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(71) Applicant (for all designated States except US): **DOLBY LABORATORIES LICENSING CORPORATION** [US/US]; 100 Potrero Avenue, San Francisco, CA 94103-4813 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **RADHAKRISHNAN, Regunathan** [IN/US]; 100 Potrero Avenue, San Francisco, CA 94103-4813 (US). **BAUER, Claus** [DE/US]; 100 Potrero Avenue, San Francisco, CA 94103-4813 (US).

(74) Agents: **ANDERSEN, Robert, L.** et al.; Intellectual Property Group, 999 Brannan Street, San Francisco, CA 94103-4938 (US).

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[Continued on next page]

(54) Title: SIGNATURE DERIVATION FOR IMAGES

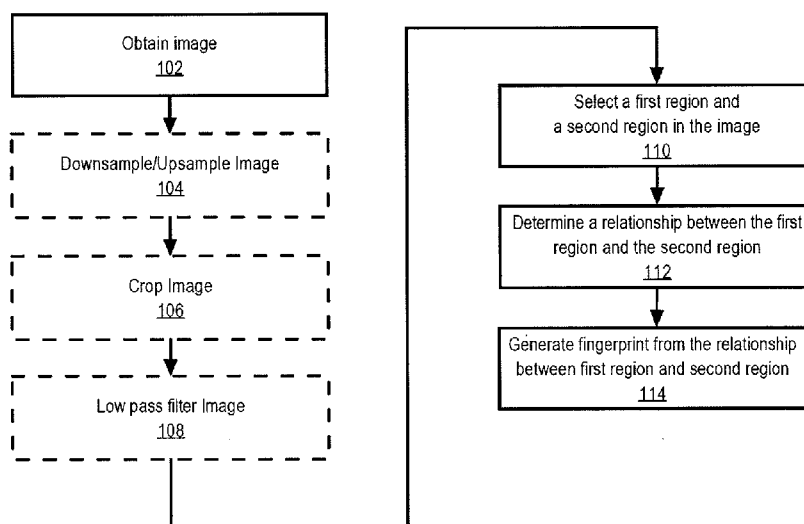


FIG. 1

(57) Abstract: Deriving a fingerprint of an image corresponding to media content involves selecting at least two different regions of the same image, determining a relationship between the two regions, and deriving a fingerprint of the image based on the relationship between the two regions of the image.



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SIGNATURE DERIVATION FOR IMAGES

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 61/089,553, filed 17 August 2008, hereby incorporated by reference in its entirety.

TECHNOLOGY

[0002] The present invention relates generally to image signatures. More specifically, embodiments of the present invention relate to generating signatures for images that correspond to media clips.

BACKGROUND

[0003] Media clips or media content are segments of audio media, video media, or audio/visual (AV) media and include information that is embodied, stored, transmitted, received, processed, or otherwise used with at least one medium. Common media clip formats include FLV format (flash video), Windows Media Video, RealMedia, Quicktime, MPEG, MP3, and DivX. As used herein, the terms "media clips", "media content," "information content," and "content" may be used interchangeably.

[0004] Media clips may be defined with one or more images. For example, video media may be a combination of a set of temporally related frames or images at particular points in time of the video media. Additionally, audio media may be represented as one or more images using many different techniques known in the art. For example, audio information may be captured in a spectrogram. In the spectrogram, the horizontal axis can represent time, the vertical axis can represent frequency, and the amplitude of a particular frequency at a particular time can be represented in a third dimension. Further, in a two dimensional spectrogram, the amplitude may be represented with thicker lines, more intense colors or grey values. Those skilled in the art will appreciate that many different modifications to the above example and other representations may be used to represent an audio clip as an image.

[0005] Images that define media content (audio and/or video) may be associated with a corresponding fingerprint ("fingerprint" used interchangeably with and equivalent to "signature"). Some fingerprints of media content may be derived (*e.g.*, extracted, generated) from information within, or which comprises a part of the media content. A media fingerprint embodies or captures an essence of the media content of the corresponding media and may be uniquely identified therewith. Video fingerprints are

media fingerprints that may be derived from images or frames of a video clip. Audio fingerprints are media fingerprints that may be derived from images with embedded audio information (*e.g.*, spectrograms). Further, the term media fingerprint may refer to a low bit rate representation of the media content with which they are associated and from which they are derived.

[0006] Fingerprints may be used to determine whether two media clips are identical or if a suspect media clip has been derived from the original media clip. In order to compare multiple media clips to make this determination, a fingerprint of each media clip may be derived, and thereafter the fingerprints may be compared.

[0007] The approaches described in this section are approaches that could be pursued, but not necessarily approaches that have been previously conceived or pursued. Therefore, unless otherwise indicated, it should not be assumed that any of the approaches described in this section qualify as prior art merely by virtue of their inclusion in this section. Similarly, issues identified with respect to one or more approaches should not assume to have been recognized in any prior art on the basis of this section, unless otherwise indicated.

BRIEF DESCRIPTION OF DRAWINGS

[0008] The present invention is illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

[0009] FIG. 1 depicts a first example procedure, according to an embodiment of the present invention;

[0010] FIG. 2 depicts a segmented video clip, according to an embodiment of the present invention;

[0011] FIG. 3A-FIG. 3E depict examples of region selection, according to embodiments of the present invention;

[0012] FIG. 4 illustrates a second example procedure, according to an embodiment of the present invention; and

[0013] FIG. 5 illustrates a third example procedure, according to an embodiment of the present invention.

[0014] FIG. 6 illustrates a fourth example procedure, according to an embodiment of the present invention.

[0015] FIG. 7 depicts an example computer system platform, with which an embodiment of the present invention may be implemented; and

[0016] FIG. 8 depicts an example integrated circuit device, with which an embodiment of the present invention may be implemented.

DESCRIPTION OF EXAMPLE EMBODIMENTS

[0017] The example embodiments described herein relate to deriving (*e.g.*, extracting, generating, determining, computing) signatures for images that correspond to media clips. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, to one skilled in the art that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the present invention.

[0018] Example embodiments are described herein according to the following outline:

- 1.0 General Overview
- 2.0 Functional Overview
 - 2.1 Generation of a Media Fingerprint
 - 2.2 Example Embodiment
- 3.0 Implementation Mechanisms—Hardware Overview
- 4.0 Equivalents, Extensions, Alternatives, and Miscellaneous

1.0 GENERAL OVERVIEW

[0019] In an embodiment, derivation of a fingerprint of an image corresponding to media content, at least two different regions of the same image are selected. Thereafter, a relationship between the two regions is determined and a fingerprint of the image is derived based on the relationship between the two regions of the image.

[0020] Determining the relationship between the first region and the second region of the image may include: for each pixel in the first region, computing a value based on an intensity of the pixel in the first region and an intensity of a corresponding pixel in the second region to obtain a plurality of values.

[0021] Each of the plurality of values may include at least one of: a difference between an intensity of the pixel in the first region and the corresponding pixel in the second region, or a ratio between an intensity of the pixel in the first region and an intensity of the corresponding pixel in the second region.

[0022] Deriving the fingerprint of the image may include: generating a matrix based on the plurality of values, projecting the matrix onto each of a plurality of vectors to obtain a plurality of projected values, determining a signature bit for each of the plurality of projected values to obtain a plurality of signature bits, and deriving the fingerprint based on the plurality of signature bits.

[0023] Generating the matrix based on the plurality of values may include: determining a rank of each value in relation to the plurality of values, and generating the matrix using the rank of each value in the plurality of values.

[0024] Projecting the matrix onto each of a plurality of vectors to obtain a plurality of projected values may include: computing the hadamard product of the matrix and each of the plurality of vectors to obtain a plurality of matrices, and determining the plurality of projected values corresponding to the plurality of matrices based on a combination of elements in each of the plurality of matrices.

[0025] Determining a signature bit for each of the plurality of projected values may include: determining a median of the projected values, representing each of the projected values that exceed the median with a first signature bit, and representing each of the projected values that are exceeded by the median with a second signature bit.

[0026] In an embodiment, signature bits that are within a predetermined range of values from the median are classified as weak bits, wherein the weak bits are ignored when determining whether a suspect image is derived from the image or toggled when determining whether the suspect image is derived from the image.

[0027] The image may include one or more of: a video frame of a plurality of video frames, or a graphical representation of an audio clip.

[0028] In an embodiment, the image is modified, prior to selecting the first region and the second region, with one or more of: downsampling, letterbox detecting and cropping, or low pass filtering.

[0029] Determining the relationship between the first region and the second region of the image may include: partitioning pixels in the first region into a first plurality of groups, partitioning pixels in the second region into a second plurality of groups, for each group in the first plurality of groups and for each group in the second plurality of groups, determining a group intensity statistic for pixels within each of the groups, and for each group in the first region, computing a value based on the group intensity statistic of the group in the first region and the group intensity statistic of a corresponding group in the second region.

