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## (54) Video compression

(57) In video motion vector generation and compensation, it is common for the chrominance sampling rate to be half the luminance sampling rate. When only a luminance motion vector is used, there can be rounding problems if either the horizontal or vertical motion vector (or both) is odd valued and the luminance motion vector is divided by two to generate a chrominance motion vector. For this reason, the luminance motion vector is provided with an additional bit for either or both axes if odd valued, and a rounding decision, if necessary, is made on the basis of the digital value of the additional bit.

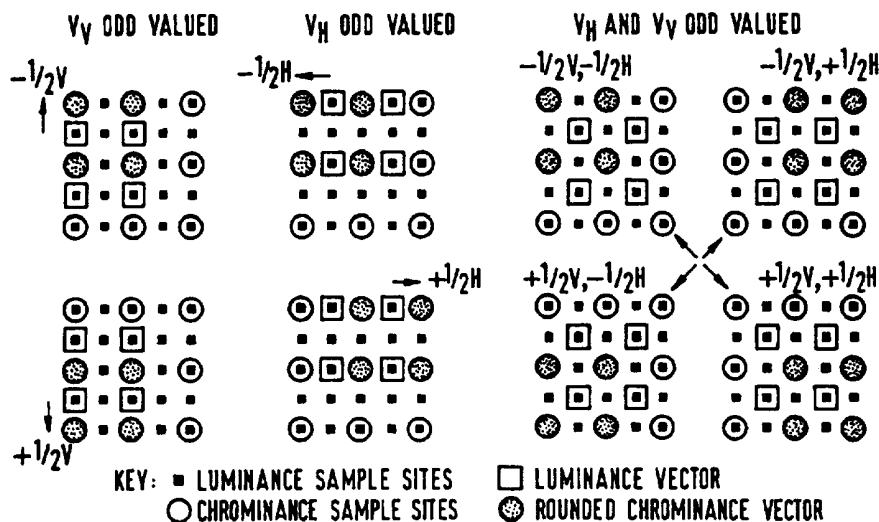


FIG. 2

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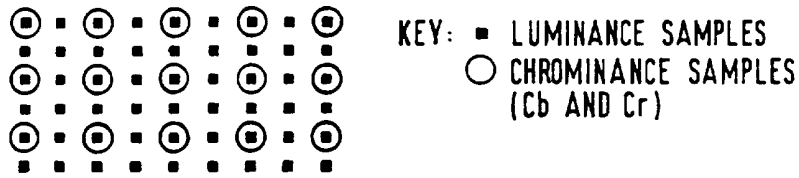


