

12-4-01

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PTO/SB/16 (6-95)

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PROVISIONAL APPLICATION COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION under 37 C.F.R. § 1.53(c)

Docket Number:
53812-00003USPL

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jc921 U.S. PTO
60/334979

11/30/01

INVENTOR(S)/APPLICANT(S)

LAST NAME	FIRST NAME	MIDDLE INITIAL	RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)
Fröjd	Per		Stockholm SWEDEN
Sjöberg	Rickard		Tumba SWEDEN
Einarson	Torbjörn		Stockholm SWEDEN

TITLE OF THE INVENTION: GLOBAL MOTION COMPENSATION FOR VIDEO PICTURE SEGMENTS

CORRESPONDENCE ADDRESS: James O. Skarsten
Jenkins & Gilchrist, P.C.
1445 Ross Avenue, Suite 3200
Dallas

(STATE) TX (ZIP CODE) 75202-2799 (COUNTRY) USA

ENCLOSED APPLICATION PARTS (check all that apply):

- ☒ Specification Number of Pages 11 ☐ Small Entity Statement
- ☐ Drawing(s) Number of Figures ☐ Other (specify)

- ☒ A check in the amount of \$160 is enclosed to cover the provisional application filing fees.
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☒ \$160.00
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Was the invention made by an agency of the United States Government or under a contract with an agency of the United States government?

- ☒ No.
- ☐ Yes, and the name of the U.S. Government agency and the government contract number(s) are:

Respectfully submitted,

James O. Skarsten

DATE

November 30, 2001

NAME James O. Skarsten

REGISTRATION NO.
(if appropriate)

28,346

- ☐ Additional inventors are being named on separately numbered sheets attached hereto.

PROVISIONAL APPLICATION FILING ONLY

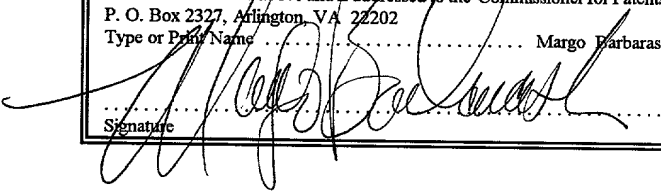
Applicant(s) herein make claim to a new and useful process, machine, manufacture, or composition of matter, or any new and useful improvement thereof as substantially shown or described herein.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Fröjd, et al.

For: GLOBAL MOTION COMPENSATION FOR VIDEO PICTURE SEGMENTS

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Respectfully submitted,

James O. Skarsten

Date: November 30, 2001

James O. Skarsten
Registration No. 28,346

JENKENS & GILCHRIST
A Professional Corporation
1445 Ross Avenue, Suite 3200
Dallas, Texas 75202-2799
(214) 855-4482
(214) 855-4300 (Fax)

**Invention Disclosure: *Global Motion Compensation
for Video Picture Segments***

1

NAME OF INVENTION

Global Motion Compensation for Video Picture Segments

2

INVENTOR(S)

Name : Per Fröjdh
Department : T/VV
Employee no. : 382934
Phone no. : +46 8 4048188
e-mail/memo : per.frojd@era.ericsson.se

Name : Rickard Sjöberg
Department : T/VV
Employee no. : 116500
Phone no. : +46 8 7572373
e-mail/memo : rickard.sjoberg@era.ericsson.se

Name : Torbjörn Einarsson
Department : T/VV
Employee no. : 112449
Phone no. : +46 8 7572346
e-mail/memo : torbjorn.einarsson@era.ericsson.se

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BACKGROUND

This invention relates to the compression of digital video signals. In non-compressed form, these typically contain large amounts of data, whereas the actual information content is considerably smaller due to high temporal and spatial correlations. In the coding process one can utilize the temporal redundancy by making so-called motion-compensated predictions, where regions of a frame (picture) are predicted from similar regions of a previous frame. If no region in the past gives a good match, predictions within a frame can be used to reduce spatial redundancy. With a successful prediction scheme, the prediction error will be small and the amount of information that has to be coded greatly reduced. Moreover, by transforming pixels to a frequency domain, e.g. using discrete cosine transform, spatial correlations give further gains in efficiency.