[0030] The group intensity statistic may include one or more of: an average intensity of the pixels within the group, a standard deviation of intensities of the pixels within the group, a median intensity of the intensities of the pixels within the group, a correlation associated with the intensities of the pixels within the group, or a distribution associated with the intensities of the pixels within the group.

[0031] Other embodiments of the invention may include a system and computer readable medium with functionality to execute the steps described above.

2.0 FUNCTIONAL OVERVIEW

[0032] Examples of embodiments, which relate to generating media fingerprints that correspond to media content, are described herein. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the present invention. It will be apparent, however, that the present invention may be practiced without these specific details. In other instances, well-known structures and devices are not described in exhaustive detail, in order to avoid unnecessarily occluding, obscuring, or obfuscating the present invention.

[0033] Media fingerprints may be described herein with reference to one or more example media, including video and/or audio media. The selection of an example medium in this description may be made for simplicity and concise unity and, unless expressly stated to the contrary, should not be construed as limiting an embodiment to a particular medium as embodiments of the present invention are well suited to function with audio and/or video media. Furthermore, embodiments of the present invention are well suited to function with images, corresponding to media content, which may represent two or three spatial dimensions.

2.1 GENERATION OF A MEDIA FINGERPRINT

[0034] As depicted in FIG. 1, in order to derive a media fingerprint from media content, an image corresponding to the media content is first obtained (Step 102). In an embodiment, the image may be received from a program or process. In an embodiment, the image may be embedded with audio information associated with audio content. For example, a spectrogram with embedded audio information may be generated or received.

[0035] In an embodiment, one or more images may be derived from a stream of video content. The input video may be temporally downsampled to a reference frame rate, *e.g.*, a frame rate for which the video content fingerprints remain robust. In an embodiment, downsampling to a reference frame rate prior to generation of a signature allows for

comparisons of videos with varying frame rates. As depicted in FIG. 2, frames of the video sequence stream over time may be segmented into time intervals T_{int} , and fingerprints may be derived once per time interval T_{int} . For example, if the original video is at 30 fps (frames per second) and the signature is to be robust for frame rate conversion down to 12 fps, then signatures would be derived every time interval $T_{int} = 1/12$ of a second. In an embodiment, the video frame closest to the time step 'j', referred to as F_j may be used as the image for fingerprint generation.

[0036] Returning to FIG. 1, the obtained image may be downsampled or upsampled to a desired spatial resolution (Step 104). Downsampling of an image may be used to account for spatial resolution changes in a suspect image. For example, the frame F_j may be downsampled to reference spatial resolution 120*160 from any original spatial resolution. The registration between the original video and spatially scaled video is not disturbed as long as the aspect ratio is not changed. In an embodiment, an image may be upsampled to the desired reference spatial resolution subsequent to letterbox detection and removal which may be performed by identifying a strong horizontal edge and a region of almost constant intensity values in the top of the frame. In this example, once the letterbox is detected, it may be removed, and the remaining active region of the frame may be upsampled to the chosen spatial resolution (for example, 120*160). In an embodiment, the image may be cropped (Step 106) to remove a portion of the original image where text, logos, or other graphics are likely to be placed or are placed in suspect video clip. The removed portion is not used for deriving the signature and accordingly, the signature is robust against any modification to the removed region. In an embodiment, cropping prior to generation allows for generation of a fingerprint of the image that is robust against text, logos, graphics or other additions to the cropped out region.

[0037] Low-pass filtering may be performed on the image to improve the robustness of extracted features prior to derivation of the fingerprint (Step 108). Low-pass filtering allows low frequency data, or data that does not change much from pixel to neighboring pixel, to pass through, removing the high frequency data or data that changes rapidly from pixel to neighboring pixel. The visible result is the image appears blurred or smoothed. For an image that contains a lot of noise, low pass filtering would smooth out the image and reduce the noise with minimal affect on large features in the image. The amount of low-pass filtering determines the trade-off between robustness against processing and sensitivity to content. The amount of low-pass filtering could also be chosen based on the analysis of the input frame. A frame with a lot of detailed features would require a

smaller amount of low-pass filtering to preserve sensitivity than would a frame without much detailed information.

[0038] After the optional image prepping steps (Steps 104, 106, and 108) described above, two or more regions in the image are selected or identified (Step 110). Region selection may be performed using many different deterministic and/or non-deterministic methods. A few examples of possible region selections are depicted in FIG. 3A-FIG. 3E, where R1 represents a first region and R2 represents a second region. As shown in FIG. 3A-FIG. 3E, each region may be contiguous or non-contiguous. Furthermore, embodiments of the invention may be applied to any number of regions. For example, three regions may be identified within the image. In an embodiment, multiple region selections may be used for generating a fingerprint of the image. For example, partitioning the image into top and bottom regions, as illustrated in FIG. 3A may be used to derive a portion of the image fingerprint and further, partitioning the image into left and right regions, as illustrated in FIG. 3B may be used to derive another portion of the image fingerprint. In an embodiment, random region selection as shown in FIG. 3C may also be used to derive yet another portion of the image fingerprint.

[0039] Next, a relationship is determined between the first region and the second region (Step 112). The relationship may be determined with first, pairing each of the pixels in the first region with a corresponding pixel in the second region. For an image partitioned into more than two images, pixels in a first region may be paired with pixels in the second region and further, the pixels in the first region may also be paired with pixels in a third region. Further, embodiments of the invention may also apply to grouping of more than two pixels. For example, a pixel in a first region, a pixel in a second region, and a pixel in a third region, may all be grouped together. Once the pairing or grouping is determined, a relationship between the pixels within each pair or group is determined with computing a value based on an attribute of the pixels. Computation for a value may comprise any calculation, comparison, determination, derivation, or other suitable method(s). For example, for each pair of pixels (*e.g.*, a pixel from a first region and a corresponding pixel from the second region), an intensity of the first pixel may be subtracted from the intensity of the second pixel to determine an intensity difference relating the two pixels. In this example, the intensity of the pixel may correspond to a gray intensity or green intensity if the image is represented using gray tones or green tones, respectively. Other colors, or combinations of colors may also be used for relating pixels from the first region to the pixels from the second region. This example is further illustrated in FIG. 4A-FIG. 4C. FIG. 4A shows the intensity values for

an image scaled to a spatial resolution of 4×8 for simplicity. FIG. 4B shows a region selection within the image in which the left side of the image is selected as Region 1 (R1) and the right side of the image is selected as Region 2 (R2). Thereafter, as illustrated in FIG. 4C, to determine a relationship between R1 and R2, R2 is subtracted from R1 to obtain a set of intensity difference values shown in a 4×4 matrix. In an embodiment, determining the relationship between different regions involves determining ratios of intensities of each pixel in the first region to the intensities of corresponding pixels in the second region. In addition to intensity differences and intensity ratios, various other relationship values between pixels in different regions may be determined, such as, for example, a calculation involving a combination of intensity difference and intensity ratio between pixels from different regions. Although image intensity is used to illustrate the examples, any other value that can be derived from the image may be used. Examples include, but are not limited to, values of an intensity histogram, edge orientation histogram around each corner point, color histogram, transform domain coefficients, etc.

[0040] Next, a fingerprint for the image is derived based on the relationship between pixels in different regions (Step 114). In an embodiment, the fingerprint may be derived by computing any values from numbers representing the relationship between pixel intensities for two or more regions. For clarity, a simple example involving the difference values illustrated in FIG. 4C is described. In this example, a binary value may be determined for each of the difference values shown in FIG. 4C. Thereafter, the binary values may be concatenated to generate the signature. More complex methods may also be used to derive a signature based on the relationship between different regions. One such example of generating a signature based on the relationship between different regions is illustrated in FIG. 5.

2.2 EXAMPLE EMBODIMENT

[0041] FIG. 5 illustrates one example method for generation of a signature based on the relationship between different regions of an image. One or more steps illustrated in FIG. 5 may be modified, rearranged, or omitted all together. Furthermore, the process below may be repeated to derive signature bits for different region selections (*e.g.*, selections shown in FIG. 3A-FIG. 3E), where the signature for the image is based on a combination of the signature bits derived with using multiple region selections.

