Complementary Block-Based Motion Estimation for Frame Rate Up-Conversion

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***Abstract*—In this paper, we present complementary motion estimation algorithm for motion compensated frame rate up-conversion. The proposed algorithm combines forward and backward motion estimation results to make up for the weakness of each motion estimation method. It also allocates true motion vectors in occlusion regions by using the temporal relations of the forward and backward motion estimation. Thus, we reduce artifacts by false motion vectors near occlusion regions in a compensated frame.**

I. Introduction

Motion compensated frame rate up-conversion (MC-FRUC) is a widely used method to alleviate blurring of hold type display device such as LCD panel and judder effect of low frame rate image sequences. However, artifacts can be made in a generated frame if a true motion of an object isn't detected. Occurrence of the artifacts is more possible in an occlusion region near object boundary, for it is more difficult to detect a true motion vector in that area.

In this paper, complementary motion estimation, which combines forward and backward motion search results, is proposed. This method makes up for each weakness of the forward and backward motion estimation. By using relations between forward and backward motion search, true motions of occlusion regions can be also detected. The proposed algorithm is simplified by applying block-based structure and implemented to FRC SoC supporting a 240Hz FHD display.

II. Proposed Algorithm

A. Motion vector search

The proposed motion estimation algorithm uses two directional search methods – forward and backward search. The forward search seeks the matching block from a previous frame in a current frame. Oppositely, the backward search uses the block in a current frame as a reference and seeks the matching block in a previous frame. During the motion estimation processing, the forward search is executed first, and then the backward search is carried out.

In motion vector search processing, neighbor and previous motion vectors of a given block are selected as candidates of block matching [1]. The matching cost of a candidate motion vector is defined as a following equation.

$$C = \sum_{B}\left(c_0 \cdot E_Y^2 + c_1 \cdot E_{\nabla Y}^2\right) + c_2 \cdot \Delta MV_N + c_3 \cdot \Delta MV_P \qquad (1)$$

The first and second terms are sum of matching error of the block. The third and fourth terms are weight functions by the neighbor and previous motion respectively, and those terms make the searched motion vectors to maintain the spatio-temporal motion regularity. The motion vector having the minimum matching cost among the candidates is selected as a result motion vector of a given block.

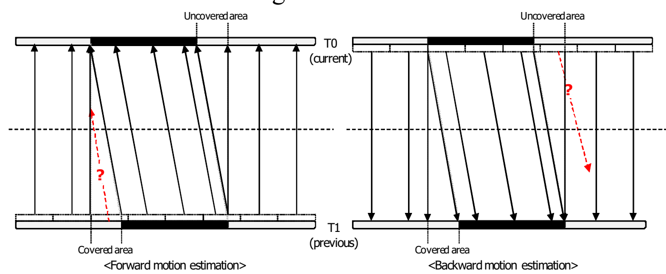

Fig. 1. Forward and backward motion estimation

Normally, we can detect the true motion vector of an object with block matching method if the object exists in both current and previous frames without deformation. However, it is impossible to detect a true motion vector in an occlusion region because no matched object exists in a target frame. As shown in Fig. 1, the objects in covered regions of forward search or uncovered regions of backward search only appear in a reference frame and disappear in a target frame. We define those regions as motion vector (MV-) converging regions because two motion vectors converge in a target frame. In the MV-converging regions, it is more probable that false motion vectors are selected as result motion vectors, and those can make bad effects to following block matching process. Therefore, the quality of motion vectors worsens near MV-converging regions. On the other hand, uncovered regions of forward search and covered regions of backward search are defined as motion vector diverging regions. The quality of motion search is fair in the MV-diverging regions because corresponding objects exist in both reference and target frames.

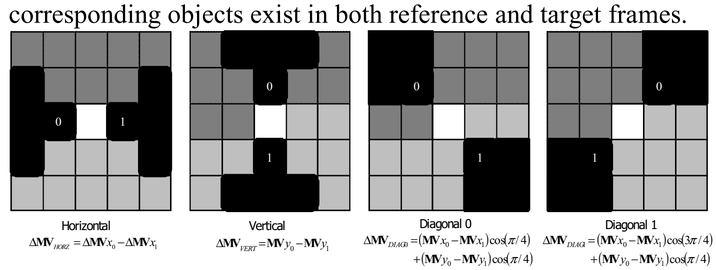

Fig. 2. Detecting a region property

After motion vector search processing, we decide the property of a given block by investigating the spatial relations of neighbor motion vectors. As shown in Fig. 2, 5x 5 motion vectors with a given blocks as a center are gathered and the difference between both side motion vectors is calculated for each four directions – horizontal, vertical and two diagonals. Among four pairs of neighbor motion vectors, the motion vector pair which majorly decides the property of the region is selected. If the selected neighbor motion vectors converge in a target frame, the property of the region is decided as a MV-converging region. On the other hand, the region is marked as a MV-diverging region if those motion vectors diverge toward a target frame. The block of MV-diverging region is segmented to smaller size blocks by the selected two motion vectors. Thus, the motion vectors in a MV-diverging region are more precisely distinguished by the shape of an object boundary.