High temporal correlations are characteristic of video. Hence, much effort in optimizing video compression is focused on making accurate temporal predictions of regions of a frame. The better the prediction, the less bits are needed to code the discrepancy. The prediction itself is coded as instructions on how to translate, or maybe even scale or rotate, an already coded region in the past. If many regions of a frame have similar motion, such as in a pan or zoom, further improvements in compression efficiency can result from coding a global motion separately, which then

applies to all or some regions of the frame. The technique is often referred to as global motion compensation (GMC).

There are several reasons, however, why one should not address the whole frame when global motion compensation is used. The first one is due to error resilience. In order to prevent error propagation from corrupted parts of an image, prediction is often constrained within bounded segments called slices. Each slice of a frame should therefore be self-contained also regarding global motion information. Another reason is that global motion compensation may not be relevant for an entire frame, although smaller parts of the frame could benefit from global motion compensation applied to each part separately.

The present invention addresses the problem of using global compensation for frames with slices. By signaling global motion compensation for each slice, the advantages of global motion compensation can be used without neglecting error resilience.

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STATE-OF-THE-ART

Still image coding versus motion compensation

A typical video coder, such as ITU-T Recommendations H.261 and H.263, MPEG-1 part 2, MPEG-2 part 2 (H.262), or MPEG-4 part 2, operates by sequentially code a video sequence frame by frame. A frame is further divided into blocks that are coded sequentially row by row, starting at the top left corner and ending at the bottom right corner. A typical block size is that of a macroblock (MB) covering 16x16 luminance pixels.

The first frame is encoded as a still image, called an *intra* frame. Such a frame is self-contained and does not depend on previously coded frames. However, they are not only used at the start of the sequence, but also advantageous to use at instances where the video changes abruptly, such as scene cuts, or where it is desirable to have a random-access point, from which a decoder can start decoding without having to decode the previous part of the bitstream. The pixel values of intra-coded macroblocks are usually transformed to a frequency domain, e.g. using discrete cosine transform, and the transform coefficients quantized in order to reduce the size of the resulting bitstream.

In contrast, an *inter* frame is coded as a *motion-compensated* difference image relative to an earlier frame. By using an already decoded frame (reconstructed frame) as reference, the video coder can signal for each macroblock a set of motion vectors (MVs) and coefficients. The motion vectors (one or several depending on how the macroblock is partitioned) inform the decoder how to spatially translate the corresponding region of the reference frame in order to make a prediction for the macroblock under consideration. This is referred to as motion compensation. The difference between the prediction and the original is encoded in terms transform coefficients. However, not all macroblocks of an inter frame need to be motion compensated. If the change from the reference macroblock to the current macroblock

is small, it can be *skipped*, i.e. not coded but signaled to be *copied*. On the other hand, if the macroblocks differ substantially, it may be better to code it as an intra macroblock.

Global motion compensation in H.263

Instead of addressing the motion compensation on a block basis only, it might be advantageous to extract the global motion of a frame separately and code the deviations from the global motion for each block. In a panning or zooming sequence, or when a large object moves over the frame, the overall motion information is likely to be kept at a minimum by such a scheme. A well-known technique is to add an additional step in the coding process before an inter frame is coded. Annex P "Reference Picture Resampling" of H.263 provides a method for "warping" the reference picture given four displacement vectors $\underline{v}^{00}$, $\underline{v}^{H0}$, $\underline{v}^{0V}$, and $\underline{v}^{HV}$ specifying the displacements of the corner pixels of a frame. See Figure 1 for a schematic picture.