FIG. 1

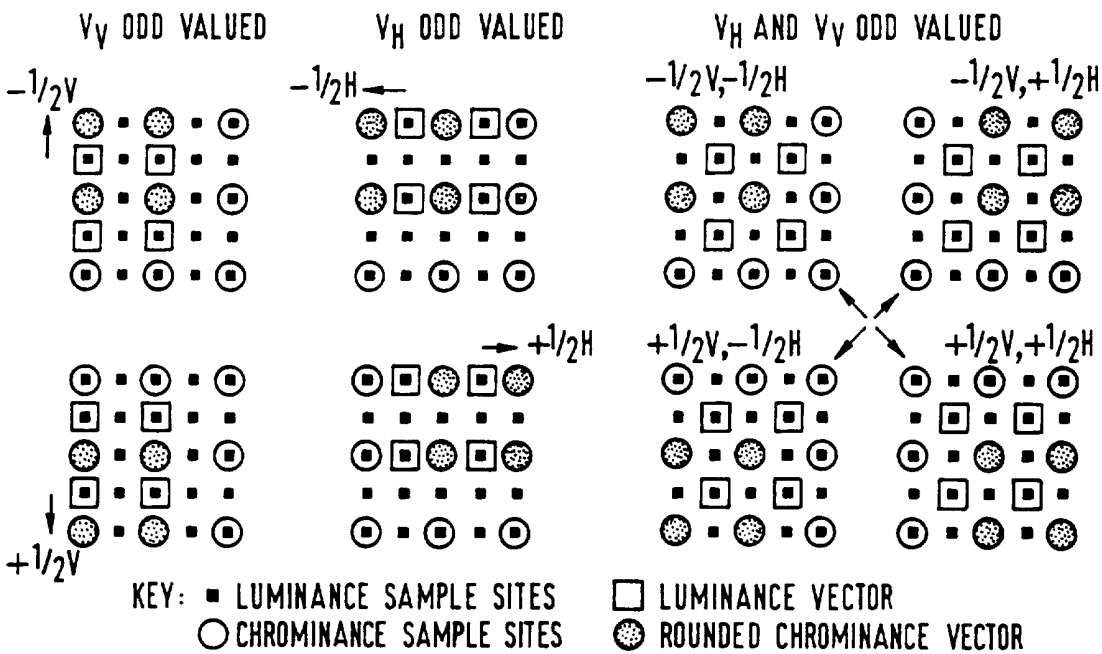


FIG. 2

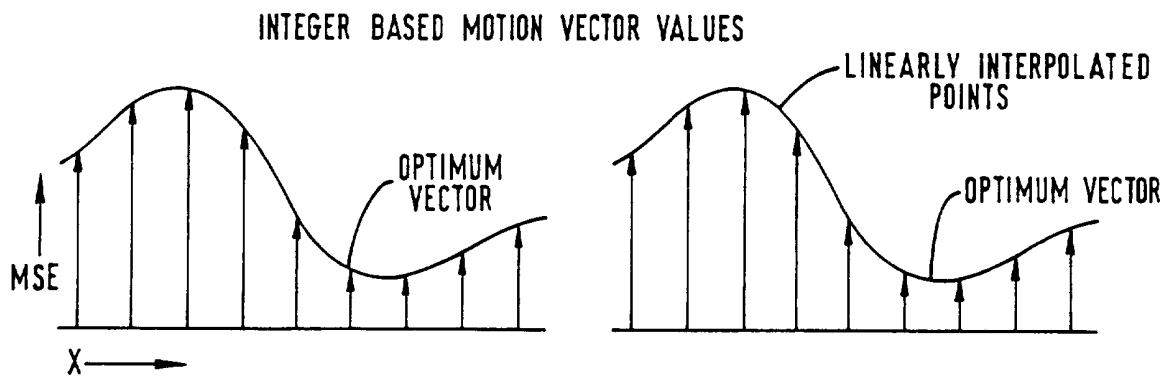


FIG. 3

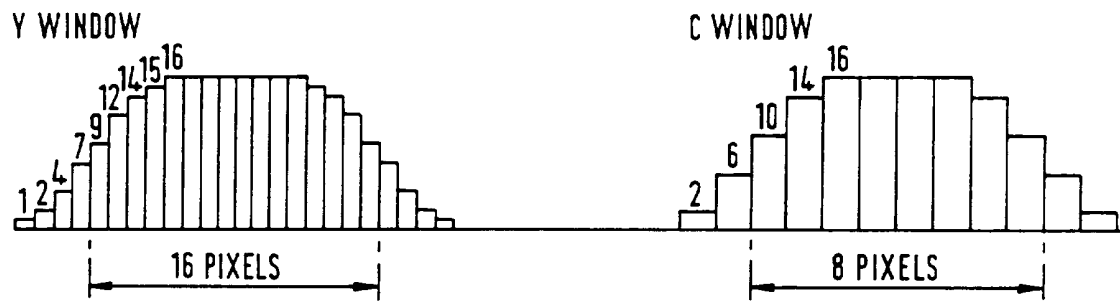


FIG. 4

SUM OF WINDOW TEMPLATES = 16

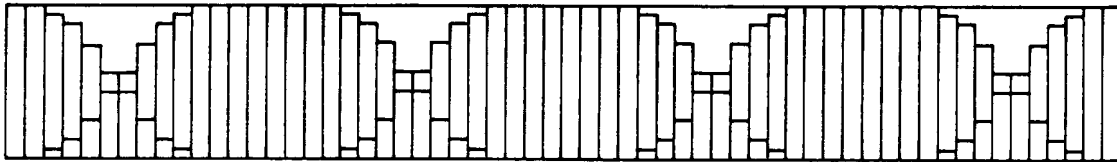
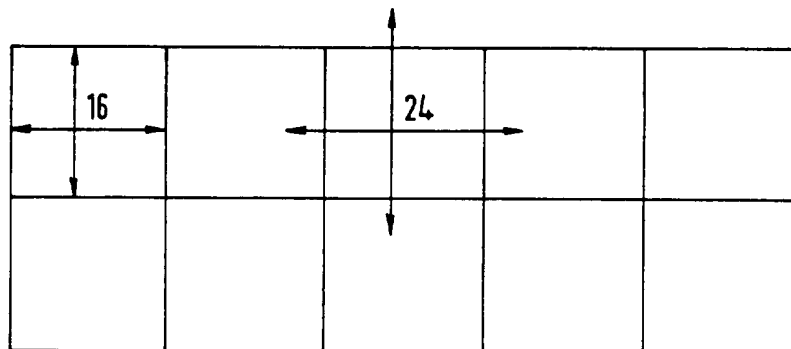
2-DIMENSIONAL  
TILING MODEL

FIG. 5

VIDEO COMPRESSION

This invention relates to video compression methods and apparatus, in particular in the context of motion vector compensation techniques.

5        One digital compression standard, known as MPEG, was devised by and named after the Motion Picture Experts Group of the International Standards Organisation (ISO). In one form, known as MPEG1, early versions of the draft standard made use of forward prediction between past and current frames of a video signal. In later forms of MPEG1 and another MPEG2, the standard additionally makes use of  
10    bidirectional prediction, namely a combination of forward and backward prediction with the prediction made as an average of the forward and backward predictive frames.

The use of motion compensation is an important aspect of MPEG coding. Motion compensation aims to minimise the error signal in difference frames by  
15    compensating for inter-frame movement. The process of motion compensation involves two separate processes:

- i)        Motion Vector Estimation (MVE); in which the motion offset between a frame pair is calculated; and
- ii)       Motion Vector Compensation (MVC); which uses the results of the  
20    MVE calculations to produce a difference signal with minimum artifacts.

