CCITT SG XV
Specialists Group on Coding for Visual Telephony

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Title: Fractional Motion Vectors for Movement Compensating Prediction in Hybrid Coders

1. Introduction

At the last Tokyo meeting we discussed whether fractional motion vectors can provide coding gain over integer vectors. In this paper we report about a study on fractional motion vectors for movement compensating prediction in a hybrid coding scheme with DCT. The motion vectors are transmitted as side information, in parallel to the transformed and quantized prediction error.

It has to be studied, whether fractional motion vectors can provide a smaller prediciton error, which would result in a decreased bit rate for transmission of this error. On the other hand the bit rate for the motion vectors is increased, as the fractional part has to be transmitted in addition to the integer part.

The hardware of a codec with fractional motion vectors is more complex than a scheme with integer vectors. Thus it has to be carefully considered whether or not this is payed back by a significant better picture quality.

2. Coder Structure and Computer Simulation

The investigation is done on the basis of the reference model, defined in Doc.No. 104, specially extended to handle fractional motion vectors. The coding scheme is depicted in Fig. 1, were I is an interpolating spatial filter. Note that this structure requires only one interpolation filter. Fig. 2 outlines the interpolation process. Fig. 3 shows an example of a simple interpolation filter with coefficients c_n, $n = 1, \ldots, 4$. They depend on the non-integer motion vector. This filter was used in the present investigation.

For block matching, a full search algorithm was employed. The motion vector was in the range -7, ..., 8, both in horizontal and vertical direction. In principle, the total bit stream of the encoder is composed of

1. the quantized DCT coefficients of prediction error
2. the components of motion vectors
3. other side information

The following items are considered using computer simulation with the "split-screen" scene at 10 Hz picture rate:

a) Fractional values 0.5, 0.2 and 0.1 of the motion vector components
b) Bit rate for DCT coefficients
c) Bit rate for motion vectors
d) Subjective picture quality.

The schemes operate in open loop, to see whether or not a reduction of bit rate for DCT-coefficients can be obtained with fractional motion vectors. In either case, the reconstructed picture is the result of encoding the associated prediction error with approx. 20000 bits/picture, which yields a bit rate of about 200 kbit/s.

To compare the resulting bit rate for DCT coefficients on an equal basis for fractional versus integer motion vectors, the same quantizer is used in both schemes. But for comparison of the subjective picture quality, both schemes operate in closed loop.

3. Results

In Fig. 4 the relative bit rates for DCT coefficients are shown versus the step size of the fractional motion vector. Reference value is the bit rate of approx. 200 kbit/s for the step size 0.5.

Obviously, a vector "finer" than 0.5 provides only a slight gain. For this reason, a restriction to step size 0.5 seems allowed for further discussion.

If a fixed word-length code with 8 bits is used for integer motion vectors, fractional motion vectors with step size 0.5 require 10 bits per vector and the bit rate for motion vectors is increased by 25%. With the simulated picture material this is approx. 17 kbit/s. This is about the same which is gained in Fig. 4 (~8% corresp. to ~16 kbit/s).
For this reason, we have considered techniques to reduce the bit rate for the fractional motion vectors. We have quantized the vector positions to represent them with only 8 bits. With this scheme small vectors are quantized finer than larger ones. In the following example the components of the motion vector can take the values

-6, -4, -3, -2, -1.5, -1, -0.5, 0, 0.5, 1, 1.5, 2, 3, 4, 6.

With this technique, 6% bit rate reduction for DCT-coefficients can be obtained.

4. Subjective Picture Quality

The picture quality with the scheme described in section 3 was improved slightly compared to the reference model, whereby a full search algorithm for motion estimation was used.

5. Conclusions

Fractional motion vectors can provide a coding gain to the expense of an increased hardware complexity. The encountered savings in bit rate are approx. 6%. The picture quality with this scheme is improved slightly compared to the reference model.

The motion vector was quantized non-uniformly: Small vector components are quantized finer than large ones.
It is worth noting, that movement compensating prediction with fractional vectors can be considered as a filtering technique, (filter I in Fig. 1), where the filter characteristic can be changed from block to block controlled by the motion estimator. In this sense the filter I in Fig. 1 is an adaptive intra-picture predictor.

