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(71) Applicant *(for all designated States except US)*: **THOMSON LICENSING** [FR/FR]; 46, Quai A. Le Gallo, F-92100 Boulogne-Billancourt (FR).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **LIN, Shu** [CN/US]; 11148 Vista Sorrento Parkway, Apt. 209, San Diego, California 92130 (US). **IZZAT, Izzat, Hekmat** [IQ/US]; 17753 Cape Jasmine Road, Santa Clarita, California 91387 (US). **NIJIM, Yousef, Wasef** [JO/US]; 27622 Olive Mill Court, Valencia, California 91354 (US).

(74) Agents: **LAKS, Joseph, J.** et al.; Thomson Licensing LLC, Two Independence Way, Suite #200, Princeton, New Jersey 08540 (US).

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(54) **Title:** LOOK-UP TABLE ON FILM

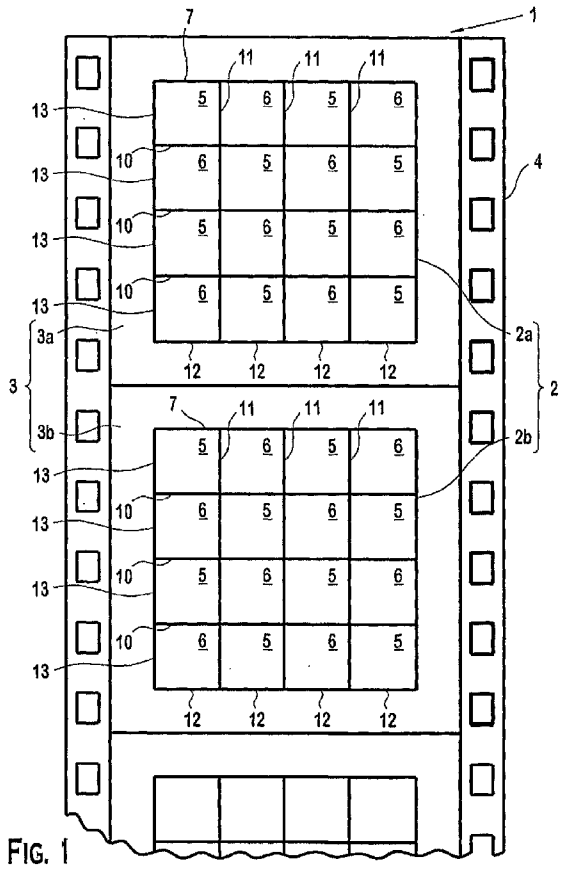

FIG. 1

(57) **Abstract:** A color look-up table includes a plurality of images recorded on a film. Each of the images being recorded on a separate picture of the film and containing at least a first level and a second level. The first and second levels having different pixel color values and are arranged to form a detectable geometric pattern on each of the pictures. The first field and a second field having detectable boundaries assigned to characterize distortions on the film.

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LOOK-UP TABLE ON FILM

Field of the Invention

The present invention relates to a method for recording a color look-up table on film wherein at least two levels are recorded on each picture of the film, and the levels are recorded such that a detectable geometric pattern is formed. The invention further relates to a method of recording and using the same.

Background of the Invention

In order to be able to restore colors in pictures of a film, a color look-up table is recorded on the film. The color look-up table is typically recorded on the film, for example, in 21 levels. The value of each level is recorded on a picture of the film. After the pictures that contain the color look-up table are scanned, a scanner, computer, or other devices restore the colors of the pictures in the film based on the color look-up table.

The above-described color look-up table, however, has the drawback that when a film is in need of restoration, 21 levels do not provide sufficient resolution to accurately restore the film. Increasing the amount of levels recorded on the film, however, directly increases the amount of space needed on the film to record the color look-up table. Additionally, there is no current method to correct geometric distortions in the film due to film degradation.

It is therefore desirable to provide a color look-up table that can provide sufficient resolution to accurately restore the film without taking-up excessive space on the film. It is further desirable to provide a color look-up table that enables geometric distortion due to film degradation to be detected and corrected.

Summary of the Invention

The invention provides a film capable of correcting physical distortion comprising at least one of image recorded on a film, each of the at least one images being recorded on a separate picture of the film and containing at least a first field or level and a second field or level having detectable boundaries. The at least one images can be a color look-up table, wherein the first and second levels having different pixel color values.

An embodiment of the invention is a method that includes the steps of providing on film one or more images of a geometric pattern, scanning the images, detecting distortions of the geometric pattern of the images, generating instructions for correcting distortions in the geometric pattern and applying corrections to other images on the film. The method can further comprise building a color look-up table in the images and performing color corrections on the film, wherein the color look-up table on the images contain at least a first color level and a second color level and selecting the first and second color levels to have different values. The first and second color levels can be shaped to form a detectable geometric pattern on each of the images. The generating instructions step can comprise generating an affine transformation to correct deviations in the geometric pattern and the applying corrections step can comprise applying the affine transformation to the other images.