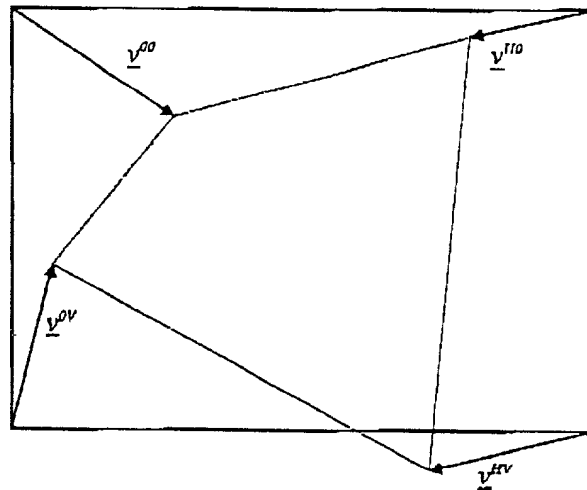


Figure 1. Illustration of global motion compensation of a frame in H.263.

The displacements of all other pixels are given by a bilinear interpolation of these vectors,

$$\underline{v}(x, y) = \underline{v}^0 + \left(\frac{x}{H}\right)\underline{v}^x + \left(\frac{y}{V}\right)\underline{v}^y + \left(\frac{x}{H}\right)\left(\frac{y}{V}\right)\underline{v}^{xy}$$

where

$$\begin{aligned}\underline{r}^0 &= \underline{v}^{00} \\ \underline{r}^x &= \underline{v}^{x0} - \underline{v}^{00} \\ \underline{r}^y &= \underline{v}^{0y} - \underline{v}^{00} \\ \underline{r}^{xy} &= \underline{v}^{00} - \underline{v}^{x0} - \underline{v}^{0y} + \underline{v}^{xy}\end{aligned}$$

For a detailed description of implementation of these formulac we refer to Recommendation H.263.

When this global motion compensation is used, the reference frame for an inter frame is resampled, pixel-by-pixel, using the above interpolation. After the resampling has been performed, the coder can continue with coding an inter frame based on the resampled reference frame.

Global Motion Compensation in MPEG-4 part 2

Global motion compensation is also specified in the MPEG-4 visual standard using so-called S(GMC)-VOPs. Here the global motion compensation is applied pixel-by-pixel as for H.263 Annex P. However, one can still choose on a macroblock level whether the (interpolated) global motion compensated reference frame should be used or not.

Global Motion Compensation Proposed for H.26L

ITU-T is currently developing a new video-coding standard, Recommendation H.26L, which is also likely to be jointly published as an International Standard by ISO/IEC called MPEG-4 AVC (ISO/IEC 14496-10). The current H.26L follows the above-mentioned general video coding design with frames and macroblocks, where each picture is encoded by a picture header followed by macroblocks. See Figure 2 for a symbolic representation of the bitstream syntax.

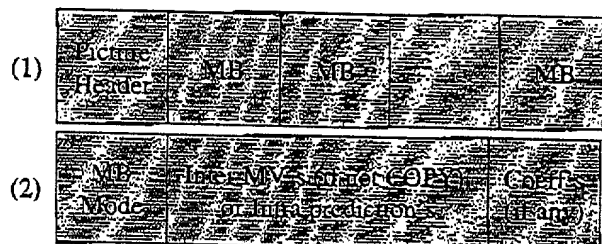


Figure 2. Representation of the bitstream syntax of the current H.26L design on (1) picture level and (2) macroblock (MB) level. An inter macroblock may include motion vectors (MVs) and coefficients.

The macroblocks of an inter frame can have one of several modes, which currently include 7 inter modes (16x16, 16x8, 8x16, 8x8, 8x4, 4x4), 1 intra mode for 4x4 and 23 intra modes for 16x16. Here NxM refers to the size of the blocks the macroblock is partitioned into. For inter MBs, each block has an MV each and for intra MBs, each block is predicted as a unit. Furthermore, there is one COPY mode, which uses no MV and no coefficients. This is the cheapest mode to signal. In fact, run-length coding is used to signal a number of copied (skipped) macroblocks with one codeword. The first 8 non-copy modes are listed in Table 1.

