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(54) **Spatial interpolator for video format conversion**

(57) Conversion is carried out with the aid of direction-dependent interpolation within moving objects. Interpolation lines (RL1, RL2, etc), which are rotated with respect to one another, are projected through the pixel to be generated (X) and their intersections (A, B, C) with adjacently situated lines of pixels in the first pixel raster (71, 72) are determined. The changes in brightness value between the intersects on the adjacent lines, said intersects being allocated to the individual interpolation directions, are determined and the interpolation line whose change in brightness value is a minimum compared with the changes in brightness value of adjacently situated interpolation lines is selected. If the minimum change is greater than a specific threshold the vertical interpolation direction is selected. The brightness value of the pixel to be generated is then generated by interpolation in the direction of the interpolation line determined.

FIG 3

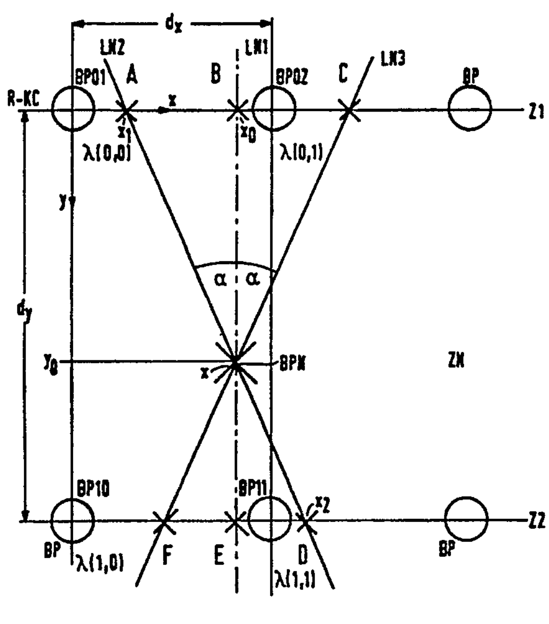

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FIG 1

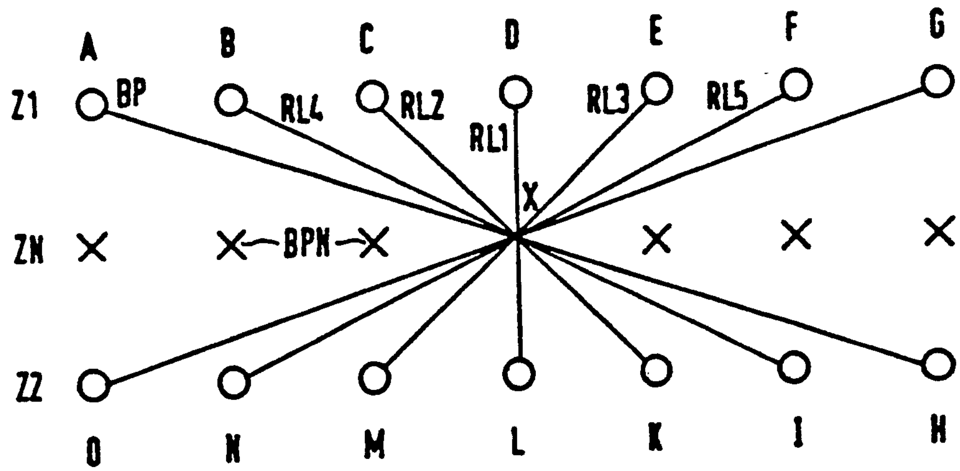

A
B
C
D
E
F
G
Z1
BP
RL4
RL2
RL1
RL3
RL5
X
ZN
BPN
Z2
O
N
M
L
K
I
H

FIG 2

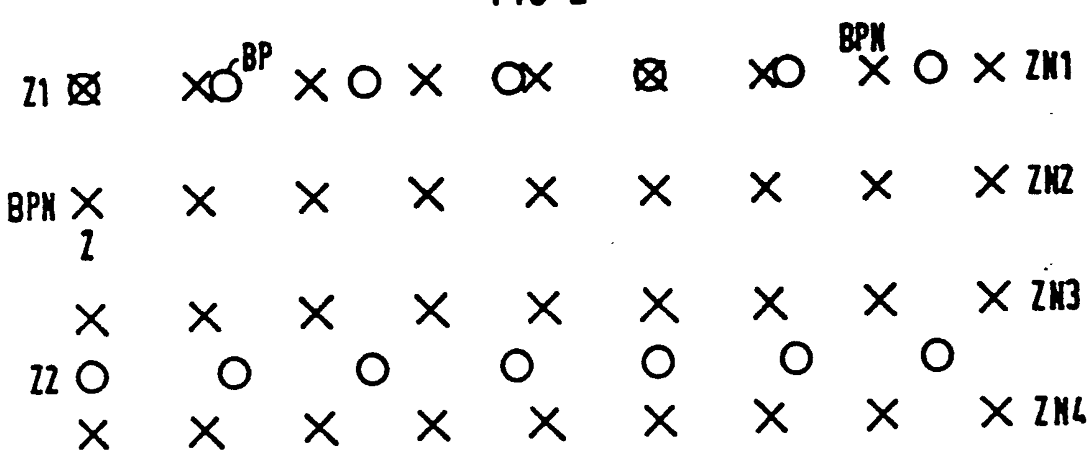
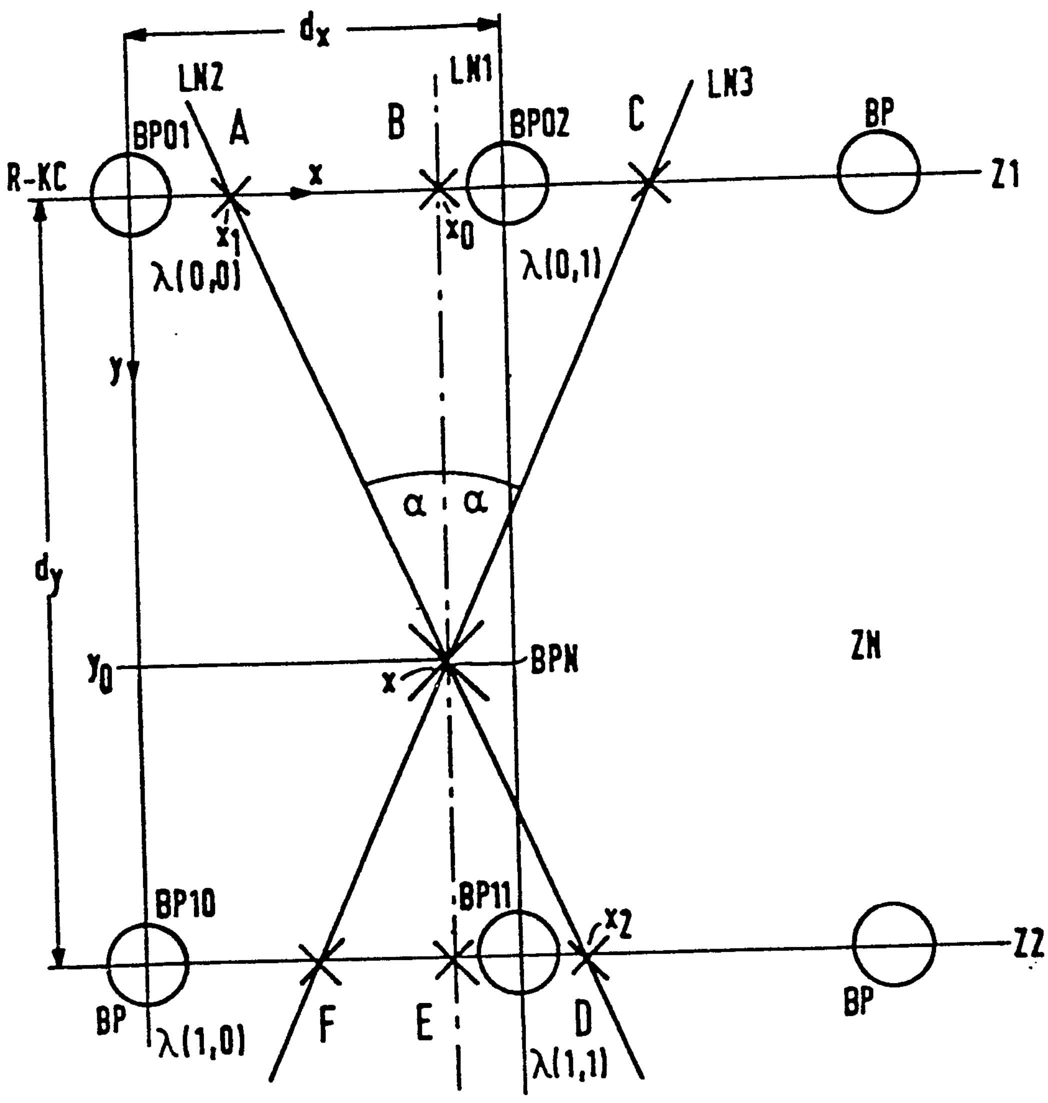