[0042] In this example, initially, an image is obtained, and spatially sampled to size 160×120 after low pass filtering, where the intensity values of the pixels are represented in a matrix F^L_j . Further, in this example, the relationship values are calculated with

computing the difference between two pixel values separated by equal distance from the center of the image along the width. This may be described with reference to equation (1) below:

$$F_j^{lr}(m, n) = F_j^L(m, \frac{W}{2} - n) - F_j^L(m, \frac{W}{2} + n)$$

$$m = 1, 2..H$$

$$n = 1, 2..\frac{W}{2}$$
(1)

[0043] Here W is the width and H is the height of F_j^L . In this case it is 160 and 120 respectively. Accordingly, the F_j^{lr} matrix is of dimensions $H*W/2$. Similarly, another the F_j^{tb} matrix is derived by computing the difference between the top-half and the bottom-half of the F_j^L matrix. Here, each element in the F_j^{tb} matrix computes the difference between two pixel values separated by equal distance from the center of image along the height. This may be described with reference to equation (2) below:

$$F_j^{tb}(m, n) = F_j^L(\frac{H}{2} - m, n) - F_j^L(\frac{H}{2} + m, n)$$

$$m = 1, 2..\frac{H}{2}$$

$$n = 1, 2..W$$
(2)

[0044] The F_j^{lr} matrix is of dimensions $H*W/2$ and the F_j^{tb} matrix is of dimensions $H/2*W$. Since both of these matrices capture difference values any constant brightness change across the whole frame would affect the values in these matrices. These two matrices record the relationships between different pairs of pixels in a given image. As long as any processing on the image does not change the relationships between these pairs, these features would be preserved. In this example embodiment, the pairing of the pixels is deterministic. There may be other ways to perform pairing between the pixels to derive these matrices. Also, in general, the pairing could be based on a pseudo-random number generator as well.

[0045] Next, coarse representations Z and V of the F_j^{lr} and F_j^{tb} matrices are derived, respectively, with an averaging of pixel intensities in image blocks of size $W_x * W_y$. These coarse representations help achieve robustness with allowing for certain variations within a block while preserving the average within a block. The coarse representation Z of the F_j^{lr} matrix is of size $(M_1 * M_2)$ where $M_1 = W/(2*W_x)$ ($M_1=160/(2*8)=10$) and $M_2 = H/W_y$ ($M_2 = 120/8 = 15$). Z is computed according to equation (3) below:

$$Z(k, l) = \frac{1}{W_x * W_y} \sum_{m=(k-1)W_x}^{kW_x} \sum_{n=(l-1)W_y}^{lW_y} F_j^{lr}(m, n)$$

$$k = 1, 2 \dots M_1; l = 1, 2 \dots M_2$$

(3)

[0046] Here ‘m’ and ‘n’ represent the indices for the horizontal and vertical dimensions for the F_j^{lr} matrix, ‘k’ and ‘l’ represent the indices of the image Z. Similarly, the coarse representation V of F_j^{tb} is of size $(U_1 * U_2)$ where $U_1 = (W/W_x)$ and $U_2 = H/(2*W_y)$ and is computed according to equation (4), below:

$$V(k, l) = \frac{1}{W_x * W_y} \sum_{m=(k-1)W_x}^{kW_x} \sum_{n=(l-1)W_y}^{lW_y} F_j^{tb}(m, n)$$

$$k = 1, 2 \dots U_1; l = 1, 2 \dots U_2$$

$$m = 1, 2 \dots H$$

(4)

[0047] In this step, from each tile in the intra-frame difference matrices (F_j^{lr} and F_j^{tb}) average pixel values are calculated to obtain Z and V. In general, one could compute other statistics such as the variance, standard deviation, correlation, and distribution from the tiles of these difference matrices to summarize them.

[0048] Instead of using the actual elements of the matrices Z and V for fingerprint generation, ranks are used for improved robustness. For instance, in the matrix Z, the value of its elements is replaced with its rank among all the elements. That is, if $Z(0,1)$ element is the 4th smallest element among all $M_1 * M_2$ entries, $Z(0,1)$ is replaced with 4. In this example, the transformed matrix which holds the ranks of elements of Z is noted as Z_r . Similarly, V_r holds the ranks of elements of V. This step ensures robustness to changes in values of elements in Z and V as long as the rank is maintained.

[0049] Next, signature bits for the matrices Z_r and V_r are created using a hashing function. In this example, the signature bits are created identically for both matrices (Z_r and V_r). Therefore, the bit creation procedure is explained for one of them, Z_r and illustrated in FIG. 6. In order to derive K_1 bits from Z_r , K_1 vectors ($P_1, P_2 \dots P_{K_1}$) are first created and the matrix Z_r is projected onto this set of K_1 vectors. Projecting the matrix Z_r onto the set of K_1 vectors may include taking the Hadamard product of the matrix and each of the K_1 vectors to obtain a set of matrices. Thereafter, a computation related to two or more elements within each of the matrices may be used to determine a scalar value for each of the matrices. In this example, a sum of all the elements in each of the matrices is used to compute a set of projected values ($H_1, H_2 \dots H_{K_1}$). Each of these

projected values ($H_1, H_2 \dots H_{K1}$) is compared to a threshold (in this example, the median of the projected values) to derive K_1 hash bits. In an embodiment, the threshold may be a value-dependent threshold, *e.g.*, computed based on the projected values $H_1, H_2 \dots H_{K1}$, or other values generated based on the image. Examples of value-dependent threshold include median of values, average of values, predetermined percentile in range of values, etc. Accordingly, the value-dependent threshold may dynamically change based on the set of values being applied against the threshold. The threshold may also be a fixed number, a constant number, a user selected number, etc. For each projected value above the median, a first signature bit may be assigned, and for each projected value below the median, a second signature bit may be assigned. Similarly, K_2 hash bits are created from the matrix V_r .

[0050] The K_1 hash bits based on the set of K_1 vectors ($P_1, P_2 \dots P_{K1}$) may capture different aspects of the matrix Z_r as long as each of the vectors ($P_1, P_2 \dots P_{K1}$) differ from one another. If any two of the K_1 vectors are identical, then 2 bits out of the K_1 bits may be identical. Identical bits may be avoided with use of an orthogonal basis set of K_1 vectors or with use of any set of different K_1 vectors.

[0051] Thereafter, the fingerprint of length ($K_1 + K_2$) bits is derived by concatenating the two sets of hash bits K_1 and K_2 from Z_r and V_r , respectively. Although, two relationships (*e.g.*, top-bottom and left-right) were used to generate the signature in this example, the invention can be used with any number of deterministic and/or non-deterministic relationships, as shown in examples of FIG. 3A-FIG. 3E.

[0052] In an embodiment, a notion of weak bits may be used when comparing signatures of original and modified video using a hash table based look-up. The hash-table look-up based matching could be easily misguided with a single bit-flip in the signature of the modified content. A subset S of the signature bits derived from the modified video may be marked as weak. These bits are termed weak as they are more likely to flip than other bits, *e.g.*, upon processing the content. Given the knowledge of these S “weak” bits, all 2^S possibilities may be tried while performing the hash-table look-up to find the exact hash entry of the original matching signature.

[0053] A method for identifying the subset of weak bits in the context of the above method of signature generation, according to an embodiment, may be described as follows. As described above, K_1 hash bits are derived from Z_r based on projections onto K_1 vectors as shown in FIG. 6. These projections result in numbers $H_1, H_2 \dots H_{K1}$. Each of these values is compared to a threshold (in this example, the median of the numbers $H_1, H_2 \dots H_{K1}$) to derive K_1 hash bits. In the case of processing operations on the content,

the values that are closer to the threshold may be more likely (perhaps significantly) to flip bits than other values. Based on this observation, $G_1, G_2 \dots G_{K1}$ may be computed where $G_{(i)} = \text{absolute value } |H_{(i)} - \text{Threshold}|$. Here the median of these projections is used as the Threshold. Finally, $G_1, G_2 \dots G_{K1}$ is sorted in the order of decreasing values. Then, the predicted S weak bits are those positions that are corresponding to the last S values in the sorted array. Weak bits may also be obtained with a comparison of $G_1, G_2 \dots G_{K1}$ to another threshold. In this case, the number of weak bits may depend on this chosen threshold.

[0054] A method for comparing signatures of the original video and the modified video, based on consecutive matching bits from the strongest signature bits to the weakest signature bits, may be described as follows. Initially a set of values, each associated with signature bits is obtained for an original image of the original video. The set of values may be a set of projected values obtained as described in the methods above or other set of values derived from an image. Thereafter, the set of values is rearranged from strongest bits to weakest bits, where the strength of each bit is based on a distance of the value from a threshold used for determining the signature bit, as described above. The greater the distance a value is from the threshold, the stronger the corresponding bit. Conversely, the lower the distance a value is from the threshold, the weaker the corresponding bit. In the example below, the average of the values is used as the threshold, however any other value may be used as the threshold (*e.g.*, median, a random number, a user selected number, etc.). In this example, a set of values ordered $H_1 - H_2 - H_3 - H_4 - H_5 - H_6$ with an average of 20, the threshold, and corresponding signature bits 100110, may be as follows:

Table 1

Value	Distance from Threshold 20	Above or Below Threshold	Signature Bit	Strength/ Reorder Sequence of Bits
$H_1 : 21$	1	Above	1	6
$H_2 : 6$	14	Below	0	2
$H_3 : 18$	2	Below	0	5
$H_4 : 39$	19	Above	1	1
$H_5 : 27$	7	Above	1	4
$H_6 : 9$	11	Below	0	3

[0055] According, since the greater the distance from the threshold, the stronger the bit, the set of values $H_1 - H_2 - H_3 - H_4 - H_5 - H_6$ corresponding to signature bits 100110 may be rearranged from strongest bits to weakest bits as follows: $H_4 - H_2 - H_6 - H_5 - H_3 - H_1$ corresponding to signature bits 100101. Accordingly, the signature bits for the original image are rearranged from strongest bits to weakest bits.