There are several aspect of MVE and MVC which must be considered such as:

- i)        The type of motion permitted. In MPEG and other similar systems, the type of motion is limited simply to translational vectors in the 'X' and 'Y' axes. Researchers working in other fields have used other motion types, such as rotation,  
25    skew and size. The benefits of this work are not clear since using more complex

shape matching may reduce the signal in the difference picture, but requires more data to transmit the shape parameters.

ii) The size of the macroblock is a compromise between smaller blocks having better coding efficiency but higher macroblock data rate, and larger blocks having worse coding efficiency but lower macroblock data rate (where a macroblock is the block size used for motion estimation and compensation).

iii) How to combine the results from Luminance (Y) and Chrominance (C) block matching. If completely separate vectors are used for Y and C motion vectors, the macroblock data rate will be doubled and there may be the possibility of picture disturbances created by poor matching of Y and C vectors. Combining the Y and C vectors will result in a lower macroblock data rate but the coding efficiency may drop slightly.

iv) The use of sub-pixel estimation and compensation. Often, motion between frames does not appear at integer pixel distances so some form of sub-pixel MVE and MVC will be beneficial. More vector data is generated to be transmitted/recorded and the data increase is very small but simple half-pixel estimation requires at least four times the computational power of a pixel based estimator and this must be considered.

There is a need for further developments in motion compensation coding with emphasis on low bit-rate systems in the range 64Kbps to 2Mbps.

Many motion compensated prediction systems use only luminance information for motion vector generation and compensation. However, there are instances of pictures in which much of the motion detail is present in the chrominance data. In such instances, separate motion vectors may be calculated for luminance and chrominance signals. If the luminance and chrominance pixel rates were identical,

then a single motion vector could be calculated for both luminance and chrominance signals. However, the chrominance pixel rate is half the luminance rate in both horizontal and vertical axes.

According to the present invention there is provided a video compression  
5 method involving motion vector processing, wherein the chrominance sampling rate is half the luminance sampling rate, the method comprising estimating a luminance motion vector representing luminance motion in a video picture, making a rounding decision, if necessary, as to the best corresponding chrominance motion fit, and including an additional bit in the luminance motion vector, the digital value of the  
10 additional bit representing the rounding decision, wherein the luminance motion vector with additional bit conveys information as to both luminance and chrominance motion.

A chrominance motion vector is then derived by division of the luminance vector by two, and if a rounding decision is necessary following the division, that decision is made in response to the digital value of the additional bit of the luminance  
15 motion vector.

The preferred embodiment is capable of generating and applying motion vectors with the addition of one extra bit in each axis, if necessary, to ensure accurate luminance and chrominance motion vectors. Experimental results show a particular improvement for chrominance data.

20 The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which:

Figure 1 shows a sample grid of luminance and chrominance components;

Figure 2 shows a rounding process used for chrominance vector estimation;

25 Figure 3 shows the use of interpolation filters to create sub-pixel vectors;

Figure 4 shows window functions for luminance and chrominance macroblocks;  
and

Figure 5 shows overlay of the motion vector windows in one and two dimensions.

5 Three sizes of picture have been used with motion compensation;

i) 'VID' files: 720\*576 pixels (and 704\*576), with a target bit rate of  
around 4Mbps.

ii) 'SIF' files: 352\*288 pixels with a target bit rate of around 1Mbps (video  
only) and

10 iii) 'QIF' files: 176\*144 pixels with a target bit rate of around 220Kbps  
(video only).

In each case, the chrominance pixel size is half in each axis for each  
component.

Experiments have been conducted to find the optimum macroblock size for  
15 each of the above systems. In each case the position was clear in that a macroblock  
size of 16\*16 pixels for luminance and 8\*8 for each chrominance produced the best  
results. In all three cases above, smaller macroblocks such as 8\*8 for Y and 4\*4 for  
C resulted in too much vector data, and larger macroblocks such as 24\*24 for Y and  
12\*12 for C resulted in low levels of macroblock data but high error signals in the  
20 difference pictures. In this respect MPEG has correctly set the optimum motion vector  
block size.

The vector data to be transmitted depends on the picture size, but the following  
calculations were used as a guide to the data rate required for vector transmission:

**Case 1: 'VID' files, 720\*576 pixels**

Number of macroblocks =  $45 \times 36 = 1620$  per frame

Assuming the logarithmic temporal decimation structure and for Y data a vector range limit of  $\pm 31$  pixels/frame, for an 8-Frame GOP (group of pictures):

5	No of Frames	Vector Range	Bits	+&-	H&V	Y&C	Total Bits
	4	$\pm 31$	6	*2	*2	*2	192
	2	$\pm 63$	7	*2	*2	*2	112
	1	$\pm 127$	8	*2	*2	*2	<u>64</u>
	TOTAL BITS/GOP-MACROBLOCK:						<u>368</u>

10      The total vector bit rate is then  $368 \times 25/8 \times 1620 = \underline{1.863\text{Mbps}}$

Assuming that entropy coding can lower this by about 50%, then the overall vector bit rate can be reduced to around 900Kbps. As mentioned in the introduction, if the Y and C vectors are combined, then this data rate can be further reduced to around 500Kbps. More about the method of combination will follow in the next section.