Z1
BP
BPN
ZN1
BPN
Z
ZN2
ZN3
Z2
ZN4

FIG 3


dx
LN2
LN1
LN3
A
B
C
BP01
BP02
BP
R-KC
x
Z1
x1
x0
λ(0,0)
λ(0,1)
y
α
α
dy
y0
x
BPN
ZN
BP10
BP11
x2
Z2
BP
F
E
D
BP
λ(1,0)
λ(1,1)

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METHOD FOR THE FORMAT CONVERSION OF PICTURE SEQUENCES PRESENT IN A FIRST PIXEL RASTER INTO A SECOND PIXEL RASTER

A multiplicity of picture formats (pixel rasters), which are mostly incompatible with one another, exist for the recording, transmission and reproduction of picture sequences. Depending on the application, the recording takes place with varying height/width ratio and with varying local and lateral resolution. In addition, scanning takes place, for example, either using a line interlace method or progressively, line-by-line. Corresponding differences exist during reproduction of the picture.

A central problem is format incompatibility in the linking of the "television world" with the "computer world". With the appearance of multimedia applications, however, it becomes necessary to eliminate this incompatibility and to carry out a picture format conversion from "interlaced TV" at 50 hertz or 60 hertz field frequency into the computer format (progressive mode with picture frequencies between 60 and 100 hertz).

However, this problem has not yet been taken into account in the computer cards currently available commercially. On the contrary, the two fields of a frame are always written into a picture memory and the latter is read out sequentially. In stationary areas, this method is perfect, but in the case of movement, disturbing effects (i.e. comb-like distortion of vertical edges or double contours during horizontal movement, scrambling of a moving object and background during vertical movement, scrambling of finely structured textures during all movements) occur because of the time displacement of the two fields. This method is not acceptable for high-quality reproduction of video on computer terminals. A further, very simple solution is to supplement the missing lines in each field by vertical interpolation. Although the effects mentioned above are thereby avoided, a loss in the vertical resolution now occurs, i.e. the pictures are not sharp in the vertical direction in all areas. Even the combination of the two methods by moving-object segmentation still fails to provide a satisfactory result since the impression of lack of sharpness in moving objects is retained.

Solutions to this de-interlacing problem have been suggested in the literature. Relatively simple methods use linear or nonlinear (median) filtering for a positional time interpolation (i.e. P. Haavisto, J. Juhola, and Y. Neuvo: "Motion adaptive scan rate up-conversion". Multidimensional System and Signal Processing, Vol. 3 No. 2, pp. 113-130, May 1992; M. Weston and D.M. Ackroyd. Fixed, adaptive and motion compensated interpolation of interlaced TV pictures. International Broadcasting Convention 1988, IEE Conference Publication No. 293, pp. 220-223, Sept. 1988). A further method is based on a direction-dependent interpolation using edge information (i.e. T. Doyle and M. Looymans: "Progressive scan conversion using edge information". Proc. 1989 HDTV-Workshop, Torino). The best results are achieved with movement-compensating methods (i.e. M. Ernst: "Motion compensated video processing for studio applications". Conf. "Les Assisès des Jeunes Chercheurs", Tokyo, 8 - 12 June 1992). In such methods, any movement of objects occurring in the scene is estimated, and an interpolation is carried out taking into consideration the movement vectors determined in this way. However, these methods are extremely computationally intensive and are consequently also expensive to implement in terms of hardware. Specifically, compared with the movement estimation for the moving picture coding, the vectors have to be determined not only block by block but individually for each pixel instead. Furthermore, reliability tests have to be carried out so that the vectors also describe the actual movement as accurately as possible.

The problem underlying the present invention is to provide a method by which picture sequences of a first pixel raster can be converted into a second pixel raster, for example "interlaced" picture sequences into a progressive format ("de-interlacing"). The main application would be the reproduction of video on computer viewing screens in multimedia terminals. Said method should be as simple as possible so that, on the one hand, as good a picture quality as possible is achieved, but, on the other hand, an inexpensive hardware implementation is also made possible.

The method may, however, also be applied to television with improved picture quality, i.e. as an intermediate step in increasing the picture frequency for the so-called "flicker-free television set" or directly to reproduction in progressive format.