[0056] Next, the same translation (" $H_1 - H_2 - H_3 - H_4 - H_5 - H_6$ " to " $H_4 - H_2 - H_6 - H_5 - H_3 - H_1$ ") used for rearranging the signature bits for the original image is used for rearranging the signature bits for the modified image (or suspected modified image) from the modified video (or suspected modified image). A set of values $I_1 - I_2 - I_3 - I_4 - I_5 - I_6$ is derived from the modified image, with an average of 40, the threshold, and the corresponding signature bits 001110 is as follows:

Table 2

Value	Distance from Threshold 40	Above or Below Threshold 40	Signature Bit	Same Reorder Sequence
$I_1 : 41$	1	Above	1	6
$I_2 : 10$	30	Below	0	2
$I_3 : 41$	1	Above	1	5
$I_4 : 76$	36	Above	1	1
$I_5 : 54$	14	Above	1	4
$I_6 : 18$	22	Below	0	3

[0057] However, the signature bits $I_1 - I_2 - I_3 - I_4 - I_5 - I_6$ (101110) corresponding to the modified image are rearranged using the same translation, determined based on the strength of the signature bits of the original image, to obtain the sequence $I_4 - I_2 - I_6 - I_5 - I_3 - I_1$ (100111) for the modified image.

[0058] Accordingly, signature bits for the original image (100101) and signature bits for the modified image (100111) are both rearranged according to the strength of the original bits in descending order with the strongest bits first and the weakest bits last.

[0059] Thereafter, the rearranged signature bits for the original image (100101) are compared to the rearranged bits for the modified image (100111) to determine the longest consecutive match. In this example, the first four consecutive bits (1001) for both signatures match. The fifth bit does not match as it is '0' for the original image and '1' for the modified image. A degree of similarity between the original image and the modified

image may be then be computed based on the strongest four of the six bits that are matching.

[0060] In an embodiment, each bit may be assigned a percentage strength value based on the corresponding value's distance from the threshold. In the example described above, the signature bits of the original image may each be assigned a strength percentage based on the distance from the threshold 20 divided by the total distance from the threshold of all values. The total distance from the threshold shown in Table 1 is 54 ($1 + 14 + 2 + 19 + 7 + 11$). Thereafter each of the differences may be divided by the total 54 to determine the relative strength of the bit. Accordingly, H_4 the bit reordered first (the strongest bit) has a strength of $100 * 19/54 = 35\%$. H_4 , the bit ordered second has a strength of $100 * 14/54 = 26\%$. H_6 , the bit ordered third has a strength of $100 * 11/54 = 20\%$. H_5 , the bit ordered fourth has a strength of $100 * 7/54 = 13\%$. H_3 , the bit ordered fifth has a strength of $100 * 2/54 = 4\%$. H_1 , the bit ordered sixth has a strength of $100 * 1/54 = 2\%$. Accordingly, a degree of similarity between the original image and the modified image based on the first consecutive matching bits (first four bits in above example) is 94% ($35\% + 26\% + 20\% + 13\%$). If all matching bits (not just the first consecutive matching bits) are considered the degree of similarity is 96% ($35\% + 26\% + 20\% + 13\% + 2\%$) based on bits 1, 2, 3, 4, and 6.

[0061] In an embodiment, the robustness of a signature derivation method may be determined by comparing the first consecutive matching bits, ordered by strength, of an original image and a modified image, as described above. For example, the signature bits of an original image may be derived and ordered by strength. The original image may then be modified using a known modification such as increase in brightness to obtain a modified image. Thereafter the signature bits of the modified image may be derived and reordered according to the translation applied to the original image. Then a degree of similarity (*e.g.*, a percentage based on strength of first consecutive matching bits as described above) may be obtained between the original image and the modified image. The higher the degree of similarity, the more robust the signature derivation method may be. Furthermore, the use consecutive matching bits ordered by strength instead of any matching bits may more accurately indicate the robustness of a signature derivation method against a particular type of modification.

[0062] Although the above example was directed to the ordering of bits for both the original image and the modified image based on the strength of the signature bits corresponding to the original image, the ordering of bits for both images may also be based on the strength of the signature bits corresponding to the modified image.

[0063] In an embodiment, each of a set of functions may be applied to a set of values determined based on the image to obtain one or more signature bits per function of the set of functions. The set of values based on the image may be used as input for each of the functions where the output for each function corresponds to one or more signature bits for a fingerprint. Accordingly, each of the signature bits within the fingerprint correspond to a function and the set of values based on the image. For example, a set of values based on the image may be used to generate a matrix and the matrix may be provided as input to each of a plurality of functions. Each of the functions may correspond to different functions (*e.g.*, different mathematical formulas), a function with different constants (*e.g.*, projections of the matrix onto vectors with differing values for each function), or a combination thereof. Accordingly, the same set of values may be used to determine signature bits that are based on the functions applied to the set of values.

[0064] Example embodiments of the present invention are described above in relation to media fingerprints that generally correspond to media content. In the description of example embodiments, video media have been used as an example. As described above, video media was selected as an example medium in the description above merely for simplicity and unity and, except as expressly stated to the contrary, should not be construed as limiting an embodiment to a particular medium. Embodiments of the present invention are well suited to function with audio and graphical (*e.g.*, still, text based,) media, as well as video media.

[0065] For instance, embodiments are well suited to derive acoustic signatures and composite acoustic fingerprints (which may also be referred to as "audio" fingerprints, *e.g.*, synonymously, interchangeably) thereof from images associated with audio media such as sound, music and speech recordings. The audio media may be associated with video media, such as a recorded soundtrack that may be encoded with video media, and/or with another multimedia format.

[0066] While video frames are used above as examples in describing media content elements, embodiments are well suited to function with audio spectrograms of an audio clip as media content clips, as well. As applied to the description above, an audio clip may thus comprise a portion of audio media content that streams over time. The above methods may be applied over a spectrogram of the audio clip to derive a corresponding acoustic fingerprint.

3.0 IMPLEMENTATION MECHANISMS – HARDWARE OVERVIEW

[0067] Embodiments of the present invention, may be implemented with a computer system, systems configured in electronic circuitry and components, an integrated circuit (IC) device such as a microcontroller, a field programmable gate array (FPGA), or an application specific IC (ASIC), and/or apparatus that includes one or more of such systems, devices or components.

[0068] FIG. 7 depicts an example computer system platform 400, with which an embodiment of the present invention may be implemented. Figure 7 is a block diagram that illustrates a computer system 700 upon which an embodiment of the invention may be implemented. Computer system 700 includes a bus 702 or other communication mechanism for communicating information, and a processor 704 coupled with bus 702 for processing information. Computer system 700 also includes a main memory 706, such as a random access memory (RAM) or other dynamic storage device, coupled to bus 702 for storing information and instructions to be executed by processor 704. Main memory 706 also may be used for storing temporary variables or other intermediate information during execution of instructions to be executed by processor 704. Computer system 700 further includes a read only memory (ROM) 708 or other static storage device coupled to bus 702 for storing static information and instructions for processor 704. A storage device 710, such as a magnetic disk or optical disk, is provided and coupled to bus 702 for storing information and instructions.

[0069] Computer system 700 may be coupled via bus 702 to a display 712, such as a cathode ray tube (CRT), liquid crystal display (LCD), plasma screen display, or the like, for displaying information to a computer user. An input device 714, including alphanumeric (or non-alphabet based writing systems and/or non-Arabic number based) and other keys, is coupled to bus 702 for communicating information and command selections to processor 704. Another type of user input device is cursor control 716, such as a mouse, a trackball, or cursor direction keys for communicating direction information and command selections to processor 704 and for controlling cursor movement on display 712. This input device typically has two degrees of freedom in two axes, a first axis (e.g., x) and a second axis (e.g., y), which allows the device to specify positions in a plane.

[0070] Embodiments may relate to the use of computer system 700 for implementing techniques described herein. According to an embodiment of the invention, such techniques are performed by computer system 700 in response to processor 704 executing one or more sequences of one or more instructions contained in main memory 706. Such instructions may be read into main memory 706 from another machine-readable medium, such as storage device 710. Execution of the sequences of instructions contained in main

memory 706 causes processor 704 to perform the process steps described herein. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement the invention. Thus, embodiments of the invention are not limited to any specific combination of hardware circuitry and software.