15

**Case 2: 'SIF' files, 352\*288 pixels**

Number of macroblocks =  $22 \times 18 = 396$  per frame

Similar calculations to VID picture coding follow, bearing in mind that the vector range limit can be reduced to  $\pm 15$  pixels/frame:

20	No of Frames	Vector Range	Bits	+&-	H&V	Y&C	Total Bits
	4	$\pm 15$	5	*2	*2	*2	160
	2	$\pm 31$	6	*2	*2	*2	96
	1	$\pm 63$	7	*2	*2	*2	<u>56</u>
	TOTAL BITS/GOP-MACROBLOCK:						<u>312</u>

25      The total vector bit rate is then  $312 \times 25/8 \times 396 = \underline{386.1\text{Kbps}}$

With entropy coding and Y/C vector combination, this can be reduced to around 100Kbps.



**Case 3: 'SIF' files, 176\*144 pixels**

Number of macroblocks =  $11*9 = 99$  per frame

For 'QIF' coding, and using a vector range limit as for SIF pictures because motion errors are much more critical with such a low resolution source, then the total  
5 vector bit rate becomes;

$$312*25/8*99 = \underline{96.5\text{Kbps}}$$

which, with entropy reduction and Y/C vector combination, reduces to around 25Kbps.

In each case above, the vector data rate is around 10% of the total required bit  
10 rate which is a reasonable allowance and not a level at which the motion vectors would severely limit the primary coding method. The use of macroblocks at a quarter of the size used above would increase the vector data rate to around 40% of the total data rate and become a severe overhead to the coding efficiency. The benefit gained by the use of quarter sized macroblocks is less than the quality loss resulting in the  
15 main coding area. Likewise, use of larger macroblocks reduces the vector data rate but only gains a small benefit for other coding areas. Such large macroblocks result in larger difference picture errors which cannot be so easily compensated in the remaining coding elements.

The use of sub-pixel vectors will require a small amount of extra data  
20 equivalent to an extra 14 bits per macroblock-GOP.

It has been mentioned that sending separate vectors for Y and C is wasteful of data bandwidth and could lead to misalignment of luminance and colour information. It is a commonly observed fact that the motion vectors of the chrominance components almost always follow the luminance component. There are  
25 exceptions, but these are very rare. Furthermore, the B-Y and R-Y components tend to have the same motion vectors. Therefore, a set of three vectors can easily be reduced to one by this simple assumption.

The problem with this assumption is a result of the nature of the chroma sub-sampling. Each chrominance component has half the sampling rate of the luminance  
30 component, leading to the sampling grid shown in Figure 1.

Then, if a vector value has an odd luminance pixel value, there is a rounding

problem in the chrominance vector value since the vector does not point directly to a chrominance pixel site. At first it may seem that simple rounding could be applied, and first experiments used this. However, it was found in subsequent tests that the choice of round-up or round-down resulted in a significant performance change for the chrominance coding. The rounding must be selected on a macroblock basis, and since there are two axes for the vectors, there are several rounding combinations as shown in Figure 2.

In the first case, as shown in Figure 2, where the horizontal vector is even valued and the vertical vector is odd valued, then the horizontal chrominance vector is simply half the luminance vector. However, the odd valued vertical vector can be rounded either up or down as indicated in the figure. Likewise for the second case where the vertical vector is even valued and the horizontal vector is odd valued. In this case, the horizontal rounding can be either up or down as indicated. In the last case, both horizontal and vertical vectors are odd valued resulting in four possible rounding options as shown.

The method of dynamically rounding on a macroblock basis could be avoided if the chrominance data were interpolated to the same size as the luminance data; however, this is expensive and uses extra memory. This alternative method works well and can be simply implemented by adding one extra bit to each luminance vector. If the bit is zero, then the rounding of the chrominance vector is 'down'; if the bit is one, then the rounding is 'up'. This small overhead will cover all the options shown in Figure 2 and is a much lower overhead than that required to send independent chrominance vector data. Note that the technique is applied to both MVE and MVC processes.

A further issue concerns the relationship between the scaling of Y and C values to generate the mean square error MSE (or mean absolute difference MAD) values for MVE. Both Y and C are used since the vector will represent both components and where, for example, block matching of the luminance component may show little difference, the chrominance difference value may hold the balance of vector selection. In various experiments, the ratio did not seem to be critical and both the following expressions were used for vector selection at various points in the project timescale:

$$\text{MSE(a)} = (Y_c)^2 + (C_c)^2$$

$$\text{MSE(b)} = (Y_c)^2 + 2*(C_c)^2$$

Since there seems to be little benefit for either, the first case is to be recommended because of its simplicity.

In the experiments conducted to assess the benefits of sub-pixel MVE and MVC, only 1/2 pixels have been considered. Using 'VID' files presents a problem in that the video is interlaced and the question arises as to the best method of vertical interpolation. Horizontal interpolation is not a problem.

Using 'SIF' and 'QIF' picture sources presents a simple linear interpolation process since both are effectively frame based progressively scanned at 25 frames per second. However, the filter order becomes an important issue as the pixel sizes reduce since the filter ringing artifacts become increasingly visible.

All interpolation filters have been based on half-band filters. Four types were used offering increasing tap lengths and sharper transition bands as follows:

1)					1	2	1								
2)				-1	0	9	16	9	0	-1					
3)		3	0	-16	0	77	128	77	0	-16	0	3			
4)	-6	0	26	0	-79	0	315	512	315	0	-79	0	26	0	-6

These filters will be referred to as respectively 1, 2, 3 and 4.