According to the present invention, there is provided a method for the format conversion of picture sequences present in a first pixel raster into a second pixel raster, in which the brightness values of the pixels in the second pixel raster are generated by interpolation from the pixels in a first and second line of the first pixel raster adjacent the pixel (X) to be generated, comprising the following steps:

a) selecting a plurality of pairs of points, each pair of points having one point on said first line and one point on said second line, which pair of points are fixed by interpolation lines (LN) which pass through the pixel (X) to be generated and are rotated with respect to one another, at least one of said interpolation lines being vertical;

b) determining the change in brightness between the pair of points fixed by the vertical interpolation line (LN1);

c) determining the change in brightness between pairs of points fixed by successive interpolation lines in two directions of rotation until the change in brightness value in the direction of one interpolation line is a minimum compared with the changes in brightness in the direction of the adjacently situated interpolation lines; and
d) generating the brightness value of the pixel by interpolating in the direction having the minimum change in brightness value.

The starting point in the method according to the invention is the method explained in T. Doyle and M. Looymans: "Progressive scan conversion using edge information". Proc. 1989 HDTV-Workshop, Torino. In the latter, a direction-dependent interpolation inside the moving objects is described. However, in this publication, the edge information is used to determine the direction of interpolation, while, in the case of the invention, a homogeneity criterion is used.

In this connection, the method according to the invention is based on the following observation. Most of the objects present in a scene have a certain homogeneity in relation to the brightness in a local neighbourhood. That is to say, because of the shape and the structure of the objects, a direction can be found for which the change in brightness value is minimal. This means that, in said respective direction, the proportion of high local frequencies is minimal. Accordingly, an interpolation in said direction may also result only in a minimum impairment of the resolution of the picture to be generated.

The method according to the invention makes it possible not only to generate pixels in a progressive display in the centre of two adjacently situated lines of the interlace format, but, in contrast, this method may also be used to generate any desired pixels of a second pixel raster, for example in a progressive display, starting from the pixels in a first pixel raster, for example in interlace format. It is consequently possible also to generate picture portions in windows of variable size, that is to say to scale pictures, i.e. to enlarge and reduce them. It is also possible to carry out enlargements of portions.

Further advantageous features of the method of the present invention are set out in the subclaims.

For a better understanding of the present invention, and to show how it may be brought into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 shows a basic diagram which indicates how missing pixels can be generated in a progressive display from a frame by direction-dependent interpolation,

Figure 2 shows a diagram illustrating the combination of de-interlacing with raster conversion;

Figure 3 is a diagram illustrating a method of determining the interpolation direction in a raster conversion.

Figure 1 shows a portion of a field, and specifically, two lines Z1 and Z2 of pixels BP in an interlace format are shown. The pixels BP in the interlace format are denoted by capital letters. From these pixels BP in the interlace format, pixels BPN are to be generated which are shown in Figure 1 in a line denoted by ZN midway between the lines Z1 and Z2.

In order to generate the pixels BPN, i.e. to determine their brightness value, the environment of the pixel to be generated, denoted by X in Figure 1, is investigated. In doing this, the starting point in Figure 1 is a window in the field which has a size of 7 x 2 pixels. The procedure is initially exactly as described in T. Doyle and M. Looymans: "Progressive scan conversion using edge information". Proc. 1989 HDTV-Workshop, Torino. Interpolation lines RL are projected through the pixel X to be generated and, in particular, are rotated through a specifiable angle with respect to one another. Said interpolation lines RL pass through the pixel X to be generated and through the pixels BP of the lines Z1 and Z2 in the field in Figure 1. For example, an interpolation line which is denoted by RL1 is produced in the vertical direction and adjacent interpolation lines are produced which are denoted by RL2 and RL3.

For each interpolation line RL, the change of brightness value between the pixels BP common to said line is now determined. In doing this, the starting point is the vertical interpolation line RL1 and the change in brightness value which exists between the points D and L is determined. Then the change in brightness value between the pixels C and K, for example, which are fixed by the interpolation line RL2, is then determined. If the change in brightness value between C and K is greater than between D and L, the change in brightness value between the pixels E and M is determined. If this is less than that between the points D and L, the interpolation line RL5 is now proceeded to and the change in brightness value which exists between the pixels F and N is determined. Assuming this change in brightness value is greater than that between the pixels E and M, a minimum in change in brightness value has been determined and the direction fixed by the interpolation line RL3 is used for the interpolation of the brightness value of pixel X. Starting from the brightness values of the pixel E and the pixel M, the brightness value which the pixel X to be generated should have is therefore determined by a known method.