Brief Description of the Drawings

The invention will now be described by way of example with reference to the accompanying drawings.

Figure 1 is a schematic illustration of a color look-up table provided on a reel of film according to the invention.

Figure 2 is a schematic illustration of an image recorded on the color look-up table of Figure 1.

Figure 3 is a schematic illustration of a first image recorded on the color look-up table of Figure 1.

Figure 4 is a flow chart showing a method of use of the color look-up table of Figure 1.

Figure 5 is an image having distortions prior to correction.

Figure 6 is the image of Figure 5 after correction according to the invention.

Detailed Description of the Invention

Figure 1 shows a color look-up table 1 according to the invention. As shown in Figure 1, the color look-up table 1 comprises a series of images 2 (or steps) formed over a plurality of pictures 3 (or frames) on a film 4. The color look-up table 1 may be formed, for example, over a plurality of the pictures 3 at a beginning of a reel of the film 4. The color look-up table 1 contains representative pixel information that may be used for restoring colors in the film 4. The color look-up table 1 corresponds to one color component on the film 4, for example, red, green, or blue.

The color look-up table 1 in the film 4 may have 8-bits, 10 bits, 12 bits, or 16 bits to represent a pixel. As shown in Table 1, which is illustrated below, if the film 4 uses 8 bits to represent a pixel, then the color look-up table 1 may have 256 possible pixel color values (which can be referred to as color values, levels or intensities). Table 1 can be the color look-up table for red, green, or blue. (In other words each color has its own look-up table.) If the

film 4 uses 10 bits to represent a pixel, then the color look-up table 1 may have 1024 possible pixel color values. It will be appreciated by those skilled in the art, however, that the number of bits used to represent a pixel may vary depending on the desired application of the color look-up table 1.

Table 1: True Intensity vs. Level Recorded

Level L_n	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
8-bits	0	4	8	12	16	20	24	28	32	36	40	44	48	52	56
10-bits	0	16	32	48	64	80	96	112	128	144	160	176	192	208	224
Level L_n	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
8-bits	60	64	68	72	76	80	84	88	92	96	100	104	108	112	116
10-bits	240	256	272	288	304	320	336	352	368	384	400	416	432	448	464
Level L_n	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44
8-bits	120	124	128	132	136	140	144	148	152	156	160	164	168	172	176
10-bits	480	496	512	528	544	560	576	592	608	624	640	656	672	688	704
Level L_n	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59
8-bits	180	184	188	192	196	200	204	208	212	216	220	224	228	232	236
10-bits	720	736	452	468	784	800	816	832	848	864	880	896	912	928	944
Level L_n	60	61	62	63	64										
8-bits	240	244	248	252	256										
10-bits	960	976	992	1008	1024										

The pixel color values are recorded on the film 4 in levels. The more levels that are recorded on the film 4, the greater the resolution of the images reproduced. In Table 1, 65 levels (0-64) are recorded on the film 4. It will be appreciated by those skilled in the art, however, that the number of levels recorded on the film 4 may vary depending on the desired image and the amount of available storage space.

The configuration of the color look-up table 1 will now be described in greater detail. As shown in Figure 1, the color look-up table 1 comprises the images 2. As shown in Figure 2, each of the images 2 contains a first level 5 (or a first intensity level 5) and a second level 6 (or a second intensity level 6). In the illustrated embodiment, the first level 5 is represented

by the formula (L_n), and the second level 6 is represented by the formula (L_{n+32}). The value of n increases with each of the images 2 and is determined by the number of levels that are to be recorded on the film 4. For example, in the illustrated embodiment, the value of n increases with each of the images 2 from 0-32, because 65 levels are recorded on the film 4. The first and second levels 5, 6 are substantially recorded in columns 12 and rows 13. The first and second levels 5, 6 substantially alternate along the columns 12 and the rows 13 such that the first level 5 is positioned next to the second level 6.

Although the images 2 are shown and described herein as each having been recorded with only two of the levels, it will be appreciated by those skilled in the art that either a single level or more than two of the levels may be recorded on each of the images 2 depending on the desired image and the amount of available storage space. Additionally, although the levels are shown and described herein as being formed in four columns and four rows, it will be appreciated by those skilled in the art that the levels may be formed in any number of columns and/or the rows depending on the desired image and the amount of available storage space.

A feature of the invention is that the images 2 containing the first and second levels 5, 6 on the pictures 3, form detectable geometric patterns on each of the pictures 3. (Detectable geometric pattern means that each level 5, 6 is a field having a defined boundary that can be mathematically characterized.) For example, an outer edge of the first and second levels 5, 6 defines a perimeter 7 of the image 2 on the picture 3. Additionally, the color differences between the first and second levels 5, 6 as the first and second levels 5, 6 alternate along the columns 12 and the rows 13 define a plurality of intersecting first cross-bars 10 and second cross-bars 11. In the illustrated embodiment, the first cross-bars 10 extend substantially parallel to each other, and the second cross-bars 11 extend substantially parallel to each other.