B. *Motion vector allocation for occlusion regions*

The blocks are projected onto an opposite frame by the detected motion vectors after the forward and backward motion estimation processing. That is, the blocks of the forward motion estimation are projected from a previous frame to a current frame, and those of backward motion estimation are projected reversely. As shown in Fig. 3, the projected blocks in MV-diverging regions make the form of occlusion regions, which are characterized by not-projected areas in an opposite frame. Therefore, the not-projected areas in MV-converging regions, which are decided by the spatial relations of neighbor motion vectors, are defined as occlusion regions. Because the detected motion vectors near occlusion regions are unreliable, they are substituted with the projected motion vectors. Two motion vectors causing the occlusion regions are also selected by spatial motion relation analysis. One of them can be a motion vector of a foreground object, and the other can be that of a background object near the occlusion region.

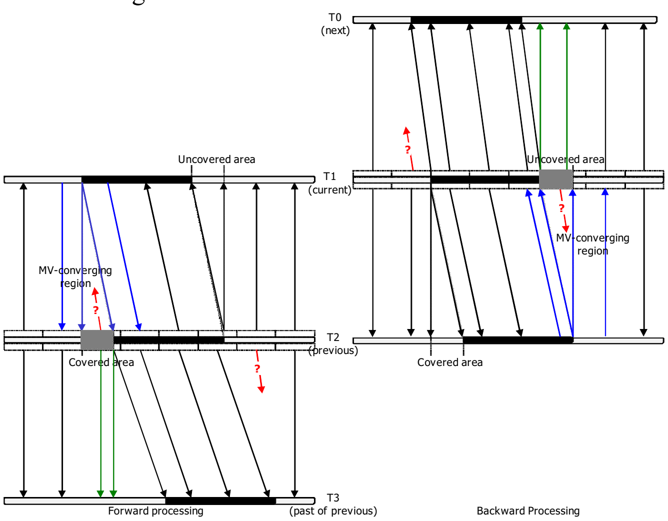

Fig. 3. Allocating motion vectors in occlusion regions

The motion vector of an occlusion region should be equal to that of a background object. We use the temporal relations of motions to detect the motion vectors in occlusion regions. As shown in Fig. 3, a covered area of the forward motion estimation is usually a well-matched region of previous backward motion estimation near a MV-diverging region. Because a directional tendency of an object is usually maintained in an image sequence, it is highly probable that the motion estimation in a current covered region is similar to the motion vector of previous backward motion estimation in the corresponding region. Therefore, between the selected two motion vectors making the covered region, the motion vector more similar to that of previous backward motion estimation is selected as the covered region motion vector, which is marked as an occlusion motion vector of forward processing. In the same way, the motion vector of an uncovered region is also detected by using the motion vectors of next forward motion estimation, and that is marked as an occlusion motion vector of backward processing.

C. *Motion vector field generation in an intermediate frame*

The forward and backward motion vectors are projected onto an intermediate frame to be generated between previous and current frames by a projection ratio, which is determined by the temporal position of a motion compensated frame. The occlusion motion vectors projected from the forward and backward processing results decide the covered and uncovered regions respectively. The occlusion motion vectors projected to a certain block are overwritten by normal motion vectors if the normal motion vectors are also projected to the same block. The projected normal motion vectors are regarded as valid motion vectors if the motion vectors projected to a certain block from both forward and backward processing are similar to each other. Otherwise, the motion vectors of the corresponding block are invalidated and filled by spatial motion vector filtering. This validation processing increases the reliability of normal motion vectors.

III. RESULTS AND CONCLUSION

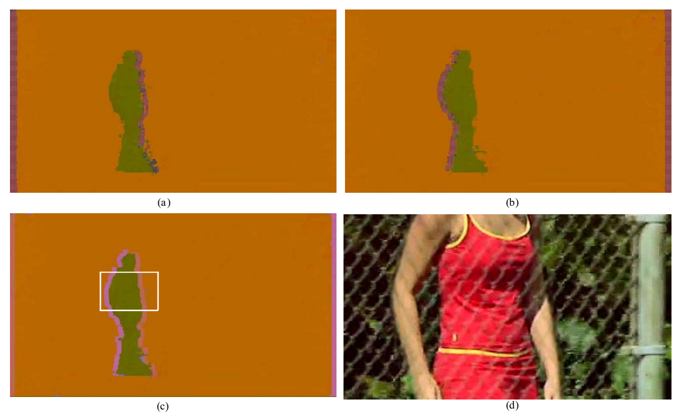

Fig. 4. (a) Forward processing result (b) Backward processing result (c) Motions in an intermediate frame (d) Enlarged compensated image

Fig. 4 shows the motion vector results of the forward and backward motion estimation processing, the projected motion vectors of an intermediate frame and a motion compensated image. The motion vectors of covered and uncovered regions are represented as the occlusion motions in the forward and backward processing results respectively. We can show the distinguished covered and uncovered regions and motion vectors around a foreground object in an intermediate frame. Pixels from only one frame are used for generating compensated images in occlusion regions – a previous frame for covered regions and a current frame for uncovered regions. Therefore, artifacts such as halos or distortions near object boundaries diminish in frame rate up-converted image sequences.

REFERENCE

[1] G. de Hann, P.W.A.C Biezen, H. Huijgen, O.A. Ojo, "True-Motion Estimation with 3-D Recursive Search Block Matching", IEEE Transaction on Circuits and Systems for Video Technology, Vol. 3, Oct. 1993, pp-368-379