According to the method, starting from the vertical line RL1, a minimum in the change in brightness value should therefore be sought in both directions of rotation and once a first minimum of this type has been found, the appropriate interpolation line, i.e. the pixels situated on this line, is selected and, proceeding from its brightness values, the brightness value of the pixel X to be generated is generated by interpolation.

If a possible interpolation direction has been found in this way, the question of whether this direction also reflects an adequately high homogeneity of the brightness is then investigated. This is so if the minimum in the change in brightness value is less than a specifiable threshold, otherwise the vertical interpolation direction is preferred. The interpolation can be achieved by simple averaging, but more expensive symmetrical transversal filters may also be used.

The location of the interpolation direction described in this way provides markedly fewer movement effects than the simple minimum location. The reason is that more remotely situated neighbouring points are only taken into account if the absolute difference in the changes in brightness value becomes increasingly smaller with rotation from the vertical. In the case of the method disclosed in T. Doyle and M. Looymans: "Progressive scan conversion using edge information". Proc. 1989 HDTV-Workshop, Torino, on the other hand, the minimum in the changes in brightness value is determined for all directions for, for example three interpolation lines or seven interpolation lines, and the interpolation is carried out proceeding from said minimum.

In Figure 1, the pixels BPN of the line ZN to be generated are situated in the centre between the lines Z1, Z2 of a field. Using the method according to the invention, however, it is also possible to generate a pixel in such a way that portions of the picture can be enlarged or reduced. A raster conversion for the local scaling of picture sequences and individual pictures is therefore made possible. The result of the method is therefore another pixel raster so that, for example, the interlaced/ progressive conversion can be linked to a pixel raster conversion. This change in pixel raster can be understood in principle, for example, from Figure 2. Here, again, two lines Z1 and Z2 in the field format are shown and lines ZN1 to ZN4 containing pixels BPN to be generated are shown in an altered pixel raster. In this diagram, the first line ZN1 is situated within the line Z1, the individual pixels BPN to be generated being displaced with respect to the pixels BP in the field format. Two further lines of pixels BPN to be generated, namely ZN2 and ZN3 are projected between the lines Z1 and Z2 in the field format and, finally, a further line ZN4 of pixels BPN to be generated is also situated on the other side of the line Z2.

From Figure 3, the method of obtaining individual pixels BPN from the field format during the pixel raster conversion can be understood in principle. Two lines Z1 and Z2 of pixels BP in field format are shown and between them a new line ZN of pixels BPN is to be generated. The present pixel X to be generated now no longer lies in the centre between the lines Z1 and Z2 but is displaced in the direction of the vertical lines between two pixels BP of the two lines Z1, Z2. Said pixel X can nevertheless be generated by the method according to the invention. As already explained, interpolation lines denoted by LN1, LN2 and LN3 are projected through the pixel X at a specifiable angle α. The lines LN meet the lines Z1, Z2 in the field format but not at the pixels BP present therein. The intersects of the lines LN with the lines Z1, Z2 are denoted by A, B, C on the line Z1 and F, E, D on the line Z2.

In order to determine the brightness value of the pixel X to be generated, the brightness value of the points A, B, C or F, E, D must first be determined since these points are not situated on the pixels BP. The minimum in the changes in the brightness value on the interpolation lines LN can then be determined in accordance with the method already explained, and the brightness value of the pixel X can be generated by interpolation after determining the direction having the minimum change in brightness value.

The determination of the brightness values of the pixels A, B, C is carried out by interpolation between adjacently situated pixels BP on the line Z1, on which the points A, B, C are situated. The same applies to the points F, E, D. The minimum in the changes in brightness value is then determined in the manner specified above and then the brightness value of the pixel X to be generated is determined by interpolation.

For the purpose of clarification, a coordinate network R-KC has been inserted in Figure 3. In this diagram:

d_x	=	horizontal spacing of two pixels BP,
d_y	=	vertical spacing of two pixels BP,
x_0, y_0	=	coordinates of the pixel X to be interpolated,
α	=	angle of inclination of the interpolation direction,
x_1	=	intersect of the interpolation lines LN2 with the upper line Z1,
x_2	=	intersect of the interpolation line LN2 with the lower line Z2,
$\lambda(0,0)$	=	brightness value of the pixel BP01,
$\lambda(0,1)$	=	brightness value of the pixel BP02,
$\lambda(1,0)$ and $\lambda(1,1)$	=	brightness values of the pixels BP10 and BP11, respectively.

