

Currently, the gradient filter and the interpolation filter in BIO are additional processes to the conventional HEVC. These filters are different from the interpolation filter used for motion compensation. The BIO related filters cause additional cost to the BIO process. However, the purpose of the interpolation filter in BIO and the purpose of the interpolation filter in motion compensation are similar since both are intended for approximating the fractional-pel motion. Furthermore, these filters will derive the related information such as interpolated pixel values and gradient values. The gradient filter in BIO can be derived directly from the interpolation filter in BIO. The method will further unify the interpolation filter in BIO with the interpolation filter in fractional-pel motion compensation, and derives the gradient filter from the interpolation filter.

[0028] According to the method of unifying interpolation filters as disclosed above, there is no need for an additional interpolation filter. Therefore, the computation becomes unified and simplified. An 8-tap interpolation filter or 4-tap interpolation filter can be used instead of 6-tap interpolation filter as specified in BIO. When 8-tap interpolation filter is used, the gradient filter is also changed and derived directly from the difference between filter coefficients with different fractional positions. For example, for the fractional position equal to $1/2$ -pel, the gradient filter coefficients can be derived from the differences between the interpolation filter coefficients for the fractional position equal to $3/4$ -pel and the interpolation filter coefficients for the fractional position equal to $1/4$ -pel divided by $2 \times (1/4)$. The coding performance of BIO is improved because of the same interpolation filter is used for BIO and motion compensation. However, the computational complexity is increased also. If a 4-tap interpolation filter is used, no additional filter is required and the computation complexity can be further reduced.

[0029] Another method to improve the performance of BIO is to apply BIO for all bi-directional predicted blocks regardless of whether the blocks are “true bi-prediction” or not. According to the assumption of optical flow and steady motion, the corresponding equations and solutions for bi-directional predicted blocks can be used, where both reference frames are previously coded frames by using a similar approach. For example, the x-offset values and the y-offset values for the two corresponding positions (i.e., position A and B in Fig. 1) have the same value, but opposite sign. Accordingly, the x-offset values and the y-offset values for two corresponding positions in two reference blocks of two previously coded frames may have the same value, but opposite sign. In the assumption of steady motion, the temporal distances between current block and two

art to practice the present invention as provided in the context of a particular application and its requirement. Various modifications to the described embodiments will be apparent to those with skill in the art, and the general principles defined herein may be applied to other embodiments. Therefore, the present invention is not intended to be limited to the particular embodiments shown and described, but is to be accorded the widest scope consistent with the principles and novel features herein disclosed. In the above detailed description, various specific details are illustrated in order to provide a thorough understanding of the present invention. Nevertheless, it will be understood by those skilled in the art that the present invention may be practiced.

[0042] Embodiment of the present invention as described above may be implemented in various hardware, software codes, or a combination of both. For example, an embodiment of the present invention can be one or more circuits integrated into a video compression chip or program code integrated into video compression software to perform the processing described herein. An embodiment of the present invention may also be program code to be executed on a Digital Signal Processor (DSP) to perform the processing described herein. The invention may also involve a number of functions to be performed by a computer processor, a digital signal processor, a microprocessor, or field programmable gate array (FPGA). These processors can be configured to perform particular tasks according to the invention, by executing machine-readable software code or firmware code that defines the particular methods embodied by the invention. The software code or firmware code may be developed in different programming languages and different formats or styles. The software code may also be compiled for different target platforms. However, different code formats, styles and languages of software codes and other means of configuring code to perform the tasks in accordance with the invention will not depart from the spirit and scope of the invention.

[0043] The invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described examples are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

CLAIMS

1. A method of motion compensation for video data, the method comprising:
 - receiving input data associated with a current block in a current picture;
 - 5 determining a first reference block in a first reference picture based on a first motion vector and a second reference block in a second reference picture based on a second motion vector, wherein the first reference picture and the second reference picture are two previously coded pictures;
 - deriving x-direction gradient difference corresponding to a given position of the
 - 10 current block between first x-direction gradient of the first reference block and second x-direction gradient of the second reference block;
 - deriving y-direction gradient difference corresponding to the given position of the
 - current block between first y-direction gradient of the first reference block and second y-direction gradient of the second reference block;
 - 15 determining an x-offset value and a y-offset value according to an optical flow model, wherein the x-offset value and the y-offset value are selected to obtain a reduced or minimum flow difference between a first position and a second position, and the first position and the second position are two positions in the first reference block and the second reference block respectively corresponding to the given position of the current
 - 20 block;
 - deriving bi-directional optical-flow prediction corresponding to the given position based on the first reference block, the second reference block, the x-direction gradient difference weighted by the x-offset value, and the y-direction gradient difference weighted by the y-offset value; and
 - 25 encoding or decoding pixel data at the given position of the current block using the bi-directional optical-flow prediction corresponding to the given position, wherein two x-offset values for the first position and second position have a same x-offset value with a same sign and two y-offset values for the first position and the second position have a same y-offset value with the same sign.
- 30 2. The method of Claim 1, wherein two x-offset values for the first position and the second position are proportional to two relative temporal distances between the first reference picture and the current picture and between the second reference picture and the current picture and two y-offset values for the first position and the second position

