have been proposed and some of them were implemented with ASIC. Their main approach is to estimate the motion flow between original frames and interpolate new frames based on the motion field. A major well-known problem of FRC is the halo effect which is caused by false motion field. Figure 1 shows some example images showing halo effect. Many factors such as occlusion, object deformation, blurring, overlapping, and luminance variation can cause false motion fields during motion field estimation. Halo effect is visually very annoying because it distorts image content with noticeably wrong image patch. Thus, it is crucial to first try and overcome these obstacles during motion estimation, and even more crucial to avoid halo effects during frame interpolation when false motion fields could not be avoided.

Fig. 1. Example of halo artifacts, left image with original frame and right image magnifying halo artifacts in the interpolated frame

The goal of this paper is to discuss algorithm issues regarding halo artifacts and shows a method to remove them.

2. Problem Description

The most common FRC approach is motion compensated FRC that requires motion estimation. It finds object motion from the scene by comparing image contents and generates new frames based on estimated object motion. Luminance invariance is basic assumption in comparing image contents. However, this assumption is not always true in real images and results to visible artifacts in the interpolated frame. An FRC algorithm should overcome these artifacts with reasonable complexity.

A block diagram of generic motion compensated

FRC algorithm can be drawn in Fig. 2.

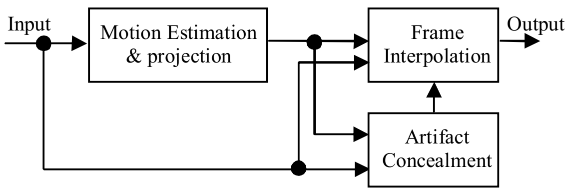

Fig. 2. A block diagram of generic motion compensated FRC

There are many motion estimation techniques such as block matching, optical flow and phase correlation, etc, but block matching is the most common approach due to relative simple implementation and fast algorithms. Again, basic assumption is luminance invariant. There are many violations against this assumption in real images. Followings are typical cases.

- Motion boundary is not aligned with block boundary (Logo/caption and object boundary)
- Repeated pattern
- Object blurring/distortion
- Flash
- Occlusion

FRC generates new frames between original frames. Thus, motion information is projected to interpolated frame grid. Basic assumption is motion continuity in the temporal direction, but there exist violations against this assumption. Typical cases are

- Motion crossing due to fast motion of small object on the stationary background or fast background motion around small object
- Occlusion

Frame interpolation is to reconstruct a new frame based on projected motion information. It perfectly reconstructs the frame with true motion information, but the motion information can never be true for whole frame due to many violations during motion estimation and projection.

FRC algorithm should solve exceptional cases during each processing step to keep video quality. Image and motion information should be analyzed to increase estimation accuracy and conceal possible artifacts due to violations. Next chapter will describe our approach.

3. Proposed Algorithm

Proposed algorithm consists of motion estimation, motion vector projection, motion refinement, artifact concealment and frame interpolation.

3.1 Motion estimation

We basically uses hierarchical search proposed in [4], but we improved this algorithm by dealing with exceptional cases from luminance invariance.

Basic search scheme undergoes the problem that block boundary is not aligned with actual motion boundary. We further segment image blocks by using available motion. Each 8x8 block can be divided along with motion boundary with 2x2 block resolution. We use matching criteria described in Eq. 1.

$$\text{cost} = \sum_{B}\left(c_0 \cdot E_P^2 + c_1 \cdot E_{\Delta P}^2 + c_2 \cdot \Delta MV_{aN} + c_3 \cdot \Delta MV_{aP}\right) \quad (1)$$

Here, former two components are matching error part. Square error of pixel data and its gradient is used for matching error. Gradient error term helps dealing with luminance change condition between two frames. Last two components are added for spatial and temporal regularity of motion vector fields. Coefficients c_0, c_1, c_2 and c_3 are controlling weights.

We uses bi-directional search: Forward and backward searches. Bi-directional search increases motion accuracy and helps further motion analysis. We treat repeated pattern during motion search and motion analysis step.

3.2 Motion vector projection

Motion vector projection is a unique processing step of FRC algorithm. Motion information of bi-directional search is projected to virtual grid on interpolated frame. Occlusion processing and motion crossing analysis are key processing steps succeeding projection step.