If these variables are taken as starting point and, for example, the brightness values of the points B and E on the lines Z1 and Z2 are determined, this can be done in accordance with the following formula:

$\lambda_B = (1 - x_{0'})\ \lambda(0,0) + x_0'\lambda(0,1)$

$\lambda_E = (1 - x_0')\ \lambda(1,0) + x_0'\lambda(1,1)$, where

$x_0' = x_0 \vee d_x$, i.e. a normalization of x_0 with respect to d_x has been carried out. The brightness values λ of the points A to F can be determined in this way. If the brightness values of the points A to F are known, the line whose change in brightness value is a minimum can be selected for the individual interpolation lines LN. For this purpose, the following investigation is carried out:

$D_0 = |\lambda_B - \lambda_E|$,

$D_{-1} = |\lambda_A - \lambda_D|$,

$D_1 = |\lambda_C - \lambda_F|$.

D denotes the changes in brightness values which are investigated for the minimum. If, for example, D_0 is a minimum, the interpolation line LN1 is selected. If D_{-1} or D_1 is a minimum, new interpolation directions having a larger deviation from the vertical are investigated. If the change in brightness value in the new direction is greater than before, the previous interpolation line is selected, otherwise the step specified above is repeated with still greater deviation from the vertical. These steps are repeated until a minimum in the change in brightness value has been found. In practice, however, it is sufficient to terminate the iterations after not more than three to four steps. Assuming that the interpolation line LN2 is the one for which the change in brightness value between the points A and D is a minimum compared with adjacently situated interpolation lines, this direction is selected and the interpolation is carried out, in particular, in accordance with the following formula:

$\lambda(x_0',y_0') = (1 - y_0')\lambda_A + y_0'\lambda_D$

where $y_0' = \frac{y_0}{d_y}$.

The method described therefore makes it possible to generate, starting from a specified pixel raster, any desired other pixel raster without a large expenditure being necessary for this purpose in terms of hardware.

CLAIMS

1. Method for the format conversion of picture sequences present in a first pixel raster into a second pixel raster, in which the brightness values of the pixels in the second pixel raster are generated by interpolation from the pixels in a first and second line of the first pixel raster adjacent the pixel (X) to be generated, comprising the following steps:

a) selecting a plurality of pairs of points, each pair of points having one point on said first line and one point on said second line, which pair of points are fixed by interpolation lines (LN) which pass through the pixel (X) to be generated and are rotated with respect to one another, at least one of said interpolation lines being vertical;

b) determining the change in brightness between the pair of points fixed by the vertical interpolation line (LN1);

c) determining the change in brightness between pairs of points fixed by successive interpolation lines in two directions of rotation until the change in brightness value in the direction of one interpolation line is a minimum compared with the changes in brightness in the direction of the adjacently situated interpolation lines; and

d) generating the brightness value of the pixel by interpolating in the direction having the minimum change in brightness value.

2. Method according to claim 1, wherein the interpolation is only carried out if the change in brightness value in the direction having the minimum in the change in brightness value is less than a specifiable threshold, otherwise the interpolation is carried out in the vertical interpolation direction for the pixel to be generated.

3. Method according to claim 1 or 2, in which the investigation of the changes in brightness value is carried

out in the direction of rotation in which the change in brightness value becomes smaller.

4. Method according to any preceding claim, in which the brightness values of the points on the lines of the first pixel raster are determined, if the latter are not pixels, by interpolation of the brightness values of the adjacently situated pixels on the common line.

5. Method according to any preceding claim, wherein interpolation between two brightness values is carried out by means of transversal filters.

6. Method according to any preceding claim, wherein the interpolation lines are each spaced apart by the same angle.

7. Method according to one of claims 1-5, wherein the points are selected to coincide with the pixels of the first and second line.

8. Method according to one of the preceding claims, in which the location of the minimum is carried out in a 7 x 2 window around the point to be determined.

9. Method for format conversion of picture sequences substantially as herein described, with reference to Figure 1 of the accompanying drawings.

10. Method for format conversion of picture sequences substantially as herein described, with reference to Figure 2 and 3 of the accompanying drawings.

The Patent Office 14

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Claims searched:	1-10	**Date of search:**	25 April 1995

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): H4F - FEP, FER, FEX, FESK, FESX, FGXX

Int Cl (Ed.6): H04N - 5/262, 5/44, 7/01

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2231460 A	(SONY) - see fig. 4	1,3,5-8
X	EP 0551036 A1	(GOLDSTAR) - see fig. 8	1,3,5-8
X	US 4985764	(TOSHIBA) - see fig. 2	1,3,5-8

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		