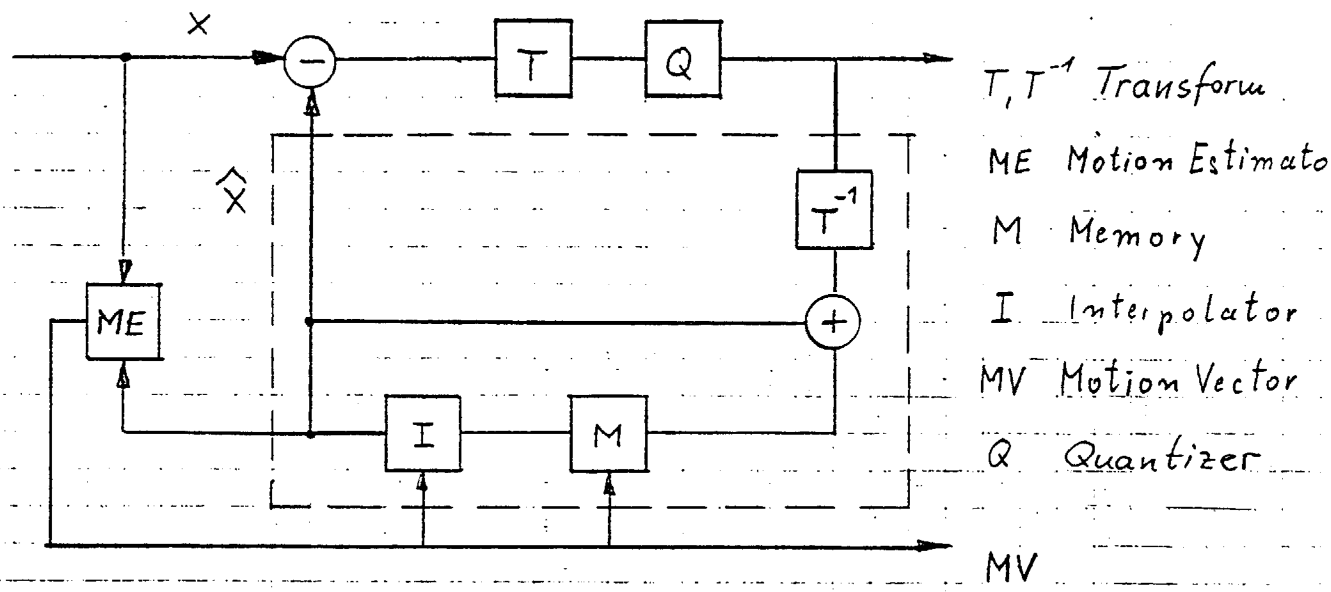

Fig. 1

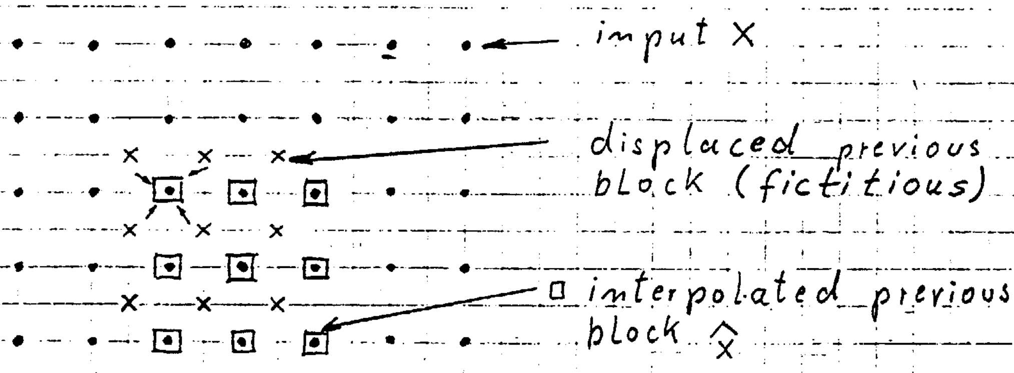

Fig. 2

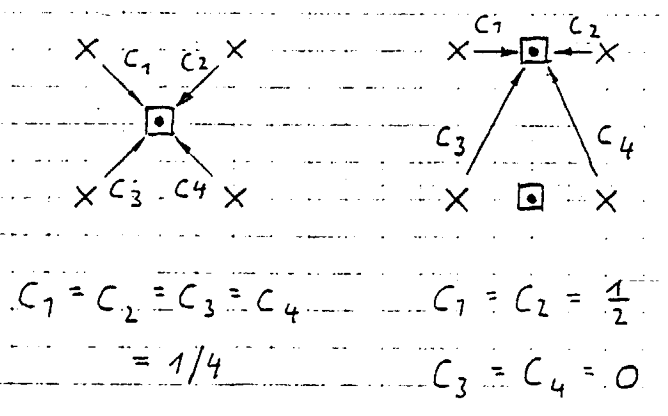

Fig. 3

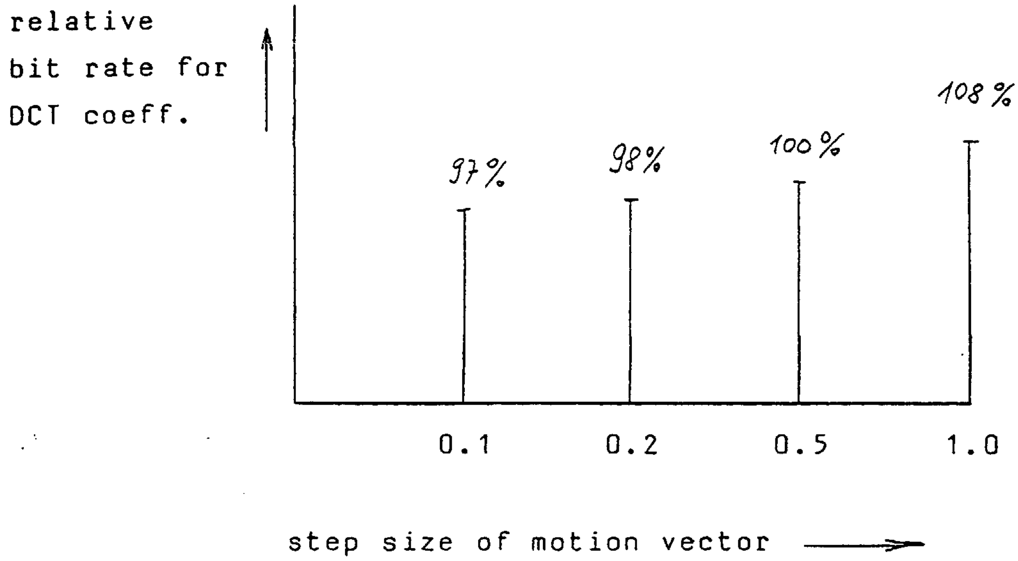
relative
bit rate for
DCT coeff.
97%
98%
100%
108%
0.1
0.2
0.5
1.0
step size of motion vector

Fig. 4