are proportional to the two relative temporal distances between the first reference picture and the current picture and between the second reference picture and the current picture.

3. An apparatus for motion compensation of video data performed by a video coding system, the apparatus comprising one or more electronic circuits or processors configured to:

receive input data associated with a current block in a current picture;

- determine a first reference block in a first reference picture based on a first motion vector and a second reference block in a second reference picture based on a second motion vector, wherein the first reference picture and the second reference picture are two previously coded pictures;

derive x-direction gradient difference corresponding to a given position of the current block between first x-direction gradient of the first reference block and second x-direction gradient of the second reference block;

- derive y-direction gradient difference corresponding to the given position of the current block between first y-direction gradient of the first reference block and second y-direction gradient of the second reference block;

- determine an x-offset value and a y-offset value according to an optical flow model, wherein the x-offset value and the y-offset value are selected to obtain a reduced or minimum flow difference between a first position and a second position, and the first position and the second position are two positions in the first reference block and the second reference block respectively corresponding to the given position of the current block;

- derive bi-directional optical-flow prediction corresponding to the given position based on the first reference block, the second reference block, the x-direction gradient difference weighted by the x-offset value, and the y-direction gradient difference weighted by the y-offset value, wherein two x-offset values for the first position and the second position have a same x-offset value with a same sign and two y-offset values for the first position and the second position have a same y-offset value with the same sign; and

encode or decode pixel data at the given position of the current block using the bi-directional optical-flow prediction corresponding to the given position.

4. The apparatus of Claim 3, wherein two x-offset values for the first position and the second position are proportional to two relative temporal distances between the

first reference picture and the current picture and between the second reference picture and the current picture and two y-offset values for the first position and the second position are proportional to the two relative temporal distances between the first reference picture and the current picture and between the second reference picture and the current picture.

5 5. A method of motion compensation for video data, the method comprising:
receiving input data associated with a current block in a current picture;

determining a first reference block in a first reference picture based on a first motion vector and a second reference block in a second reference picture based on a second motion vector;

10 deriving x-direction gradient difference corresponding to a given position of the current block between first x-direction gradient of the first reference block and second x-direction gradient of the second reference block;

15 deriving y-direction gradient difference corresponding to the given position of the current block between first y-direction gradient of the first reference block and second y-direction gradient of the second reference block;

20 determining an x-offset value and a y-offset value according to an optical flow model, wherein the x-offset value and the y-offset value are selected to obtain a reduced or minimum flow difference between a first position and a second position, and the first position and the second position are two positions in the first reference block and the second reference block respectively corresponding to the given position of the current block;

25 deriving bi-directional optical-flow prediction corresponding to the given position based on the first reference block, the second reference block, the x-direction gradient difference weighted by the x-offset value, and the y-direction gradient difference weighted by the y-offset value; and

30 encoding or decoding pixel data at the given position of the current block using the bi-directional optical-flow prediction or not depending on linearity of the first motion vector and the second motion vector or depending on block size of the current block, wherein the current block is encoded or decoded using the bi-directional optical-flow prediction if the linearity of the first motion vector and the second motion vector satisfies a linearity threshold.

6. The method of Claim 5, wherein the current block is encoded or decoded using the bi-directional optical-flow prediction if the block size of the current block is larger

than a threshold block size.