[0071] The term “machine-readable medium” as used herein refers to any storage medium that participates in providing data that causes a machine to operation in a specific fashion. In an embodiment implemented using computer system 700, various machine-readable media are involved, for example, in providing instructions to processor 704 for execution. Such a medium may take many forms, including but not limited to storage media and transmission media. Storage media includes both non-volatile media and volatile media. Non-volatile media includes, for example, optical or magnetic disks, such as storage device 710. Volatile media includes dynamic memory, such as main memory 706. Transmission media includes coaxial cables, copper wire and fiber optics, including the wires that comprise bus 702. Transmission media can also take the form of acoustic or electromagnetic waves, such as those generated during radio-wave and infra-red and other optical data communications. Such media are tangible to enable the instructions carried by the media to be detected by a physical mechanism that reads the instructions into a machine.

[0072] Common forms of machine-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, or any other magnetic medium, a CD-ROM, any other optical medium, punch cards, paper tape, other legacy media or any other physical medium with patterns of holes or darkened spots, a RAM, a PROM, and EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave as described hereinafter, or any other medium from which a computer can read.

[0073] Various forms of machine-readable media may be involved in carrying one or more sequences of one or more instructions to processor 704 for execution. For example, the instructions may initially be carried on a magnetic disk of a remote computer. The remote computer can load the instructions into its dynamic memory and send the instructions over a telephone line using a modem. A modem local to computer system 700 can receive the data on the telephone line and use an infra-red transmitter to convert the data to an infra-red signal. An infra-red detector can receive the data carried in the infra-red signal and appropriate circuitry can place the data on bus 702. Bus 702 carries the data to main memory 706, from which processor 704 retrieves and executes the instructions. The instructions received by main memory 706 may optionally be stored on storage device 710 either before or after execution by processor 704.

[0074] Computer system 700 also includes a communication interface 718 coupled to bus 702. Communication interface 718 provides a two-way data communication coupling to a network link 720 that is connected to a local network 722. For example, communication interface 718 may be an integrated services digital network (ISDN) card or a digital subscriber line (DSL) or cable modem (traditionally modulator/demodulator) to provide a data communication connection to a corresponding type of telephone line. As another example, communication interface 718 may be a local area network (LAN) card to provide a data communication connection to a compatible LAN. Wireless links may also be implemented. In any such implementation, communication interface 718 sends and receives electrical, electromagnetic or optical signals that carry digital data streams representing various types of information.

[0075] Network link 720 typically provides data communication through one or more networks to other data devices. For example, network link 720 may provide a connection through local network 722 to a host computer 724 or to data equipment operated by an Internet Service Provider (ISP) 726. ISP 726 in turn provides data communication services through the world wide packet data communication network now commonly referred to as the "Internet" 728. Local network 722 and Internet 728 both use electrical, electromagnetic or optical signals that carry digital data streams. The signals through the various networks and the signals on network link 720 and through communication interface 718, which carry the digital data to and from computer system 700, are exemplary forms of carrier waves transporting the information.

[0076] Computer system 700 can send messages and receive data, including program code, through the network(s), network link 720 and communication interface 718. In the Internet example, a server 730 might transmit a requested code for an application program through Internet 728, ISP 726, local network 722 and communication interface 718.

[0077] The received code may be executed by processor 704 as it is received, and/or stored in storage device 710, or other non-volatile storage for later execution. In this manner, computer system 700 may obtain application code in the form of a carrier wave.

[0078] FIG. 8 depicts an example IC device 800, with which an embodiment of the present invention may be implemented. IC device 800 may have an input/output (I/O) feature 801. I/O feature 801 receives input signals and routes them via routing fabric 810 to a central processing unit (CPU) 802, which functions with storage 803. I/O feature 801 also receives output signals from other component features of IC device 800 and may control a part of the signal flow over routing fabric 810. A digital signal processing (DSP) feature performs at least function relating to digital signal processing. An interface

805 accesses external signals and routes them to I/O feature 801, and allows IC device 800 to export signals. Routing fabric 810 routes signals and power between the various component features of IC device 800.

[0079] Configurable and/or programmable processing elements (CPPE) 811, such as arrays of logic gates may perform dedicated functions of IC device 800, which in an embodiment may relate to deriving and processing media fingerprints that generally correspond to media content. Storage 812 dedicates sufficient memory cells for CPPE 811 to function efficiently. CPPE may include one or more dedicated DSP features 814.

[0080] An embodiment of the present invention may relate to one or more of the example embodiments enumerated below.

1. A method, comprising:
 - selecting a first region and a second region of the image;
 - determining a relationship between the first region and the second region of the image; and
 - deriving a fingerprint of the image based on the relationship between the first region and the second region of the image.
2. The method as recited in enumerated example embodiment 1, wherein determining the relationship between the first region and the second region of the image comprises:
 - for each pixel in the first region, computing a value based on an intensity of the pixel in the first region and an intensity of a corresponding pixel in the second region to obtain a plurality of values.
3. The method as recited in enumerated example embodiment 2, wherein each of the plurality of values comprises at least one of:
 - a difference between an intensity of the pixel in the first region and the corresponding pixel in the second region; or
 - a ratio between an intensity of the pixel in the first region and an intensity of the corresponding pixel in the second region.
4. The method as recited in enumerated example embodiment 2, wherein deriving the fingerprint of the image comprises:
 - generating a matrix based on the plurality of values;
 - projecting the matrix onto each of a plurality of vectors to obtain a plurality of projected values;
 - determining a signature bit for each of the plurality of projected values to obtain a plurality of signature bits; and

deriving the fingerprint based on the plurality of signature bits.

5. The method as recited in enumerated example embodiment 4, wherein generating the matrix based on the plurality of values comprises:

determining a rank of each value in relation to the plurality of values; and
generating the matrix using the rank of each value in the plurality of values.

6. The method as recited in enumerated example embodiment 4, wherein projecting the matrix onto each of a plurality of vectors to obtain the plurality of projected values comprises:

computing a Hadamard product of the matrix and each of the plurality of vectors to obtain a plurality of matrices; and

determining the plurality of projected values corresponding to the plurality of matrices based on a combination of elements in each of the plurality of matrices.

7. The method as recited in enumerated example embodiment 4, wherein determining a signature bit for each of the plurality of projected values comprises:

determining a threshold;

representing each of the projected values that exceed the threshold with a first signature bit; and

representing each of the projected values that are exceeded by the threshold with a second signature bit.

8. The method as recited in enumerated example embodiment 7, wherein the threshold comprises a value-dependent threshold based on the projected values, and wherein the value-dependent threshold comprises:

a median of the projected values;

an average of the projected values; or

a value at a predetermined percentile of a range of the projected values.

9. The method as recited in enumerated example embodiment 7, further comprising:
classifying signature bits that are within a predetermined range of values from the threshold as weak bits,

wherein the weak bits are:

ignored when determining whether a suspect image is derived from the image; or
toggled when determining whether the suspect image is derived from the image.

10. The method as recited in enumerated example embodiment 1, wherein the image comprises one or more of:

a video frame of a plurality of video frames;

a graphical representation of an audio clip; or

a standalone image.

11. The method as recited in enumerated example embodiment 1, wherein the image is modified, prior to selecting the first region and the second region, with one or more of:

downsampling;

letterbox detecting and cropping; or

low pass filtering.

12. The method as recited in enumerated example embodiment 1, wherein determining the relationship between the first region and the second region of the image comprises:

partitioning pixels in the first region into a first plurality of groups;

partitioning pixels in the second region into a second plurality of groups;

for each group in the first plurality of groups and for each group in the second plurality of groups, determining a group intensity statistic for pixels within each of the groups; and

for each group in the first region, computing a value based on the group intensity statistic of the group in the first region and the group intensity statistic of a corresponding group in the second region.

13. The method as recited in enumerated example embodiment 12, wherein the group intensity statistic comprises one or more of:

an average intensity of the pixels within the group;

a standard deviation of intensities of the pixels within the group;

a median intensity of the intensities of the pixels within the group;

a correlation associated with the intensities of the pixels within the group; or

a distribution associated with the intensities of the pixels within the group.

14. A system, comprising:

at least one processor, and

a computer readable storage medium with one or more sequences of stored instructions, which when executed with the processor, cause the processor to perform the steps of:

selecting a first region and a second region of the image;

determining a relationship between the first region and the second region of the image; and

deriving a fingerprint of the image based on the relationship between the first region and the second region of the image.

15. The system as recited in enumerated example embodiment 14, wherein determining the relationship between the first region and the second region of the image comprises:

for each pixel in the first region, computing a value based on an intensity of the pixel in the first region and an intensity of a corresponding pixel in the second region to obtain a plurality of values.

16. The system as recited in enumerated example embodiment 15, wherein each of the plurality of values comprise one or more of:

a difference between an intensity of the pixel in the first region and the corresponding pixel in the second region; or

a ratio between an intensity of the pixel in the first region and an intensity of the corresponding pixel in the second region.