Occlusion processing is to assign background motion to covered/uncovered region. Motion crossing analysis is to identify foreground motion when valid motion crosses at the virtual grid. This case happens when small object moves fast on the stationary background or stationary small object is surrounded by fast moving background.

3.3 Motion refinement

Motion information is further refined after deciding motion vectors on the virtual grid. We use symmetrical search centered at virtual block grid. Main role of this step is to recover motion accuracy based original images.

Another role of this step is to assign validity of motion information. We use validity information to identify the object suffering from corrupted motion.

3.4 Artifact concealment

Artifact concealment is performed in two ways: global artifact concealment and local artifact concealment. Global artifact concealment turns on when motion information is corrupted over significant area of the frame. Scene change, fast motion beyond motion search range and flashing are the cases for global artifact concealment.

We use motion segmentation to isolate moving object with false motion. We first calculate moving pixel based on speed map (See Eq.2 to find definition of speed map).

$$speed(x,y) = \frac{|\Delta P_T(x,y)|}{|\Delta P_N(x,y)|} \tag{2}$$

Here, $\Delta P_N(x,y)$ and $\Delta P_T(x,y)$ are spatial gradient and temporal difference at pixel location (x,y). The speed map enables to find moving pixel even the temporal difference is small due to blurred object. Moving objects are isolated by region growing algorithm using 8-conectivity of moving pixel. We evaluate validity of motion information for each moving region and turn on local artifact concealment when significant ratio of the moving region has false motion.

The information for global and local artifact concealment is delivered to frame interpolation to control interpolation filter.

3.5 Frame interpolation

Frame interpolation has four interpolation modes: Valid region processing, occlusion region processing, invalid region processing and artifact concealment. Motion vectors are available every 2x2 pixels. Thus, interpolation modes can be switched with this resolution. Blocking artifact reduction filter is applied final resulting image to smooth possible 2x2 block boundary.

4. Results and discussion

We tested the proposed method with more than 150 test sequences which have been carefully captured from various sources such as DVD players, broadcasting materials and proprietary company test scenes. All of the test sequences have a frame size of 1280x720 and their source frame rates are 24Hz for film (movie) and 60Hz for broadcasting materials. Frame rate up-conversion ratio was 1:2 and 1:5 for 60-to-120Hz and 24-to-120Hz conversion, respectively.

We compared the results of our proposed method with those of the state-of-the-art FRC algorithm [2] as shown in Figure 3 and Figure 4. Upper images show the result of the method in [2] and Lower images are the result from the proposed method. The proposed method provides more natural images without distortion when there is luminance variation due to moving lightsaver. In addition, proposed method shows better motion field estimation around motion boundary in Figure 4.

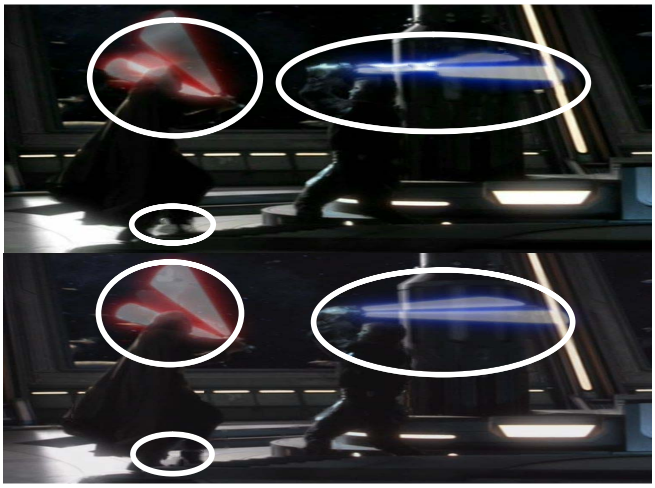

Fig. 3. Performance comparison, Ref[2] (upper) and proposed method (lower)

Fig. 4. Performance comparison, Ref[2] (upper) and proposed (lower).

5. Summary

This paper described exceptional cases that FRC algorithm should solve and proposed a method. Simulation results showed the proposed method concealed halo artifact better than the state-of-the art FRC algorithm.

6. References

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