The first test results used 'VID' pictures compressed using the 2-frame 'SX' system using alternate 'I' and 'B' frames. These results show the effects of applying first horizontal interpolation, only, then horizontal and vertical interpolation where the vertical interpolation was applied to a frame (rather than a field).

Frame Number:		1	3	5	7	9	11	13	15	17	19	
5	No Interpolation	Y mse	7.3841	6.9818	6.4252	7.7629	7.4938	7.0807	<b>9.8862</b>	8.0370	10.001	8.7079
		C mse	2.7787	2.5288	2.7253	2.6123	2.3503	2.2419	2.0432	1.8610	1.8340	1.9962
		Y S/N	36.69	36.65	36.72	36.64	36.64	36.66	36.56	36.48	36.55	36.51
		C S/N	37.31	37.24	37.32	37.35	37.27	37.29	37.18	37.06	37.07	37.02
		Y bpp	1.4937	1.4935	1.4622	1.5349	1.5334	1.4951	1.6676	1.5773	1.6626	1.5910
		C bpp	0.4685	0.4565	0.4641	0.4581	0.4465	0.4469	0.4358	0.4273	0.4278	0.4281
		$\Sigma$ bpp	1.9622	1.9500	1.9263	1.9930	1.9799	1.9420	2.1034	2.0046	<b>2.0904</b>	2.0191
10	Horizontal Interpolation Only	Y mse	7.1965	6.6262	6.0303	7.525	7.2961	7.7389	6.3086	5.8330	5.4225	7.3818
		C mse	1.9811	1.9371	1.8813	1.9883	1.9111	1.8585	2.0060	1.7843	1.9985	1.9191
		Y S/N	36.67	36.65	36.73	36.63	36.63	36.60	36.67	36.78	36.80	36.67
		C S/N	37.41	37.32	37.41	37.43	37.34	37.34	37.18	37.06	37.06	37.03
		Y bpp	1.4981	1.4905	1.4527	1.5448	1.5417	1.5707	1.4453	1.3969	1.3810	1.4948
		C bpp	0.4102	0.4108	0.4077	0.4089	0.4075	0.4107	0.4268	0.4217	0.4333	0.4244
		$\Sigma$ bpp	1.9083	1.9013	1.8604	1.9537	1.9492	1.9814	1.8721	1.8186	1.8143	1.9192
15	Horizontal and Vertical Interpolation	Y mse	7.5413	7.2948	6.8039	8.0667	7.9487	8.2087	6.4070	6.0407	5.4421	7.7807
		C mse	1.8764	1.9113	1.9978	1.9651	1.8879	1.8651	2.0660	1.8445	2.0226	1.8970
		Y S/N	36.68	36.65	36.73	36.64	36.64	36.61	36.67	36.78	36.80	36.69
		C S/N	37.42	37.34	37.43	37.44	37.34	37.36	37.19	37.07	37.06	37.03
		Y bpp	1.5114	1.5133	1.4843	1.5674	1.5645	1.5930	1.4547	1.4070	1.3840	1.5059
		C bpp	0.4099	0.4089	0.4083	0.4094	0.4054	0.4087	0.4269	0.4213	0.4324	0.4230
		$\Sigma$ bpp	1.9213	1.9222	1.8926	1.9768	1.9699	2.0017	1.8816	1.8283	1.8164	1.9289
20		Y mse	7.5413	7.2948	6.8039	8.0667	7.9487	8.2087	6.4070	6.0407	5.4421	7.7807
		C mse	1.8764	1.9113	1.9978	1.9651	1.8879	1.8651	2.0660	1.8445	2.0226	1.8970
		Y S/N	36.68	36.65	36.73	36.64	36.64	36.61	36.67	36.78	36.80	36.69
		C S/N	37.42	37.34	37.43	37.44	37.34	37.36	37.19	37.07	37.06	37.03
		Y bpp	1.5114	1.5133	1.4843	1.5674	1.5645	1.5930	1.4547	1.4070	1.3840	1.5059
		C bpp	0.4099	0.4089	0.4083	0.4094	0.4054	0.4087	0.4269	0.4213	0.4324	0.4230
		$\Sigma$ bpp	1.9213	1.9222	1.8926	1.9768	1.9699	2.0017	1.8816	1.8283	1.8164	1.9289

Table 1: Sub-Pixel Motion Compensation Using Different Methods

The horizontal filter was set to type 3 and the vertical to type 1. The results are shown in Table 1 for a system with the following parameters:

Source Picture: Mobile & Calendar, frames 0-20

Compression type: I-B, 2-frame with 3-stage Wavelet Spatial Decimation

Quantisation: Q=1070, Quantiser Viewing Height=3H

From this table, it can be clearly seen that the addition of horizontal sub-pixel motion compensation is worthwhile leading to significant drops in the overall bit rate (whilst S/N remains similar). However, the addition of vertical sub-pixel motion compensation adds nothing, indeed makes the performance worse. The benefits of vertical sub-pixel motion compensation are, therefore, difficult to justify for an interlaced scan picture source.

However, SIF and QIF pictures are frame based and do not have any problems with interlace. In experiments on both types of picture source, the application of sub-pixel motion compensation is equally valid in both the horizontal and vertical directions and as such the same filters are used for interpolation in both axes.