The first and second cross-bars 10, 11 intersect at an angle of about 90 degrees. The first and second cross-bars 10, 11 intersect the perimeter 7 at an angle of about 90 degrees.

A method for providing the color look-up table 1 on the film 4 will now be described in greater detail. As shown in Figure 1, a first image 2a is recorded on a first picture 3a of the film 4. As shown in Figure 3, the first image 2a (which can be a first frame on the film) contains the first level 5 and the second level 6. The first level 5 contains pixel color values corresponding to Level 0 (L_0), which is the lowest level illustrated in Table 1. The second level 6 contains pixel color values corresponding to Level 32 (L_{0+32} or L_{32}), which is the substantially middle level illustrated in Table 1. The first and second levels 5, 6 are recorded in the columns 12 and the rows 13 such that the first and second levels 5, 6 alternate along the columns 12 and the rows 13.

As shown in Figure 1, a second image 2b is recorded on a second picture 3b of the film 4. The second image 2b contains the first levels 5 and the second levels 6 too. The first level 5 contains pixel color values corresponding to Level 1 (L_1), which is one level above the lowest level illustrated in Table 1. The second level 6 contains pixel color values corresponding to Level 33 (L_{1+32} or L_{33}), which is one level above the substantially middle value illustrated in Table 1. The first and second levels 5, 6 are recorded in the columns 12 and the rows 13 such that the first and second levels 5, 6 alternate along the columns 12 and the rows 13.

The images 2 are continued to be recorded on the film 4 until all 65 levels are recorded on the film 4. In the illustrated embodiment, the color look-up table 1 can contain 33 of the images 2 wherein each of the images 2 is a step and contains two of the levels shown in Table 1. For example, if the color values are based on 10 bit system, Level 0 (L_0) will have a true intensity value of 0 and Level 32 (L_{0+32} or L_{32}) will have a true intensity value

of 512. The combination of Level 0 (L_0) and Level 32 (L_{0+32} or L_{32}) can comprise a step 1 or a 1st frame on the color look-up table 1 of the film. Level 1 (L_1) will have a true intensity value of 16 and Level 33 (L_{1+32} or L_{33}) will have a true intensity value of 528. The combination of Level 1 (L_1) and Level 33 (L_{1+32} or L_{33}) can comprise a step 2 or a 2nd frame on the color look-up table 1 of the film. Level 31 (L_{31}) will have a true intensity value of 496 and Level 63 (L_{31+32} or L_{63}) will have a true intensity value of 1008. The combination of Level 31 (L_{31}) and Level 63 (L_{31+32} or L_{63}) can comprise a step 32 or a 32nd frame on the color look-up table 1 of the film. (Following a final step 33, the following frames or pictures of the film can contain the actual motion pictures images.) An example color look-up table 1 for a system with 65 levels according to the invention is shown in Table 2. In this particular example Level L32 appears twice (i.e., once in step 1 and again in step 33).

Table 2: Example Color Look-up Table

Step No. in Color Table	L(n) = Ln	L(n+32) = Ln+32
1	L(0)	L(32)
2	L(1)	L(33)
3	L(2)	L(34)
4	L(3)	L(35)
5	L(4)	L(36)
6	L(5)	L(37)
7	L(6)	L(38)
8	L(7)	L(39)
9	L(8)	L(40)
10	L(9)	L(41)
11	L(10)	L(42)
12	L(11)	L(43)
13	L(12)	L(44)
14	L(13)	L(45)
15	L(14)	L(46)
16	L(15)	L(47)
17	L(16)	L(48)
18	L(17)	L(49)
19	L(18)	L(50)

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20	L(19)	L(51)
21	L(20)	L(52)
22	L(21)	L(53)
23	L(22)	L(54)
24	L(23)	L(55)
25	L(24)	L(56)
26	L(25)	L(57)
27	L(26)	L(58)
28	L(27)	L(59)
29	L(28)	L(60)
30	L(29)	L(61)
31	L(30)	L(62)
32	L(31)	L(63)
33	L(32)	L(64)

It will be appreciated by those skilled in the art that the images 2 may be recorded on the film 4 more than one time to ensure accuracy. Additionally, it will be appreciated by those skilled in the art that the images 2 may be recorded on the film 4 more than one time to record more than one color component on the film 4.

A feature of the invention is that the color look-up table is capable of detecting and correcting geometric distortion of the film. A method of using the color look-up table 1 will now be described with reference to the flowchart 20 shown in Figure 4. As shown in Figure 4, at process step 21, the entire film 4 including the color look-up table 1 is scanned by a conventional scanning method. At process step 22, as the color look-up table 1 is scanned, a scanner, a computer, or other device detects the first and second levels 5, 6 on the pictures 3. At process step 23, a scanner, a computer, or other device builds a color look-up table on the scanner, computer, or other device. At process step 24, the scanner, computer, or other device makes color corrections in the pictures 3 of the film 4 based on the information retrieved from the color look-up table 1 to restore the film 4, for example, to its original

condition. Because the method of scanning the film 4 and making color corrections therein are well known in the art, further description thereof has been omitted.

