FRAME-RATE UP-CONVERSION USING RELIABLE ANALYSIS OF TRANSMITTED MOTION INFORMATION

Hisao Sasai, Satoshi Kondo and Shinya Kadono

AV Core Technology Development Center, Matsushita Electric Industrial Co., Ltd.
1006 Kadoma, Kadoma, Osaka 571-8501, Japan
sasai.hisao@jp.panasonic.com

ABSTRACT

In this paper, we propose a new frame-rate up-conversion algorithm using a vector reliable analysis scheme that reduces artifacts caused by the use of inaccurately transmitted motion vectors (MVs). In conventional up-conversion algorithms using motion estimation (ME), ME is performed between two adjacent decoded frames to construct MVs that allow the frame to be interpolated, irrespective of the amount of calculation for ME required. On the other hand, in conventional up-conversion algorithms using transmitted MVs, the quality of the interpolated frame depend largely on the MV that is derived by the encoder. In our proposed scheme, transmitted MVs are first analyzed to decide whether or not they are usable for constructing interpolation frames. The interpolation method is then adaptively selected from three methods: local motion-compensated interpolation, global motion-compensated interpolation and frame-repeated interpolation. The proposed method provides high quality interpolated frames and decreases the volume of calculation needed, making it especially well suited to multimedia mobile devices that depend on low-power processing.

1. INTRODUCTION

Low bit-rate video coding has played an important role in multimedia devices such as videophones. To achieve acceptable coding results at very low bit-rates, most coding systems, such as MPEG, reduce the temporal resolution [1]. However, this raises the problem of the image sequence appearing jerky, especially during rapid or complex motion. Therefore, mechanisms that increase the frame-rate at decoder level are needed.

One simple - but unsatisfactory - solution is for the last decoded frame is to be repeated until a new one is received. Another simple solution is to use linear interpolation between decoded frames. The problem with this latter solution is that the image sequence will appear blurred in moving areas.

To overcome these problems, motion-compensated frame-rate up-conversion algorithms have been closely studied in recent years. One type performs ME at the decoder [2,3], and the other uses transmitted MV [4]. However, the former algorithms require enormous amounts of calculation for ME, and the later algorithms lead to blurriness and ghost artifacts, especially with transmitted MVs that do not represent true motion.

In this paper, a novel frame-rate up-conversion method is presented, in which interpolation methods are adaptively selected after analysis of transmitted motion information. Our proposed method can reduce artifacts without the need for heavy computation. Also, the proposed method can be applied to all video codec systems using motion compensation. In this paper, the research is conducted with MPEG-4 streams, which are generally used for very low bit-rate coding in narrow-band situations.

Section 2 presents details of the proposed method. In Section 3, experimental results are given and discussed. Section 4 presents our conclusions.

2. PROPOSED METHOD

2.1. Overview

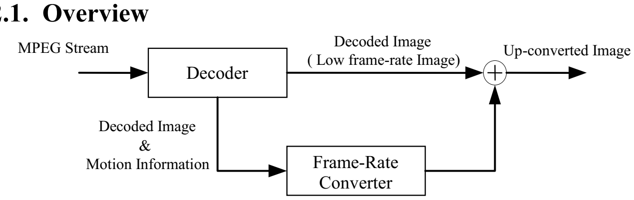

Figure 1. Data flow of the proposed method.

Figure 1 shows the data flow of the proposed frame-rate up-conversion method using decoded motion information. First, the MPEG video stream is decoded and the decoded image and motion information are obtained. The proposed frame-rate converter constructs interpolated frames between the decoded images using this information.

During low frame-rate coding, the current frame unrelated to the previous frame because the time interval between decoded frames is relatively long. In low bit-rate coding, MPEG-4 generally has a configuration that consists of only I- and P-frames. In this paper, we explain the proposed method for the case of this configuration.

Figure 2 shows our proposed up-conversion strategy for the configuration consisting of I- and P-frames. Here we discuss frame interpolation using MVs obtained from video streams. The P-frame includes MVs that represent motion between the P-frame and the previous frame. When Frame #1a is interpolated between P-frame #1 and #2, the MVs included in P-frame #2 are used. In the same way, in case of 3 times up-conversion, MVs from P-frame #2 are used for interpolation of both Frame #1a and #1b. The same can be said for more interpolated frames, so the proposed method can construct multiple interpolated frames. However, I-frames have no MVs. Therefore, Frames #3a and #3b are constructed by repeating P-frame #3 or I-frame #4.

In the proposed method, three interpolation schemes are adaptively selected. Figure 3 is a flow chart of the proposed method, which consists of the following processing.

+ MV Reliability Analysis
  The transmitted MV is analyzed and is decided whether the transmitted MV should be used for constructing an interpolated frame or not.
+ MV Correction
  Unreliable transmitted MV is corrected. Hereinafter, the corrected MV for each macro block (MB) is called local MV.
+ Frame Interpolation by local MV
  An interpolated frame is constructed by using local MV.
+ Calculating GMV
  Unreliable MV is eliminated and global motion vector (GMV) is calculated.
+ GMV Reliability Analysis
  GMV is analyzed and we decide whether GMV should be used for constructing interpolated frames or not.
+ Frame Interpolation by GMV
  An interpolated frame is constructed using GMV.
+ Insertion of Repeated Frame
  A repeated frame is inserted if both local and GMV are unreliable.