Table 1. The first 8 non-copy MB modes of H.26L. The Run codeword is used before MB Mode and at the end of a slice or picture to indicate the number of skipped MBs (COPY mode). The codewords are generated by an infinite VLC.

Indcx	Run	MB Mode	Codeword
0	0	16x16	1
1	1	16x8	001
2	2	8x16	011
3	3	8x8	00001
4	4	8x4	00011
5	5	4x8	01001
6	6	4x4	01011
7	7	intra 4x4	0000001
...	...	...	...

An infinite variable-length code (VLC) table is used to signal the codewords. They are given by

```

1
0 x 1
0 x 0 x 1
0 x 0 x 0 x 1
0 x 0 x 0 x 0 x 1
...
```

where each x can be either 0 or 1.

A global-motion compensation has been proposed for H.26L but is so far not adopted, see Ref. 7. It resembles the GMC used in Annex P of H.263 in the way the global motion vectors are defined. The main difference, however, is that the

reference picture is not resampled and that the interpolated motion vectors do not apply to pixels but rather to blocks of pixels. The motion vector of an image block with its upper-left pixel at (x,y) can be derived as

$$\underline{v}(x, y) = \underline{r}^0 + \left(\frac{x}{H-4} \right) \underline{r}^x + \left(\frac{y}{V-4} \right) \underline{r}^y + \left(\frac{x}{H-4} \right) \left(\frac{y}{V-4} \right) \underline{r}^{xy}$$

where $\underline{r}^0$, $\underline{r}^x$, $\underline{r}^y$, and $\underline{r}^{xy}$ are related to $\underline{v}^{00}$, $\underline{v}^{H0}$, $\underline{v}^{0V}$, and $\underline{v}^{HV}$ as for H.263 Annex P. However, these motion vectors apply to image blocks consisting of 4x4 pixels. In particular, the vectors $\underline{v}^{00}$, $\underline{v}^{H0}$, $\underline{v}^{0V}$, and $\underline{v}^{HV}$ apply to the corner blocks of the frame with their upper-left pixels at (0,0), (H-4,0), (0, V-4) and (H-4, V-4), respectively. For a detailed description of implementation of these formulae we refer to Ref. 7.

Global Motion Vector Coding (GMVC) for H.26L is proposed to apply only for certain macroblock modes of the picture. Whether or not it is used is signaled for each inter frame in the picture header by a flag (GMVC_flag). If GMVC is on, the four GMVs $\underline{r}^0$, $\underline{r}^x$, $\underline{r}^y$, and $\underline{r}^{xy}$ follow the flag. These are used for the current picture whenever a mode using GMVC is signaled in a macroblock. The proposed syntax is shown in Figure 3.



Figure 3. Representation of the bitstream syntax for the proposed GMC in H.26L on (1) picture level and (2) macroblock level.

The macroblock modes for macroblocks in a frame with GMVC enabled have two new modes. The COPY mode is replaced by GMVC_COPY and there is an additional mode called GMVC_16. Both modes are inter 4x4 modes, i.e. the macroblock is partitioned into image blocks of 4x4 pixels. The motion vectors for each block is given by the interpolated GMVs as given by the above formula. For GMVC_COPY no coefficients are coded, i.e. the motion-compensated reference picture is copied, whereas for GMVC_16, coefficients are added as well. In the syntax of Table 1 and its caption, GMVC_COPY replaces COPY and GMVC_16 replaces 16x16. The other MB modes are shifted to one index higher.

The disadvantage of using global motion compensation for a video frame is the loss of error resilience and flexibility by addressing entire frames. If the global motion vectors are coded only once for a picture, e.g. at the beginning of the picture, and this part of the bitstream is lost during transmission, the whole picture is likely to be corrupted. Hence, motion vectors for blocks all over the picture cannot be decoded and must be concealed. Such errors may also propagate in time as the next picture can be an inter picture as well, thus using a corrupted picture as reference. Another problem with the proposed GMVC design for H.26L is that it cannot specify different global motions for parts of a frame.