At process step 25, as the color look-up table 1 is scanned, a scanner, a computer, or other device detects the geometric pattern formed on the pictures 3. For example, in the first picture 3a shown in Figure 3, the perimeter 7 and the first and second cross-bars 10, 11 of the first image 2a are detected. At points where the first and second cross-bars 10, 11 intersect, a substantially 90 degree angle should be detected indicating that the first and second cross-bars 10, 11 are substantially straight lines. Additionally, at points where the first and second cross-bars 10, 11 intersect the perimeter 7, a substantially 90 degree angle should be detected indicating that the perimeter 7 is formed of substantially straight lines. The detected position of the perimeter 7 and the first and second cross-bars 10, 11 of the images 2 may be represented by at least one equation.

At process step 26, if the perimeter 7 of the images 2 and/or the first and second cross-bars 10, 11 of the images 2 are found not to be substantially straight lines, then an affine transformation is generated to correct deviations in the geometric pattern. At process step 27, the affine transformation is applied to warp content in all of the pictures 3 in the film 4 thereby correcting the geometry of all of the pictures 3 in the film 4. Additionally, interpolation for color pixels not on the integer grip may be made. As a result of this correction, any physical distortion appearing on the film 4 can be removed.

As shown in the flowchart 20, the detection of the first and second levels 5, 6 on the pictures 3 at process step 22 and the detection of the geometric pattern on the pictures 3 at process step 25 may occur simultaneously. The building of the color look-up table at process step 23 and the generation of the affine transformation at process step 26 may also occur simultaneously. Additionally, the color correction at process step 24 and the geometric

correction of the content of the pictures 3 in the film 4 at process step 27 may be performed simultaneously. It will be appreciated by those skilled in the art, however, that process steps 22, 23, and 24 may alternatively occur either before or after process steps 25, 26, and 27.

Although the color look-up table 1 shown and described herein is used for color correction and geometry restoration in the restoration of the film 4, it will be appreciated by those skilled in the art that the color look-up table 1 may be used for other purposes and in other applications. For example, the color look-up table 1 may be used in visible picture recording, printing for archiving, etc.

In the color look-up table 1 according to the invention, 65 levels are recorded on the film 4, which enables the color look-up table 1 to support higher resolution images. Additionally, because two levels are recorded in each of the images 2, the color look-up table 1 can be condensed into fewer of the pictures 3 on the film 4. Since the levels alternate with respect to the columns 10 and the rows 11, the images 2 are additionally provided with a geometric construction that enables geometric distortion to be detected and corrected.

An important point is that distortions of the frames or pictures of the film containing the color-look-up table 1 and the film having the actual motion pictures images are likely to distort similarly. With this concept in mind, an approach for use of the invention will be described. An image 2 shown in Figure 5, illustrates the film having distortions which can be visually observed because the borders between the first levels 5 and a second levels 6 are warped. Figure 6 illustrates how the borders and the first levels 5 and second levels 6 could ideally be shaped or how they may appear after correction. From Figure 6, one can compute coordinates of each vertex a to y by checking all edges. (The cross point of two edges is a vertex.) The coordinates of each point is (a_x, a_y), (b_x, b_y), ... (y_x, y_y). One can then find a transform for each block. For example, block abgf could be characterized as follows:

$(a_x, a_y) \sim (a'_x, a'_y)$,
$(b_x, b_y) \sim (b'_x, b'_y)$,
$(g_x, g_y) \sim (g'_x, g'_y)$, and
$(f_x, f_y) \sim (f'_x, f'_y)$.

The values of x' and y' can be described as follows:
y

$$x' = Ax + By + C$$
$$y' = Dx + Ey + F$$

A transform T for these equations can be written as

$$T = [A, B, C; D, E, F].$$

This leads to

$$A\,a_x + B\,a_y + C = a_x'$$
$$D\,a_x + E\,a_y + F = a_y'$$

$$A\,b_x + B\,b_y + C = b_x'$$
$$D\,b_x + E\,b_y + F = b_y'$$

$$A\,g_x + B\,g_y + C = g_x'$$
$$D\,g_x + E\,g_y + F = g_y'$$

$$A\,f_x + B\,f_y + C = f_x'$$
$$D\,f_x + E\,f_y + F = f_y'$$

With these 8 equations, one can find the 6-parameter affine transform T and implement the transform to appropriately warp each point in the block abgf to a'b'g'f' and get the correct image geometry. The warp determined for these images 2 of the color look-up table can then be used to appropriately warp/shape pictures 3 (or frames) on a film 4 having the motion picture images. With this methodology for correcting distortion in mind, a feature of the invention is that the film has the capability of correcting physical distortion characterized in that at least one of image is recorded on a film; each of these images are recorded on a separate picture of the film; and each of these images contains at least one first field (or level) 5' and at least one second field (or level) 6' having detectable boundaries, wherein the first and second fields do not necessarily have different pixel color values, but may have some

other distinguishable attribute (e.g. in texture, polarization, etc.). Essentially, the methodology for this feature of the invention is to use the process steps 21, 25, 26 and 27 described in Figure 4. It is to be understood that there can be a plurality of first fields and second fields in an image. (These images can be referred to as a look-up table.)