The details of each method are described below.

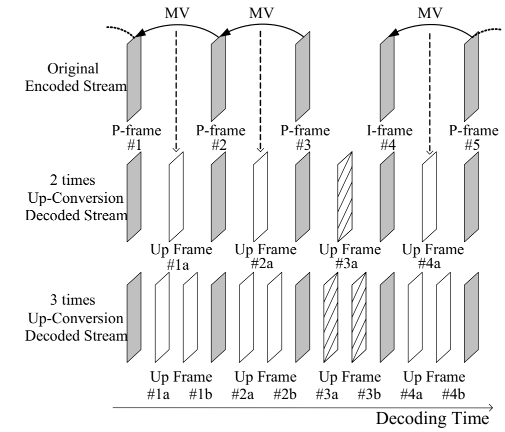

Figure 2. Proposed up-conversion strategy.

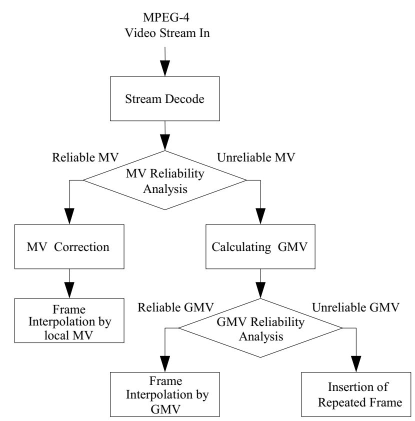

Figure 3. Flow chart of the proposed method.

2.2. MV Reliability Analysis

MVs of video streams adapted to the coding used and do not always represent true motion. Moreover, intra MBs have no MVs. To solve these problems, we analyzed transmitted MVs and decided whether or not their MVs could be used to construct interpolated frames.

The MV reliability analysis method consists of the following three steps: i) Analysis of ratio of intra MB, ii) Detection of isolated MV, iii) Analysis of variance of MV. The following presents the details of each step.

i) Analysis of ratio of intra MB

When a target MB cannot be motion-compensated in the encoder, intra MB is selected for the MB. If there are numerous intra MBs in one frame, then the correlativity between frames is low. The reliability of the MV in the frame with respect to time t can be stated as follows:

$$D_{IntraMB}(t) = \begin{cases} inadequate, & N_{IntraMB}(t)/N_{allMB} > Th_{IntraMB} \\ adequate, & otherwise \end{cases}, \quad (1)$$

where the parameter $N_{IntraMB}(t)$ is the number of intra MBs in frame(t), the parameter N_{allMB} is the number of MBs in a frame, and the parameter $Th_{IntraMB}$ is the threshold that determines whether or not the transmitted MVs are usable for construction of interpolation frame, from the viewpoint of ratio of intra MB.

ii) Detection of isolated MV

It is well known that spatial motion in video signals of natural scenes has strong correlativity. Therefore if the spatial correlativity of transmitted MV is weak, the transmitted MV is regarded as an unreliable MV. The reliability of the *MV*(*i, j*) of the MB *B*(*i, j*) can be stated as follows:

$$MaxMVD(i,j) = \left| MV(i,j) - MV(r_x, r_y) \right| \quad \forall MV(i,j), \quad (2)$$

where the $MV(r_x, r_y)$ values are define by

$$MV(r_x, r_y) = \arg \max_{r_x, r_y \in R(i,j)} \left\{ \left| MV(i,j) - MV(r_x, r_y) \right| \right\}, \quad (3)$$

where the parameter $R(i, j)$ is the adjacent MB of $B(i, j)$.

$$D_{iso}(i,j) = \begin{cases} isorated, & MaxMVD(i,j) > Th_{iso} \\ not \ \ isolated, & otherwise \end{cases}, \quad (4)$$

where the parameter Th_{iso} is the threshold for determining the closeness of the motion vector to adjacent motion vectors.

$$D_{iso}(t) = \begin{cases} inadequate, & N_{D_{iso}}(t) / N_{allMB} > Th_{isoMB} \\ adequate, & otherwise \end{cases}, \quad (5)$$

where the parameter $N_{D\ iso}(t)$ is the number of MBs that have isolated MV and the parameter Th_{isoMB} is the threshold for determining unreliable frames that have many isolated MVs.

iii) Analysis of variance of MV

As mentioned above, the spatial motion in a video signal has strong correlativity, so the variance of MV in one frame is considered to be small. Therefore, we analyze the variance of transmitted MV and estimate the reliability of transmitted MV.

The reliability of the MV in the frame at time *t* can be stated as follows:

$$\delta^2(t) = \sum_{r_x, r_y \in R} MV^2(r_x, r_y) - \left(\sum_{r_x, r_y \in R} MV(r_x, r_y) \right)^2, \quad (6)$$

$$D_{\delta^2}(t) = \begin{cases} inadequate, & \delta^2(t) > Th_{\delta^2} \\ adequate, & otherwise \end{cases}, \quad (7)$$

where the parameter *R* is all the MBs of a frame and the parameter Th_{δ^2} is the threshold for determining an unreliable frame that has inaccurate MV.