The second set of results were a rather more comprehensive comparison of pixel and sub-pixel motion compensation based on the use of SIF pictures coded at 0.4 bpp (~1Mbps) based on an 8 frame GOP with Wavelet Spatial Decimation. Results are given in Table 2 below.

Vector Type:		Integer Motion Vectors						Sub-Pixel Motion Vectors					
Sequence		Q	Y S/N	C S/N	Y bpp	C bpp	$\Sigma$ bpp	Q	Y S/N	C S/N	Y bpp	C bpp	$\Sigma$ bpp
Mobile & Calendar	0-8	185	27.57	29.69	.3363	.1065	.3895	220	28.94	30.76	.3356	.1241	.3976
	8-16	185	27.61	29.69	.3328	.1073	.3864	215	28.74	30.64	.3285	.1234	.3902
	16-24	205	28.54	30.28	.3305	.1195	.3902	230	29.32	31.12	.3327	.1254	.3954
Renata	0-8	280	31.60	35.83	.3655	.0659	.3984	300	32.04	36.10	.3645	.0700	.3995
	8-16	270	31.24	35.53	.3568	.0643	.3889	280	31.53	35.63	.3510	.0660	.3840
	16-24	290	31.44	35.69	.3637	.0631	.3952	310	31.89	36.01	.3672	.0706	.4025
Football	0-8	450	37.28	39.49	.3596	.0677	.3934	490	37.91	39.90	.3614	.0745	.3986
	8-16	415	36.52	38.72	.3629	.0576	.3917	470	37.37	39.35	.3615	.0652	.3927
	16-24	320	33.88	36.63	.3633	.0578	.3922	360	34.63	37.23	.3601	.0674	.3938
Susie	0-8	1170	43.46	45.50	.3509	.0846	.3932	1420	44.75	46.21	.3497	.1006	.4000
	8-16	1160	43.48	45.48	.3550	.0839	.3969	1410	44.60	46.25	.3459	.1016	.3967
	16-24	1095	42.98	45.31	.3475	.0744	.3847	1300	44.37	46.04	.3546	.0911	.4001
	24-32	980	42.59	44.96	.3578	.0668	.3912	1140	43.60	45.46	.3541	.0760	.3921
	32-40	800	42.10	44.34	.3559	.0698	.3908	810	42.32	44.32	.3587	.0672	.3923
	40-48	890	43.67	44.99	.3434	.1028	.3948	900	43.74	45.07	.3416	.1026	.3929

Table 2: Results of Pixel and Sub-pixel based Motion Vector Compensation for 1Mbps SIF Pictures

Note 1: the calculation of the sum bit rate is  $Y + C/2$  since the chrominance only has half the number of pixels compared to luminance.

Note 2: the interpolation filter was of type 4 (the most complex) for both horizontal and vertical axes.

5 The results show a clear benefit of using sub-pixel vectors; rather clearer than the earlier example, and where the use of sub-pixel motion vectors produces a visible improvement in picture quality in viewing tests.

Tests of QIF coding always used sub-pixel motion vector compensation since all available methods were required to make any useful results available at the low  
10 bits-per-pixel targeted for this application. Hence no comparative measurements are available for QIF coding.

The investigations of the previous section revealed an anomaly in the philosophy of motion vector estimation as currently performed. It was not clear whether this would affect coding performance.

15 The anomaly only affects 'B' frames, not 'P' frames. Each 'B' frame has associated a pair of motion vectors, one pointing to the frame behind in time, the other pointing to a frame in advance. The selection of the vectors is made by comparing the macroblock of the current frame with a macroblock in another frame, but offset by an X-Y coordinate offset. This is usually calculated forwards and backwards by  
20 independent calculations. However, a 'B' frame is created by taking the average macroblock created from macroblocks in frames forwards and backwards of the 'B' frame; i.e.

$$B_1 = I_1 - I_0/2 - I_2/2. \text{ This is equivalent to a high pass filter: } -1, 2, -1.$$

25 The optimum macroblocks from frames  $I_0$  and  $I_2$  are normally calculated independently. This is equivalent to using a filter of type: 1, -1. The filters used for MVE are not the ones used for MVC. It is possible to envisage specific patterns which could cause a serious problem with the current method of MVE.

It is also easy to envisage a method of MVE which overcomes the problem by comparing the  $I_1$  frame with all combinations of vector offsets each side. However,  
30 for a vector range of  $\pm V$  pixels, the independent vector calculation is proportional to:

$$2^* (V^3)$$

whereas, with a bidirectional search, the calculation becomes proportional to:

$$(V^3)^2 = V^6, \quad \text{i.e. many times larger.}$$

Where normal vector estimation is a severe computational problem, the prospect of bi-directional vector estimation for 'B' frame calculations is forbidding. No formal work has been done in this area. Indications given by the MSE values show that the normal method of MVE generation produces results which are close to the bi-directional value and it is suspected that for most pictures, there is no gain. However, designers should be aware of this problem should it ever become noticeable with certain motion sequences. If it becomes necessary to look into this area in more detail, it should be noted that there are ideas to minimise the processing impact – namely to use the independent results as a first estimate, then adopt a small search sub-area for each vector set to search for a minimum on the basis of a bi-directional search.