The foregoing illustrates some of the possibilities for practicing the invention. Many other embodiments are possible within the scope and spirit of the invention. For example, although the color look-up table 1 is illustrated as having two levels recorded in each of the images 2, it will be appreciated by those skilled in the art that more than two levels may be recorded in each of the images 2. Additionally, although the color look-up table 1 is illustrated as having a total of 65 levels, it will be appreciated by those skilled in the art that the number of levels may vary depending on the desired application of the color look-up table 1.

It is, therefore, intended that the foregoing description be regarded as illustrative rather than limiting, and that the scope of the invention is given by the appended claims together with their full range of equivalents.

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CLAIMS

1. A film comprising:

at least one of image on film;

each of the at least one images being a separate image and containing at least a first field and a second field having detectable boundaries assigned to characterize distortions on the film; and,

the at least one image is a color look-up table.

2. The film of claim 1, wherein the first field is a first color level and the second field is a second color level, the first and second color levels having different values.

3. The film of claim 1, wherein an outer edge of the first and second levels define a perimeter of the image.

4.The film of claim 3, wherein color value differences between the first and second levels define first and second cross-bars that intersect the perimeter.

5. The film of claim 1, wherein the first and second fields are arranged in columns and rows, the first and second fields alternating along the columns and rows.

6. The film of claim 1, wherein an outer edge of the first and second fields together define a perimeter of the image.

7. The film of claim 6, wherein the first and second levels fields define first and second cross-bars that intersect the perimeter.

8. The film of claim 7, wherein the first and second fields are arranged in columns and rows, the first and second fields alternating along the columns and rows.

9. A method comprising the steps of:

providing on film at least one image of a geometric pattern;

scanning the at least one image;

detecting distortions of the geometric pattern of the at least one image;

generating instructions for correcting distortions in the geometric pattern; and,

applying corrections to other images on the film.

10. The method of claim 9, wherein the providing step further comprises building a color look-up table in the at least one image and performing color corrections on the film.

11. The method of claim 10, wherein the providing step further comprises building the color look-up table on the at least one image to contain at least a first color level and a second color level and selecting the first and second color levels to have different values.

12. The method of claim 10, wherein the providing step further comprises shaping the first and second color levels to form a detectable geometric pattern on each of the images.

13. The method of claim 12, wherein the providing step further comprises arranging the first and second color levels in columns and rows and having the first and second color levels alternate along the columns and rows.

14. The method of claim 9, wherein the generating instructions step further comprises generating an affine transformation to correct deviations in the geometric pattern.

15. The method of claim 14, wherein the applying corrections step further comprises applying the affine transformation to other images.

16. The method of claim 9, wherein the providing step further comprises building at least a first field and a second field having detectable boundaries in to the at least one image.

17. The method of claim 16, wherein the providing step further comprises arranging the first and second fields in columns and rows and having the first and second fields alternating along the columns and rows.

18. The method of claim 17, wherein the generating instructions step further comprises generating an affine transformation to correct deviations in the geometric pattern.

19. The method of claim 18, wherein the applying corrections step further comprises applying the affine transformation to other images.