17. The system as recited in enumerated example embodiment 15, wherein deriving the fingerprint of the image comprises:

generating a matrix based on the plurality of values;

projecting the matrix onto each of a plurality of vectors to obtain a plurality of projected values;

determining a signature bit for each of the plurality of projected values to obtain a plurality of signature bits; and

deriving the fingerprint based on the plurality of signature bits.

18. The system as recited in enumerated example embodiment 17, wherein generating the matrix based on the plurality of values comprises:

determining a rank of each value in relation to the plurality of values; and
generating the matrix using the rank of each value in the plurality of values.

19. The system as recited in enumerated example embodiment 17, wherein projecting the matrix onto each of a plurality of vectors to obtain the plurality of projected values comprises:

computing a Hadamard product of the matrix and each of the plurality of vectors to obtain a plurality of matrices; and

determining the plurality of projected values corresponding to the plurality of matrices based on a combination of elements in each of the plurality of matrices.

20. The system as recited in enumerated example embodiment 17, wherein determining a signature bit for each of the plurality of projected values comprises:

determining a threshold;

representing each of the projected values that exceed the threshold with a first signature bit; and

representing each of the projected values that are exceeded by the threshold with a second signature bit.

21. The system as recited in enumerated example embodiment 20, wherein the threshold comprises a value-dependent threshold based on the projected values, and wherein the value-dependent threshold comprises:

a median of the projected values;

an average of the projected values; or

a value at a predetermined percentile of a range of the projected values.

22. The system as recited in enumerated example embodiment 20, wherein the one or more sequences of instructions, when executed with the processor, cause the processor to further perform the step of:

classifying signature bits that are within a predetermined range of values from the threshold as weak bits,

wherein the weak bits are:

ignored when determining whether a suspect image is derived from the image; or

toggled when determining whether the suspect image is derived from the image.

23. The system as recited in enumerated example embodiment 14, wherein the image comprises one or more of:

a video frame of a plurality of video frames;

a graphical representation of an audio clip; or

a standalone image.

24. The system as recited in enumerated example embodiment 14, wherein the image is modified, prior to selecting the first region and the second region, with one or more of:

downsampling;

letterbox detecting and cropping; or

low pass filtering.

25. The system as recited in enumerated example embodiment 14, wherein determining the relationship between the first region and the second region of the image comprises:

partitioning pixels in the first region into a first plurality of groups;

partitioning pixels in the second region into a second plurality of groups;

for each group in the first plurality of groups and for each group in the second plurality of groups, determining a group intensity statistic for pixels within each of the groups; and

for each group in the first region, computing a value based on the group intensity statistic of the group in the first region and the group intensity statistic of a corresponding group in the second region.

26. The system as recited in enumerated example embodiment 25, wherein the group intensity statistic comprises one or more of:

- an average intensity of the pixels within the group;
- a standard deviation of intensities of the pixels within the group;
- a median intensity of the intensities of the pixels within the group;
- a correlation associated with the intensities of the pixels within the group; or
- a distribution associated with the intensities of the pixels within the group.

27. A computer readable storage medium having encoded instructions which, when executed by one or more processors, cause the one or more processors to perform the steps of:

- selecting a first region and a second region of the image;
- determining a relationship between the first region and the second region of the image; and
- deriving a fingerprint of the image based on the relationship between the first region and the second region of the image.

28. The computer readable storage medium as recited in enumerated example embodiment 27, wherein determining the relationship between the first region and the second region of the image comprises:

for each pixel in the first region, computing a value based on an intensity of the pixel in the first region and an intensity of a corresponding pixel in the second region to obtain a plurality of values.

29. The computer readable storage medium as recited in enumerated example embodiment 28, wherein each of the plurality of values comprises at least one of:

- a difference between an intensity of the pixel in the first region and the corresponding pixel in the second region; or
- a ratio between an intensity of the pixel in the first region and an intensity of the corresponding pixel in the second region.

30. The computer readable storage medium as recited in enumerated example embodiment 28, wherein deriving the fingerprint of the image comprises:

- generating a matrix based on the plurality of values;
- projecting the matrix onto each of a plurality of vectors to obtain a plurality of projected values;
- determining a signature bit for each of the plurality of projected values to obtain a plurality of signature bits; and
- deriving the fingerprint based on the plurality of signature bits.

31. The computer readable storage medium as recited in enumerated example embodiment 30, wherein generating the matrix based on the plurality of values comprises:

- determining a rank of each value in relation to the plurality of values; and
- generating the matrix using the rank of each value in the plurality of values.

32. The computer readable storage medium as recited in enumerated example embodiment 30, wherein projecting the matrix onto each of the plurality of vectors to obtain a plurality of projected values comprises:

- computing a Hadamard product of the matrix and each of the plurality of vectors to obtain a plurality of matrices; and

- determining the plurality of projected values corresponding to the plurality of matrices based on a combination of elements in each of the plurality of matrices.

33. The computer readable storage medium as recited in enumerated example embodiment 30, wherein determining a signature bit for each of the plurality of projected values comprises:

- determining a threshold;
- representing each of the projected values that exceed the threshold with a first signature bit; and
- representing each of the projected values that are exceeded by the threshold with a second signature bit.

34. The computer readable storage medium as recited in enumerated example embodiment 33, wherein the threshold comprises a value-dependent threshold based on the projected values, and wherein the value-dependent threshold comprises:

- a median of the projected values;
- an average of the projected values; or
- a value at a predetermined percentile of a range of the projected values.

35. The computer readable storage medium as recited in enumerated example embodiment 33, wherein the encoded instructions, when executed by one or more processors, cause the one or more processors to further perform the step of:

classifying signature bits that are within a predetermined range of values from the threshold as weak bits,

wherein the weak bits are:

ignored when determining whether a suspect image is derived from the image; or toggled when determining whether the suspect image is derived from the image.

36. The computer readable storage medium as recited in enumerated example embodiment 27, wherein the image comprises one or more of:

- a video frame of a plurality of video frames;
- a graphical representation of an audio clip; or
- a standalone image.

37. The computer readable storage medium as recited in enumerated example embodiment 27, wherein the image is modified, prior to selecting the first region and the second region, by one or more of:

- downsampling;
- letterbox detecting and cropping; or
- low pass filtering.

38. The computer readable storage medium as recited in enumerated example embodiment 27, wherein determining the relationship between the first region and the second region of the image comprises:

- partitioning pixels in the first region into a first plurality of groups;
- partitioning pixels in the second region into a second plurality of groups;
- for each group in the first plurality of groups and for each group in the second plurality of groups, determining a group intensity statistic for pixels within each of the groups; and

- for each group in the first region, computing a value based on the group intensity statistic of the group in the first region and the group intensity statistic of a corresponding group in the second region.

39. The computer readable storage medium as recited in enumerated example embodiment 38, wherein the group intensity statistic comprises one or more of:

- an average intensity of the pixels within the group;
- a standard deviation of intensities of the pixels within the group;
- a median intensity of the intensities of the pixels within the group;
- a correlation associated with the intensities of the pixels within the group; or
- a distribution associated with the intensities of the pixels within the group.

40. A method, comprising the steps of:

- deriving a first signature from a first image, wherein the first signature comprises a first plurality of signature bits;
- assigning a bit strength to each of the first plurality of signature bits based on a reliability of the bit;
- deriving a second signature from a second image, wherein the second signature comprises second plurality of signature bits;
- comparing the first plurality of bits, in order from strongest to weakest, to corresponding bits in the second plurality of bits until a non-matching bit is identified to determine a plurality of reliable matching bits of the first plurality of bits;
- determining a degree of similarity between the first image and the second image based on the reliable matching bits of the first plurality of bits.

41. The method as recited in enumerated example embodiment 40, wherein comparing the first plurality of bits, in order from strongest to weakest, to corresponding bits in the second plurality of bits until a non-matching bit is identified to determine a plurality of reliable matching bits of the first plurality of bits comprises:

- rearranging the first plurality of signature bits from strongest bits to weakest bits to obtain a rearranged first plurality of signature bits; and

- comparing the rearranged first plurality of signature bits to originally corresponding bits in the second plurality of signature bits to determine consecutively matching bits in the first plurality of bits.

42. The method as recited in enumerated example embodiment 40, wherein the strength of each of the first plurality of bits is computed with:

- for each of the first plurality of signature bits, determining a distance from a corresponding value to a threshold used for determining the signature bit, and

- assigning a strength to each of the first plurality of bits proportional to the distance from the corresponding value to the threshold.

43. The method as recited in enumerated example embodiment 40, further comprising:

- modifying the first image to obtain the second image using a predetermined modification; and

- determining a robustness of a signature derivation method, used to derive the first signature and the second signature, against the predetermined modification based on the degree of similarity between the first image and the second image.