Note that the bi-directional search is only a function of encoding, and does not affect decoders; thus it is a retro-fittable feature to an encoder.

Almost all the results of integer motion vector estimation show a relatively slow variation of values around the minimum vector. This raises the prospect of using a filter to determine sub-pixel vectors by applying interpolation filters to the vector correlation profile rather than the signal. The concept is simply illustrated in Figure 3.

The interpolating filters should be of the half-band type defined earlier as filters 1-4. It is necessary for the interpolating filter to have negative valued coefficients otherwise interpolated vector values will never be minimum. Early work in this area proved the potential of this technique, but other areas of work meant that this technique was never established over the standard method of interpolating the picture data to generate sub-pixel motion vectors. This technique still needs further work to confirm if it produces vectors which are as reliable as the conventional method. The benefit is the considerable reduction in computation time taken to produce sub-pixel vector results.

A significant aspect of motion vector compensation is that of applying a soft

window to the macroblock structure. During tests on the 1Mbps 'SIF' coded pictures, it was noticed that in areas of rapid movement, the macroblock structure becomes visible. This is clearly evident when stepping through the sequence frame by frame. The macroblock became much more visible at the low rate of 256Kbps using 'QIF' pictures where the macroblocks occupy an array size of 11 by 9 and are thus 16 times the area of a 'VID' coded picture.

At such a low bit rate, it became necessary to consider methods of improving the macroblock error visibility. As mentioned earlier, using smaller sized macroblocks is not possible because of the excessive bit rate taken by larger number of vectors. However, it is possible to significantly reduce the visibility of macroblock errors by using a windowing technique. The basic size of the macroblock remains 16\*16 for luminance (8\*8 for each chrominance); however, a window of 24\*24 (12\*12 for chrominance) is used for the vector assisted frame differencing. In order for the overall estimation picture to have equal gain, the edges of the window are tapered as shown in Figure 4 which shows window functions for Y and C macroblocks.

The windows shown in Figure 4 form 'tiles' which can be overlaid on each other to form an overall flat surface as illustrated in Figure 5.

Using the 1-D template given in Figure 4 and representing the window by the expression:

```
for(x=0; x<24; x++)    window [x]=template[x];
```

then the 2-D window is given by the expression:

```
for(x=0; x<24; x++)
```

```
for(y=0; y<24; y++)
```

```
    window[x][y]=template[x]*template[y];
```

Since the 1-D window is scaled by a value of 16, then the 2-D window is scaled by a factor of 256.

Tests were carried out to assess the effectiveness of windowed motion vectors used in both the motion estimation and motion compensation processes. These results are summarised in Tables 3 and 4 which show for different types of sequence, respectively:



- (i) Using block based MVE and comparing block based MVC with window based MVC
- (ii) Using window based MVC and comparing block based MVE with window based MVE.

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MV Type:		Block MVE, block MVC						Block MVE, window MVC					
Sequence		Q	Y S/N	C S/N	Y bpp	C bpp	$\Sigma$ bpp	Q	Y S/N	C S/N	Y bpp	C bpp	$\Sigma$ bpp
Mobile & Calendar	0-8	182	28.35	32.52	.2646	.1228	.3260	184	28.42	32.56	.2636	.1242	.3257
	8-16	175	28.15	32.34	.2683	.1140	.3253	177	28.23	32.40	.2679	.1150	.3254
	16-24	182	28.48	32.72	.2681	.1185	.3273	182	28.47	32.71	.2656	.1183	.3247
Renata	0-8	294	32.88	39.61	.3027	.0447	.3250	294	32.90	39.65	.3020	.0446	.3243
	8-16	315	33.32	40.10	.2984	.0543	.3255	315	33.23	40.11	.2999	.0543	.3270
	16-24	345	34.00	40.44	.2965	.0561	.3245	350	33.96	40.51	.3006	.0571	.3291
Football	0-8	285	34.14	38.60	.3052	.0296	.3200	305	34.69	38.90	.3112	.0319	.3271
	8-16	285	33.39	38.55	.3078	.0251	.3203	300	33.81	38.78	.3126	.0263	.3257
	16-24	235	31.38	37.33	.3124	.0261	.3254	242	31.68	37.45	.3119	.0271	.3254
Susie	0-8	940	42.63	47.59	.2952	.0643	.3273	920	42.35	47.36	.2954	.0617	.3262
	8-16	930	42.72	47.54	.2956	.0622	.3267	915	42.50	47.44	.2961	.0615	.3268
	16-24	860	41.98	47.02	.2987	.0548	.3261	860	41.83	47.02	.2996	.0548	.3266
	24-32	730	40.68	46.39	.3037	.0478	.3276	735	40.63	46.53	.3024	.0483	.3265
	32-40	470	38.55	43.27	.3130	.0288	.3274	494	39.02	43.68	.3084	.0306	.3237
	40-48	470	39.44	42.36	.3107	.0251	.3232	540	40.76	43.03	.3109	.0291	.3254