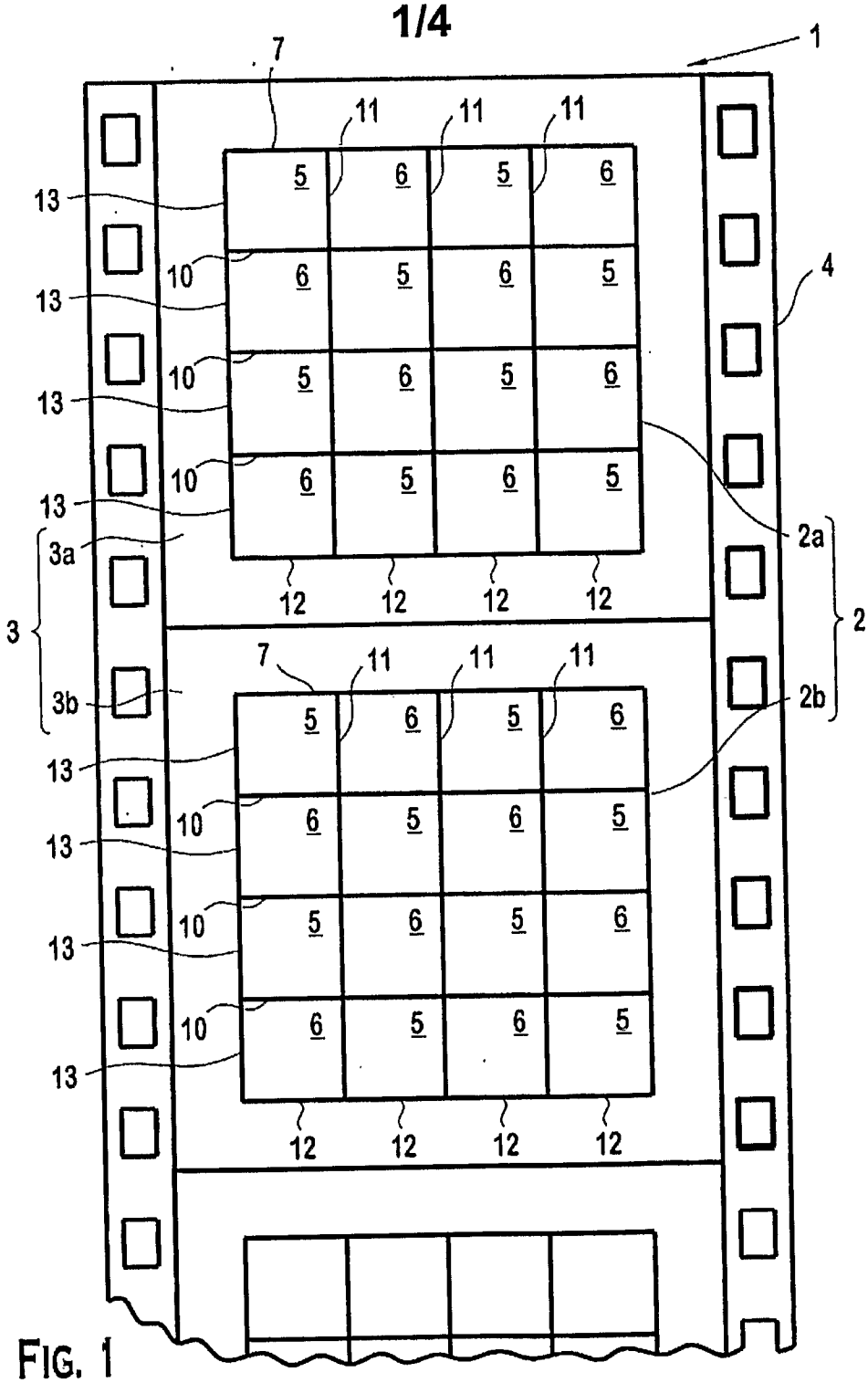
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FIG. 1

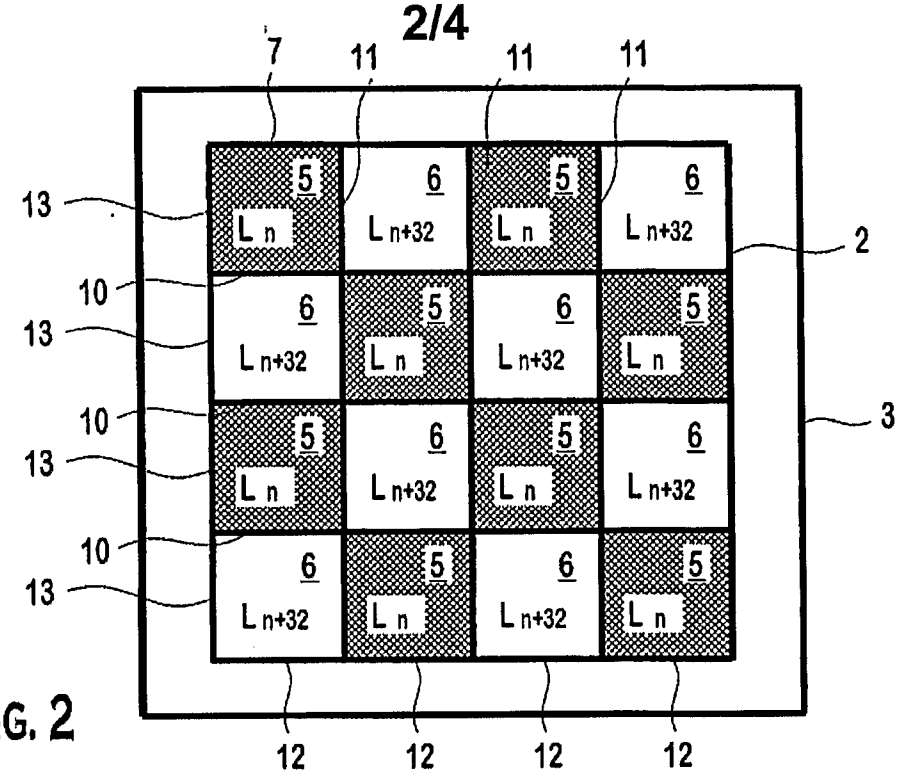
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FIG. 2