If all the three steps in one frame are adequate, then the transmitted MV in the frame is strongly reliable and an interpolated frame is constructed using the local MV.

2.3. MV Correction & Frame Interpolation by local MV

In the case of frame interpolation by local MV, unreliable MVs are corrected to reduce artifacts. It is possible to use the three steps mentioned in Section 2.2 to determine whether the MV should be corrected or not.

If the target MB is intra, the MB has no MV. If Eq.(4) identifies the MV as an isolated type, it is regarded as unreliable and therefore not to be used for interpolation. In these cases, the MV of the target MB is interpolated with MVs of adjacent MBs.

The high-variance area of MV is detected by checking the variance of each MV for region *R* by using Eqs.(6) and (7). MV in this area is considered to be unreliable. Therefore, we correct the MV of this area by using the ratio of MV variance.

Interpolated frames are constructed using the corrected MVs. This interpolation scheme is based on the following principle. In Fig.4, *MV*(*i, j, t*) is calculated using Eq.(8).

$$MV(i,j,t) = MV(i,j,t+r) \cdot \frac{L-r}{L}, \quad (8)$$

where the parameter L is the time interval between the current frame and the reference frame, and the parameter *r* is the time interval between the current frame and the interpolated frame.

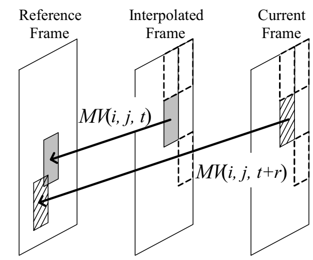

Figure 4. Interpolation MV method.

2.4. Calculating Global Motion

If the result of MV reliability analysis is unreliable, an interpolation frame using local MV will contain many artifacts. However, even in these cases, it is possible to construct a motion-compensated interpolation frame by using GMV.

In the proposed method, the GMV is calculated from reliable MVs.

2.5. GMV Reliability Analysis

There is a risk that the interpolated frame constructed by GMV will contain artifacts if there is a difference between the true movements in the video scene and GMV. To reduce these artifacts, the proposed method analyzes GMV reliability and uses the result to determine whether or not GMV can be used in frame interpolation.

The reason that artifacts occur is that there are several different movements in one frame and GMV is unable to represent all these movements. Our proposed method is to divide each frame into several areas and calculate an area global motion vector (AMV) for each area. GMV is then compared with each AMV and the result of these comparisons is analyzed. The reliability of the GMV in the frame in time t can be stated as follows.

$$N_{GMV}(t) = \sum_{a \in A} d(a,t), \tag{9}$$

where $d(a, t)$ are defined by

$$d(a,t) = \begin{cases} 1 & |AMV(a,t) - GMV(t)| > Th_{AMV} \\ 0 & otherwise \end{cases}, \tag{10}$$

where the parameter Th_{AMV} is the threshold that determines the difference between AMV and GMV. Hence $N_{GMV}(t)$ shows the number of different movement areas.

$$D_{GMV}(t) = \begin{cases} inadequate & N_{GMV}(t) > Th_{GMV} \\ adequate & otherwise \end{cases}, \tag{11}$$

where the parameter Th_{GMV} is the threshold for determining the difference between AMV and GMV.

2.6. Frame Interpolation by GMV & Insertion of Repeated Frame

If the result of GMV reliability analysis shows that it is reliable, an interpolation frame is constructed using GMV. This interpolation scheme is based on Eq.(8). On the other hand, when GMV is unreliable, the interpolation frame is constructed by insertion of a repeated frame. The decoded frame, which is close to the interpolated frame, is inserted repeatedly.

3. EXPERIMENTAL RESULTS

To evaluate the performance of the proposed method of frame-rate up-conversion which uses MV reliable analysis, we perform the following experiment. Table 1 shows the conditions under which the video stream was encoded.

Table 1. Experimental Conditions.

Codec	: MPEG-4 Simple Profile
Search Range	: ±32 pixels
Image resolution	: 176×144 pixels
Average Bit-rate	: 128 Kbits/sec
Input Image Frame-rate	: 30 frames/sec
Encode Frame-rate	: 7.5 frames/sec
(FIXED FRAME RATE)	

The encoder converts a video sequence of 30 [frames/sec; fps] to 7.5[fps] by dropping three out of every four frames in the original video sequence. The proposed method converts the 7.5[fps] video stream into 15[fps] in this experiment.

(a) Original.

(b) Conventional Method.

(c) Proposed Method.

Figure 5. Experimental Results.

We compare the proposed method with the conventional method [4]. Figure 5 shows the results of the experiment. In Fig.5, the result of the proposed method is the frame constructed using local MV. As can be seen from Fig. 5, the proposed method performs high quality frame-rate up-conversion without artifacts.

4. CONCLUSION

We propose a new frame-rate up-conversion algorithm that uses vector reliable analysis of decoded motion information. The proposed method can interpolate frames without creating distracting artifacts.

5. REFERENCES

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