7. The method of Claim 6, wherein the threshold block size is 8x8.

8. An apparatus for motion compensation of video data performed by a video coding system, the apparatus comprising one or more electronic circuits or processors

5 configured to:

receive input data associated with a current block in a current picture;

determine a first reference block in a first reference picture based on a first motion vector and a second reference block in a second reference picture based on a second motion vector;

10 derive x-direction gradient difference corresponding to a given position of the current block between first x-direction gradient of the first reference block and second x-direction gradient of the second reference block;

derive y-direction gradient difference corresponding to the given position of the current block between first y-direction gradient of the first reference block and second

15 y-direction gradient of the second reference block;

determine an x-offset value and a y-offset value according to an optical flow model, wherein the x-offset value and the y-offset value are selected to obtain a reduced or minimum flow difference between a first position and a second position, and the first position and the second position are two positions in the first reference block and the second reference block respectively corresponding to the given position of the current block;

20 derive bi-directional optical-flow prediction corresponding to the given position based on the first reference block, the second reference block, the x-direction gradient difference weighted by the x-offset value, and the y-direction gradient difference weighted by the y-offset value; and

25 encode or decode pixel data at the given position of the current block using the bi-directional optical-flow prediction or not depending on linearity of the first motion vector and the second motion vector or depending on block size of the current block, wherein the current block is encoded or decoded using the bi-directional optical-flow prediction if the linearity of the first motion vector and the second motion vector satisfies a linearity threshold.

30 9. The apparatus of Claim 8, wherein the current block is encoded or decoded using the bi-directional optical-flow prediction if the block size of the current block is larger than a threshold block size.

10. The apparatus of Claim 9, wherein the threshold block size is 8x8.

11. A method of motion compensation for video data, the method comprising:
receiving input data associated with a current block in a current picture;

determining a first reference block in a first reference picture based on a first
5 motion vector and a second reference block in a second reference picture based on a
second motion vector;

deriving x-direction gradient difference corresponding to a given position of the
current block between first x-direction gradient of the first reference block and second
x-direction gradient of the second reference block;

10 deriving y-direction gradient difference corresponding to the given position of the
current block between first y-direction gradient of the first reference block and second
y-direction gradient of the second reference block;

determining an x-offset value and a y-offset value according to an optical flow
model, wherein the x-offset value and the y-offset value are selected to obtain a reduced
15 or minimum flow difference between a first position and a second position, and the first
position and the second position are two positions in the first reference block and the
second reference block respectively corresponding to the given position of the current
block;

deriving bi-directional optical-flow prediction corresponding to the given position
20 based on the first reference block, the second reference block, the x-direction gradient
difference weighted by the x-offset value, and the y-direction gradient difference
weighted by the y-offset value;

encoding or decoding pixel data at the given position of the current block using
the bi-directional optical-flow prediction corresponding to the given position; and

25 storing refined motion vectors for bi-directional optical-flow predicted pixels of
the current block in a motion-vector buffer for motion vector prediction of one or more
following blocks, wherein the refined motion vectors are determined based on the first
motion vector or the second motion vector modified by the x-offset value and the y-
offset value, wherein if the bi-directional optical-flow prediction is applied to the
30 current block on block-level basis for sub-blocks of the current block, the refined
motion vectors associated with the sub-blocks are stored in the motion-vector buffer.

12. An apparatus for motion compensation of video data performed by a video
coding system, the apparatus comprising one or more electronic circuits or processors
configured to:

receive input data associated with a current block in a current picture;

determine a first reference block in a first reference picture based on a first motion vector and a second reference block in a second reference picture based on a second motion vector;

5 derive x-direction gradient difference corresponding to a given position of the current block between first x-direction gradient of the first reference block and second x-direction gradient of the second reference block;

10 derive y-direction gradient difference corresponding to the given position of the current block between first y-direction gradient of the first reference block and second y-direction gradient of the second reference block;

15 determine an x-offset value and a y-offset value according to an optical flow model, wherein the x-offset value and the y-offset value are selected to obtain a reduced or minimum flow difference between a first position and a second position, and the first position and the second position are two positions in the first reference block and the second reference block respectively corresponding to the given position of the current block;

20 derive bi-directional optical-flow prediction corresponding to the given position based on the first reference block, the second reference block, the x-direction gradient difference weighted by the x-offset value, and the y-direction gradient difference weighted by the y-offset value;

 encode or decode pixel data at the given position of the current block using the bi-directional optical-flow prediction corresponding to the given position; and

25 store refined motion vectors for bi-directional optical-flow predicted pixels of the current block in a motion-vector buffer for motion vector prediction of one or more following blocks, wherein the refined motion vectors are determined based on the first motion vector or the second motion vector modified by the x-offset value and the y-offset value, wherein if the bi-directional optical-flow prediction is applied to the current block on block-level basis for sub-blocks of the current block, the refined motion vectors associated with the sub-blocks are stored in the motion-vector buffer.