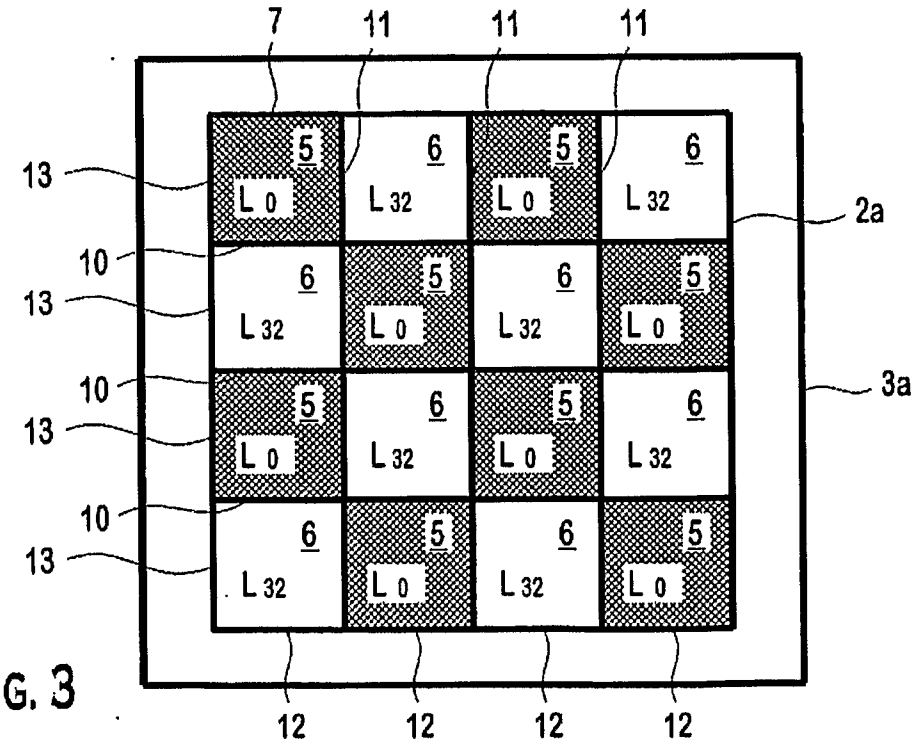
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FIG. 3

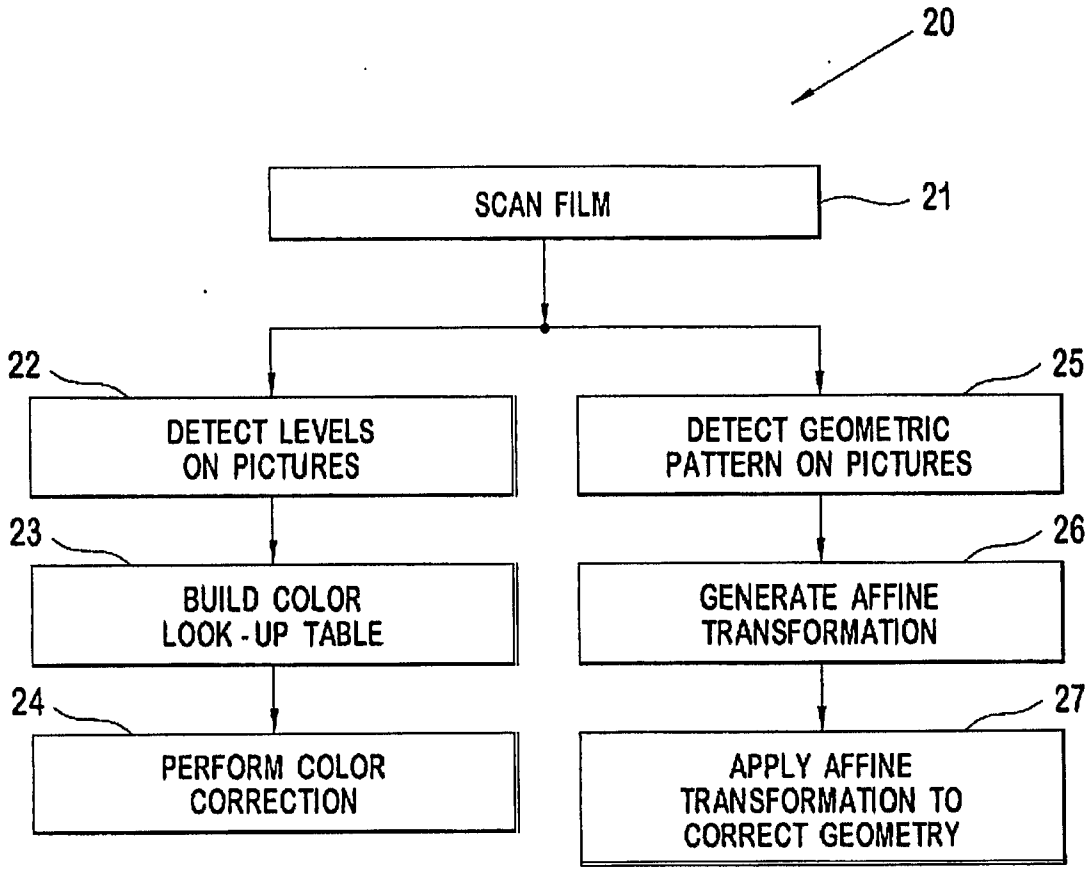
20
SCAN FILM
21
22
DETECT LEVELS ON PICTURES
23
BUILD COLOR LOOK-UP TABLE
24
PERFORM COLOR CORRECTION
25
DETECT GEOMETRIC PATTERN ON PICTURES
26
GENERATE AFFINE TRANSFORMATION
27
APPLY AFFINE TRANSFORMATION TO CORRECT GEOMETRY