Table 3: Comparing Block MVC against Windowed MVC

MV Type	Sequence	Block MVE. window MVC						Window MVE. window MVC					
		Q	Y S/N	C S/N	Y bpp	C bpp	$\Sigma$ bpp	Q	Y S/N	C S/N	Y bpp	C bpp	$\Sigma$ bpp
Mobile & Calendar	0-8	184	28.42	32.56	.2636	.1242	.3257	184	28.41	32.56	.2646	.1244	.3268
	8-16	177	28.23	32.40	.2679	.1150	.3254	176	28.17	32.36	.2667	.1146	.3240
	16-24	182	28.47	32.71	.2656	.1183	.3247	182	28.48	32.71	.2655	.1184	.3247
Renata	0-8	294	32.90	39.65	.3020	.0446	.3243	301	33.02	39.89	.3041	.0461	.3271
	8-16	315	33.23	40.11	.2999	.0543	.3270	315	33.27	40.12	.2962	.0544	.3234
	16-24	350	33.96	40.51	.3006	.0571	.3291	350	34.00	40.50	.2988	.0571	.3273
Football	0-8	305	34.69	38.90	.3112	.0319	.3271	308	34.74	39.19	.3108	.0324	.3270
	8-16	300	33.81	38.78	.3126	.0263	.3257	300	33.86	38.91	.3106	.0262	.3237
	16-24	242	31.68	37.45	.3119	.0271	.3254	242	31.64	37.49	.3101	.0271	.3236
Susie	0-8	920	42.35	47.36	.2954	.0617	.3262	920	42.36	47.35	.2980	.0617	.3296
	8-16	915	42.50	47.44	.2961	.0615	.3268	930	42.57	47.53	.2987	.0622	.3298
	16-24	860	41.83	47.02	.2996	.0548	.3266	860	41.83	47.01	.2977	.0548	.3251
	24-32	735	40.63	46.53	.3024	.0483	.3265	738	40.65	46.53	.3009	.0485	.3251
	32-40	494	39.02	43.68	.3084	.0306	.3237	494	39.04	43.69	.3087	.0306	.3240
	40-48	540	40.76	43.03	.3109	.0291	.3254	540	40.78	43.25	.3081	.0293	.3227

Table 4: Comparing Block Matched MVE and Window Matched MVE

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The cost of implementing windowed MVC is relatively small and is a practical option, particularly in view of the considerable quality improvement obtained over block based MVC. This improvement is numerically most noticeable in the last two rows of the Susie results in Table 3. Other rows show little change or even slightly worse results. The visual effect of windowed MVC is, however, always better than block based MVC.

30

Turning to the results of Table 4; the results of the comparison show small differences in some sequences, but the implementation of windowed MVE is very expensive since it involves computations over a much wider area. This is reflected in the software run-time which was noticeably slower than block based MVE. This factor, together with the results of Table 5 clearly show that the effort of using both windowed MVE and windowed MVC is not worthwhile. There is also little visual improvement also. However, using block based MVE and window based MVC is very beneficial and change a previously unacceptable picture quality (the Susie sequence in particular) to a much more acceptable quality level.

The combination of block-based MVE and window based MVC was also applied to the SIF coded pictures at 1Mbps with a similar quality improvement. It has yet to be established that the improvement is worthwhile at higher data rates (e.g. for 'VID' pictures at 4Mbps), however, it is likely that the benefit will still exist, but at lower levels.

CLAIMS

1. A video compression method involving motion vector processing, wherein the chrominance sampling rate is half the luminance sampling rate, the method comprising  
5 estimating a luminance motion vector representing luminance motion in a video picture, making a rounding decision, if necessary, as to the best corresponding chrominance motion fit, and including an additional bit in the luminance motion vector, the digital value of the additional bit representing the rounding decision, wherein the luminance motion vector with additional bit conveys information as to  
10 both luminance and chrominance motion.
2. A method according to claim 1, wherein a chrominance motion vector is derived by division of the luminance motion vector by two, and if a rounding decision is necessary following the division, that decision is made in response to the digital  
15 value of the additional bit of the luminance motion vector.
3. A method according to claim 1 or claim 2, wherein the rounding decision is made on the basis of a mean square error of motion vector estimation involving the sum of the squares of luminance and chrominance errors.  
20
4. A method according to claim 1, claim 2 or claim 3, wherein the luminance motion vector includes one additional bit whose digital value represents a rounding in the horizontal direction.
- 25 5. A method according to claim 1, claim 2 or claim 3, wherein the luminance motion vector includes one additional bit whose digital value represents a rounding in the vertical direction.
6. A method according to claim 1, claim 2 or claim 3, wherein the luminance  
30 motion vector includes first and second additional bits whose respective digital values represent rounding in both horizontal and vertical directions.

7. A video compression method substantially as herein described with reference to Figure 2 of the accompanying drawings.
- 5 8. Video compression apparatus operable in accordance with the method set out in any one of the preceding claims.

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**Patents Act 1977**  
**Examiner's report to the Comptroller under Section 17**  
**(The Search report)**

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**Relevant Technical Fields**

Search Examiner  
MR J M McCANN

- (i) UK Cl (Ed.N)      H4F (FRC, FRT, FRP, FRG, FRW, FGM)  
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7/48, 7/50)

Date of completion of Search  
22 AUGUST 1995

**Databases** (see below)

Documents considered relevant  
following a search in respect of  
Claims :-  
1

- (i) UK Patent Office collections of GB, EP, WO and US patent  
specifications.

- (ii) WPI

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