44. A method, comprising the steps of:
- deriving a first signature derived based on a first image;
 - deriving a first plurality of signature bits from the first image, wherein each of the first plurality of signature bits correspond to a value generated based on the first image;
 - and
 - assigning a strength to each of the first plurality of bits proportional to a distance from the corresponding value to a threshold used for determining the signature bit;
 - comparing the first signature derived based on the first image to a second signature derived based on a second image to determine a plurality of matching bits; and
 - determining a degree of similarity between the first image and the second image based on the strength of the plurality of matching bits from the first plurality of bits.
45. The method as recited in enumerated example embodiment 44, further comprising:
- modifying the first image to obtain the second image using a predetermined modification; and
 - determining a robustness of a signature derivation method, used to derive the first signature and the second signature, against the predetermined modification based on the degree of similarity between the first image and the second image.
46. The method as recited in enumerated example embodiment 44, further comprising:
- modifying the first image to obtain the second image using a predetermined modification; and
 - determining a robustness of a signature derivation method, used to derive the first signature and the second signature, against the predetermined modification based on the degree of similarity between the first image and the second image.
47. A method, comprising the steps of:
- generating a plurality of values based on an image;
 - determining a value-dependent threshold based on the plurality of values;
 - determining a signature bit for each of the plurality of projected values to obtain a plurality of signature bits with:
 - representing each of the plurality of values that exceed the value-dependent threshold with a first signature bit; and
 - representing each of the projected values that are exceeded by the value-dependent threshold with a second signature bit; and
 - deriving a fingerprint of the image based on the plurality of signature bits.

48. The method as recited in enumerated example embodiment 47, wherein the value-dependent threshold comprises one or more of:

- a median of the plurality of values;
- an average of the plurality of values; or
- a value at a predetermined percentile of a range of the plurality of values.

49. The method as recited in enumerated example embodiment 47, further comprising:

- classifying signature bits that are within a predetermined range of values from the value-dependent threshold as weak bits,

- wherein the weak bits are:

- ignored when determining whether a suspect image is derived from the image; or
- toggled when determining whether the suspect image is derived from the image.

50. A method, comprising the steps of:

- generating a plurality of values based on an image;
- applying each of a plurality of functions to the plurality of values to obtain one or more signature bits per function of the plurality of functions; and

- generating a fingerprint of the image based on the obtained signature bits.

51. The method as recited in enumerated example embodiment 50, wherein applying each of a plurality of functions to the plurality of values to obtain one or more signature bits per function comprises:

- generating a matrix based on the plurality of values;
- applying each of the plurality of functions to the matrix to obtain a plurality of function values; and
- determining a signature bit for each of the plurality of function values to obtain a plurality of signature bits.

52. The method as recited in enumerated example embodiment 51, wherein applying each of the plurality of functions to the matrix to obtain a plurality of function values comprises:

- projecting the matrix onto each of a plurality of vectors to obtain a plurality of projected values.

53. The method as recited in enumerated example embodiment 51, wherein generating the matrix based on the plurality of values comprises:

- determining a rank of each value in relation to the plurality of values; and
- generating the matrix using the rank of each value in the plurality of values.

54. The method as recited in enumerated example embodiment 51, wherein determining the signature bit for each of the plurality of function values to obtain the plurality of signature bits comprises:

representing each of the plurality of values that exceed a threshold with a first signature bit; and

representing each of the projected values that are exceeded by the threshold with a second signature bit.

55. The method as recited in enumerated example embodiment 54, further comprising:

classifying signature bits that are within a predetermined range of values from the threshold as weak bits,

wherein the weak bits are:

ignored when determining whether a suspect image is derived from the image; or

toggled when determining whether the suspect image is derived from the image.

4.0 EQUIVALENTS, EXTENSIONS, ALTERNATIVES AND MISCELLANEOUS

[0081] In the foregoing specification, embodiments of the invention have been described with reference to numerous specific details that may vary from implementation to implementation. Thus, the sole and exclusive indicator of what is the invention, and is intended by the applicants to be the invention, is the set of claims that issue from this application, in the specific form in which such claims issue, including any subsequent correction. Any definitions expressly set forth herein for terms contained in such claims shall govern the meaning of such terms as used in the claims. Hence, no limitation, element, property, feature, advantage or attribute that is not expressly recited in a claim should limit the scope of such claim in any way. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

CLAIMS

What is claimed is:

1. A method, comprising:
 - selecting a first region and a second region of the image;
 - determining a relationship between the first region and the second region of the image; and
 - deriving a fingerprint of the image based on the relationship between the first region and the second region of the image.
2. The method as recited in Claim 1, wherein determining the relationship between the first region and the second region of the image comprises:
 - for each pixel in the first region, computing a value based on an intensity of the pixel in the first region and an intensity of a corresponding pixel in the second region to obtain a plurality of values.
3. The method as recited in Claim 2, wherein each of the plurality of values comprises at least one of:
 - a difference between an intensity of the pixel in the first region and the corresponding pixel in the second region; or
 - a ratio between an intensity of the pixel in the first region and an intensity of the corresponding pixel in the second region.
4. The method as recited in Claim 2, wherein deriving the fingerprint of the image comprises:
 - generating a matrix based on the plurality of values;
 - projecting the matrix onto each of a plurality of vectors to obtain a plurality of projected values;
 - determining a signature bit for each of the plurality of projected values to obtain a plurality of signature bits; and
 - deriving the fingerprint based on the plurality of signature bits.
5. The method as recited in Claim 4, wherein generating the matrix based on the plurality of values comprises:
 - determining a rank of each value in relation to the plurality of values; and
 - generating the matrix using the rank of each value in the plurality of values.

6. The method as recited in Claim 4, wherein projecting the matrix onto each of a plurality of vectors to obtain the plurality of projected values comprises:
 - computing a Hadamard product of the matrix and each of the plurality of vectors to obtain a plurality of matrices; and
 - determining the plurality of projected values corresponding to the plurality of matrices based on a combination of elements in each of the plurality of matrices.
7. The method as recited in Claim 4, wherein determining a signature bit for each of the plurality of projected values comprises:
 - determining a threshold;
 - representing each of the projected values that exceed the threshold with a first signature bit; and
 - representing each of the projected values that are exceeded by the threshold with a second signature bit.
8. The method as recited in Claim 7, wherein the threshold comprises a value-dependent threshold based on the projected values, and wherein the value-dependent threshold comprises:
 - a median of the projected values;
 - an average of the projected values; or
 - a value at a predetermined percentile of a range of the projected values.
9. The method as recited in Claim 7, further comprising:
 - classifying signature bits that are within a predetermined range of values from the threshold as weak bits,
 - wherein the weak bits are:
 - ignored when determining whether a suspect image is derived from the image; or
 - toggled when determining whether the suspect image is derived from the image.
10. The method as recited in Claim 1, wherein the image comprises one or more of:
 - a video frame of a plurality of video frames;
 - a graphical representation of an audio clip; or
 - a standalone image.

11. The method as recited in Claim 1, wherein the image is modified, prior to selecting the first region and the second region, with one or more of:
 - downsampling;
 - letterbox detecting and cropping; or
 - low pass filtering.
12. The method as recited in Claim 1, wherein determining the relationship between the first region and the second region of the image comprises:
 - partitioning pixels in the first region into a first plurality of groups;
 - partitioning pixels in the second region into a second plurality of groups;
 - for each group in the first plurality of groups and for each group in the second plurality of groups, determining a group intensity statistic for pixels within each of the groups; and
 - for each group in the first region, computing a value based on the group intensity statistic of the group in the first region and the group intensity statistic of a corresponding group in the second region.
13. The method as recited in Claim 12, wherein the group intensity statistic comprises one or more of:
 - an average intensity of the pixels within the group;
 - a standard deviation of intensities of the pixels within the group;
 - a median intensity of the intensities of the pixels within the group;
 - a correlation associated with the intensities of the pixels within the group; or
 - a distribution associated with the intensities of the pixels within the group.
14. A method, comprising the steps of:
 - deriving a first signature from a first image, wherein the first signature comprises a first plurality of signature bits;
 - assigning a bit strength to each of the first plurality of signature bits based on a reliability of the bit;
 - deriving a second signature from a second image, wherein the second signature comprises second plurality of signature bits;
 - comparing the first plurality of bits, in order from strongest to weakest, to corresponding bits in the second plurality of bits until a non-matching bit is identified to determine a plurality of reliable matching bits of the first plurality of bits;

determining a degree of similarity between the first image and the second image based on the reliable matching bits of the first plurality of bits.

15. A method, comprising the steps of:
deriving a first signature derived based on a first image;
deriving a first plurality of signature bits from the first image, wherein each of the first plurality of signature bits correspond to a value generated based on the first image;
and

assigning a strength to each of the first plurality of bits proportional to a distance from the corresponding value to a threshold used for determining the signature bit;
comparing the first signature derived based on the first image to a second signature derived based on a second image to determine a plurality of matching bits; and
determining a degree of similarity between the first image and the second image based on the strength of the plurality of matching bits from the first plurality of bits.