FIG. 4

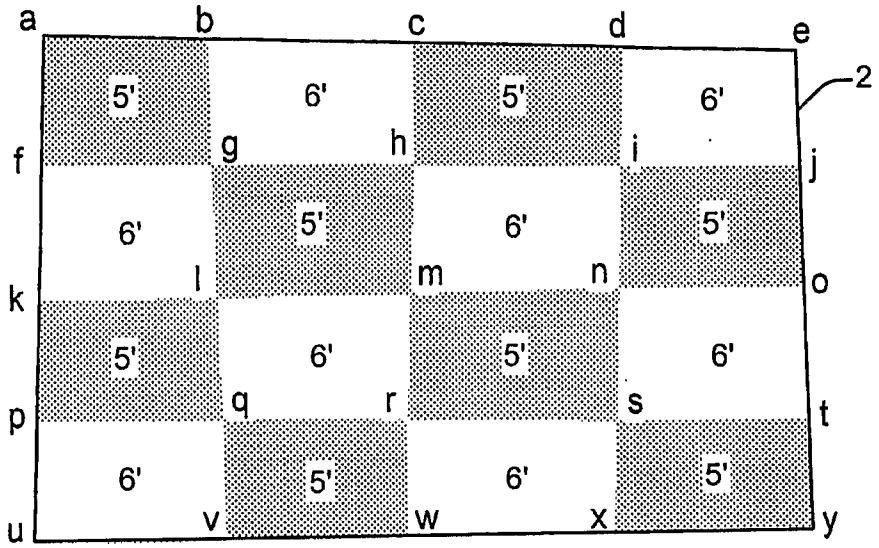
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FIG. 5

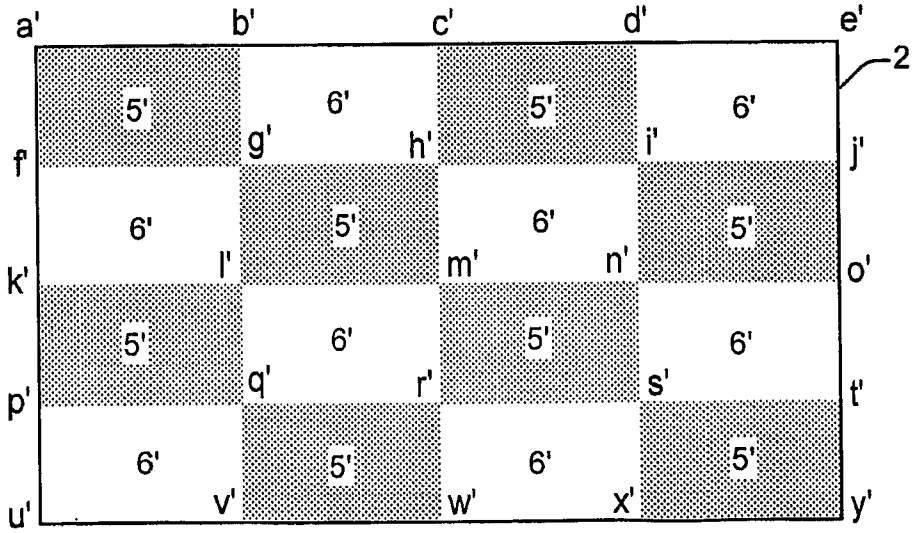
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FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 07/06840

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B05C 11/00 (2007.01)
USPC - 118/713
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - B05C 11/00 (2007.01)
USPC - 118/713

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
IPC(8) - B05C 11/00 (2007.01); USPC - 118/231, 712, 713 search terms below.

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Google search: "color look-up table", film, boundaries
USPTO - WEST - search terms: border, boundary, color, different, distort, edge, field, film, image, level, look-up, restore, table

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---- Y	US 2007/0035707 A1 (Margulis) 15 February 2007 (15.02.2007) - abstract; fig 1a; para [0009], [0013], [0055], [0080], [0081], [0099], [0101], [0102], [0105] and [0154]	1-13, 16 and 17 ---------- 14, 15, 18 and 19
Y	US 2007/0040848 A1 (Hutchinson et al.) 22 February 2007 (22.02.2007) para [0034]	14, 15, 18 and 19

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 October 2007 (02.10.2007)	16 NOV 2007
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

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