6 SOLUTION

We propose to apply global motion compensation on frames segmented into slices, i.e. self-contained units that do not use motion vectors from macroblocks outside itself for prediction. By coding global motion vectors for each slice, all motion vectors within the slice can be constructed in a self-contained way. The global motion vectors can be applied differently to each slice, or can be used to repeat global motion vectors referencing the entire frame.

The following is a list of implementation examples on how Global Motion Compensation (GMC) can be signaled:

1. Whether or not GMC should be used is signaled for each slice together with global motion information (vectors).
2. Example 1 where all slices repeat the same GMC information (GMC usage and GM vectors).
3. Example 1 where all slices can have different GMC information (GMC usage and GM vectors).
4. Example 2 and 3 where also all GMC information is repeated on picture level, such as in the picture header.

All the above examples can be combined with the different models on how to apply global motion compensation. The following is a list of such models:

5. Four global motion vectors $\mathbf{r}^0$, $\mathbf{r}^x$, $\mathbf{r}^y$, and $\mathbf{r}^{xy}$ are coded for each slice. These are used as in H.263 Annex P to calculate the global motion compensation using bilinear interpolation for each pixel contained in the slice. In analogy with H.263, all vectors use the entire frame as reference.
6. Example 5 where the global motion vectors use the bounding box of the slice as reference. More precisely, the vectors $\mathbf{v}^{x0}$, $\mathbf{v}^{x1}$, $\mathbf{v}^{y0}$, and $\mathbf{v}^{y1}$, related to $\mathbf{r}^0$, $\mathbf{r}^x$, $\mathbf{r}^y$, and $\mathbf{r}^{xy}$ as before, specify the displacements of the corner pixels of the smallest rectangle that can contain the slice.

7. Four global motion vectors r^0 , r^x , r^y , and r^y are coded for each slice. These are used as in the reviewed proposal for GMC for H.26L to calculate the global motion compensation, i.e. the global motion vector for each image block of 4x4 pixels in the slice is given by a bilinear interpolation. In analogy with the proposal, all vectors use the entire frame as reference.
8. Example 7 where the global motion vectors use the bounding box of the slice as reference. More precisely, the vectors v^{00} , v^{H0} , v^{0V} , and v^{HV} , related to r^0 , r^x , r^y , and r^y as before, specify the global motion displacements of the corner blocks of the smallest rectangle that can contain the slice.
9. Example 5 where two global motion vectors are coded for each slice. These refer to the left-most and right-most pixels, respectively, of the bounding box of the slice. For pixels along a vertical axis the global motion vectors are the same, whereas along a horizontal axis they are interpolated linearly from the two coded global-motion vectors.
10. Example 7 where two global motion vectors are coded for each slice. These refer to the left-most and right-most 4x4 image blocks, respectively, of the bounding box of the slice. For blocks along a vertical axis the global motion vectors are the same, whereas along a horizontal axis they are interpolated linearly from the two coded global-motion vectors.
11. Example 7 where one global motion vector is coded for each slice. This applies for all blocks of the slice.

The above examples can be combined with the different macroblock modes to take advantage of global motion compensation. Some, but not all, mode may use the (interpolated) global motion vectors. The following is a list of possible modes:

12. When GMC is enabled, a macroblock COPY mode signals that the encoder shall copy the macroblock from the (global) motion compensated reference picture. Hence, the displacements or motion vectors are given by the (interpolated) global motion vectors. No coefficients are coded.
13. Example 12 where coefficients are coded as well.
14. Example 12, where the mode of example 13 is added as different macroblock mode.
15. When GMC is enabled, no explicit global motion vector is sent. We refer to this as Implicit Global Motion Compensation (IGMC), where the macroblock COPY mode is reinterpreted an inter MB mode without coefficients. Just as for inter MB modes, the motion vectors for this mode are defined by the prediction from neighboring blocks. This mode can be used for macroblocks with only one motion vector (16x16 block).

16. Example 15 where the COPY mode refers to a macroblock partitioned into smaller blocks, such as 4x4 pixels etc. The motion vector for each such block is predicted, as for inter macroblocks.
17. Example 15 or 16 where one extra motion vector is sent for each slice. This motion vector is used as prediction for the first inter block of the slice.
18. Example 17 where coefficients are coded as well.
19. Example 17, where the mode of example 18 is added as different macroblock mode.

In all examples where we refer to image blocks of certain sizes, such as 4x4 pixels, one can also use image blocks of other dimensions, such as 16x16, 16x8, 8x16, 8x8, 4x8, 8x4, 4x4, and so on.

In the above examples we have used specific models for global motion compensation based on 4, 2, or 1 motion vector(s). However, our solution is not limited to those specific models, but can be used for other models for motion compensation, such as affine transformations.

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MERITS OF INVENTION

By addressing global motion compensation on a slice level,

1. error resilience of the coded bitstream is improved, as each slice will be self-contained regarding motion compensation information.
2. compression efficiency can be improved, as a better fit for the global motion can be found for smaller regions.

We also introduce a new mode for global motion compensation, which we call Implicit Global Motion Compensation (IGMC). This mode can be used as a tool in many coding scenarios where a more useful MB mode than COPY with GMC based on explicit MVs can minimize the total number of bits spent on motion vectors.

8

ENCLOSURES

1. ITU-T Recommendation H.261 (1993), *Video codec for audiovisual services at p x 64 kbit/s*.
2. ITU-T Recommendation H.263 (2001), *Video codec for low bit rate communication*.

3. ITU-T Recommendation H.26L, Test Model Long Term Number 8, Draft June 2001. <ftp://standard.pictel.com/video-site/h26L/tml8.doc>
4. ISO/IEC 11172-2:1993, *Information technology – Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/s – Part 2: Video* (MPEG-1 part 2).
5. ISO/IEC 13818-2:2000, *Information technology – Generic coding of moving pictures and associated audio information: Video* (MPEG-2 part 2).
6. ISO/IEC 14496-2:2001, *Information technology – Coding of audio-visual objects – Part 2: Visual* (MPEG-4 part 2).
7. Shijun Sun and Shawmin Lei, "Motion Vector Coding with Global Motion Parameters", document VCEG-N16, ITU-T Video Coding Experts Group (VCEG) Meeting in Santa Barbara (September 2001).
ftp://standard.pictel.com/video-site/0109_San/VCEG-N16.doc

9

CLAIMS PROPOSAL

We refer to the list of examples in Chapter 6 for what can be claimed for this invention.

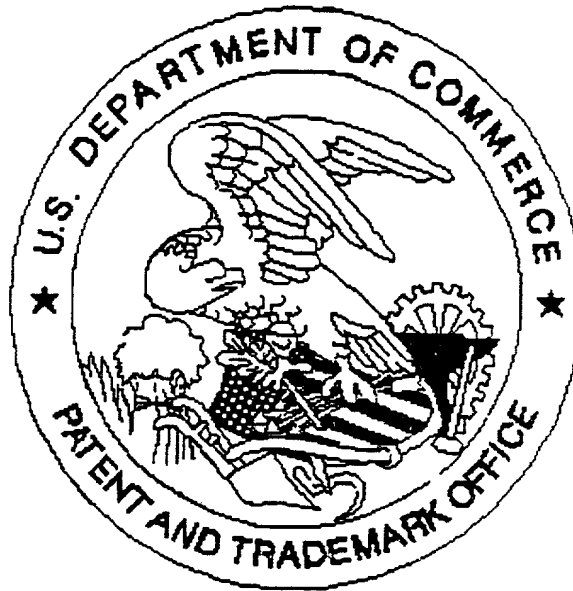
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