16. A method, comprising the steps of:
generating a plurality of values based on an image;
determining a value-dependent threshold based on the plurality of values;
determining a signature bit for each of the plurality of projected values to obtain a plurality of signature bits with:

representing each of the plurality of values that exceed the value-dependent threshold with a first signature bit; and
representing each of the projected values that are exceeded by the value-dependent threshold with a second signature bit; and
deriving a fingerprint of the image based on the plurality of signature bits.

17. A method, comprising the steps of:
generating a plurality of values based on an image;
applying each of a plurality of functions to the plurality of values to obtain one or more signature bits per function of the plurality of functions; and
generating a fingerprint of the image based on the obtained signature bits.

18. A system, comprising:
at least one processor, and

a computer readable storage medium with one or more sequences of stored instructions, which when executed with the processor, cause the processor to perform the steps recited in one or more of Claims 1-17.

19. A computer readable storage medium product having encoded instructions which, when executed by one or more processors, cause the one or more processors to perform the steps recited in one or more of Claims 1-17.

20. A use for a computer, comprising performing processes as recited in one or more of Claims 1-17.

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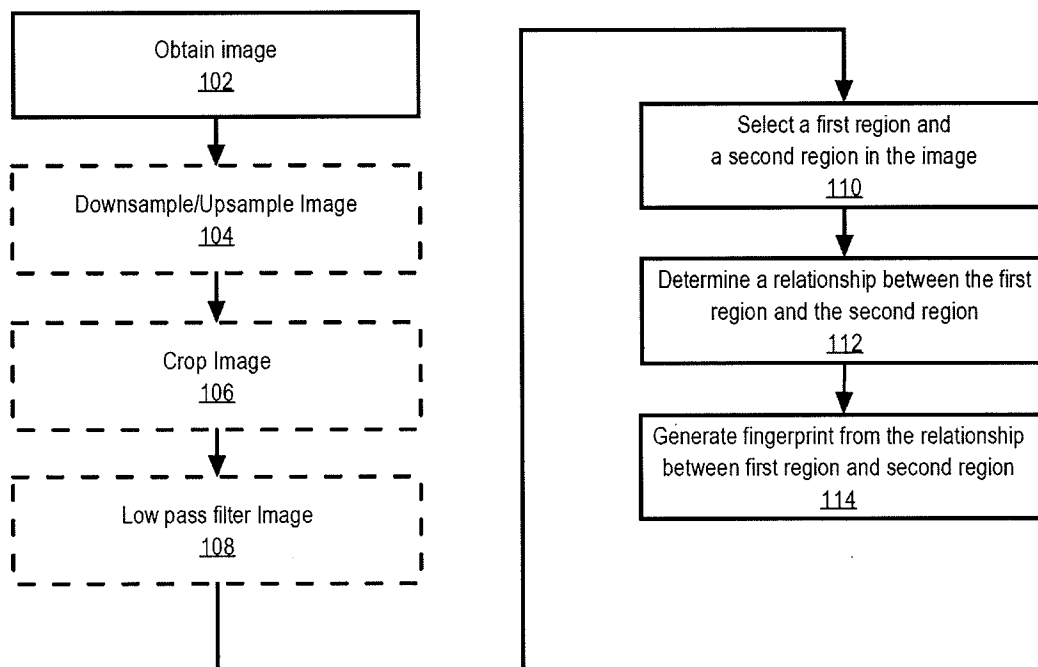


FIG. 1

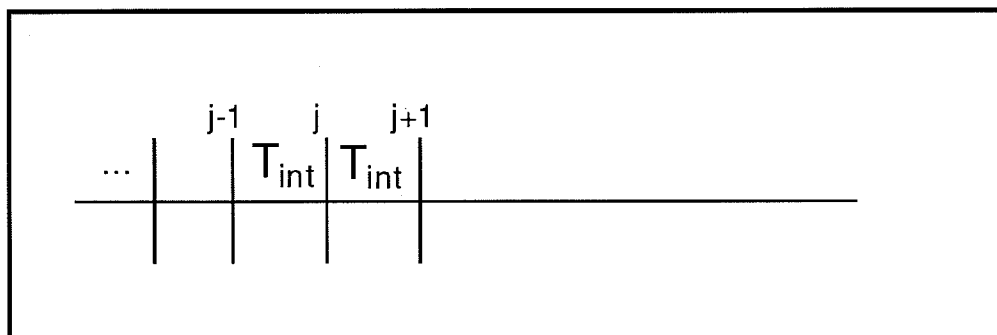


FIG. 2

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FIG. 4A

3	5	1	9	5	3	9	5
4	6	2	1	4	3	3	8
8	7	3	2	3	8	2	7
3	9	5	4	6	2	1	9

FIG. 4B

R1	R1	R1	R1	R2	R2	R2	R2
R1	R1	R1	R1	R2	R2	R2	R2
R1	R1	R1	R1	R2	R2	R2	R2

FIG. 4C

$$R1 - R2 =$$

-2	2	-8	4
0	3	-1	-7
5	-1	1	-5
-3	7	4	-5

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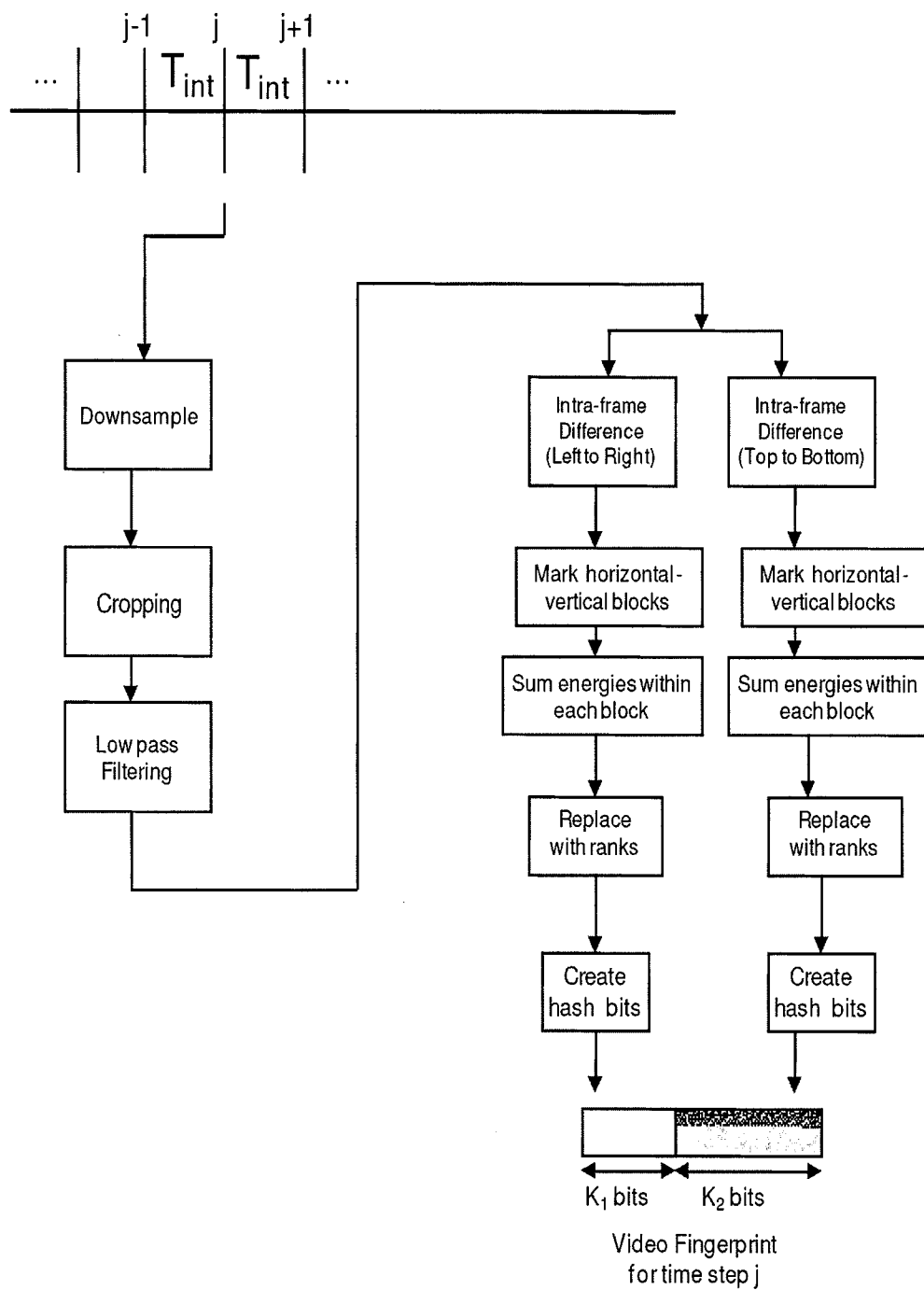


FIG. 5

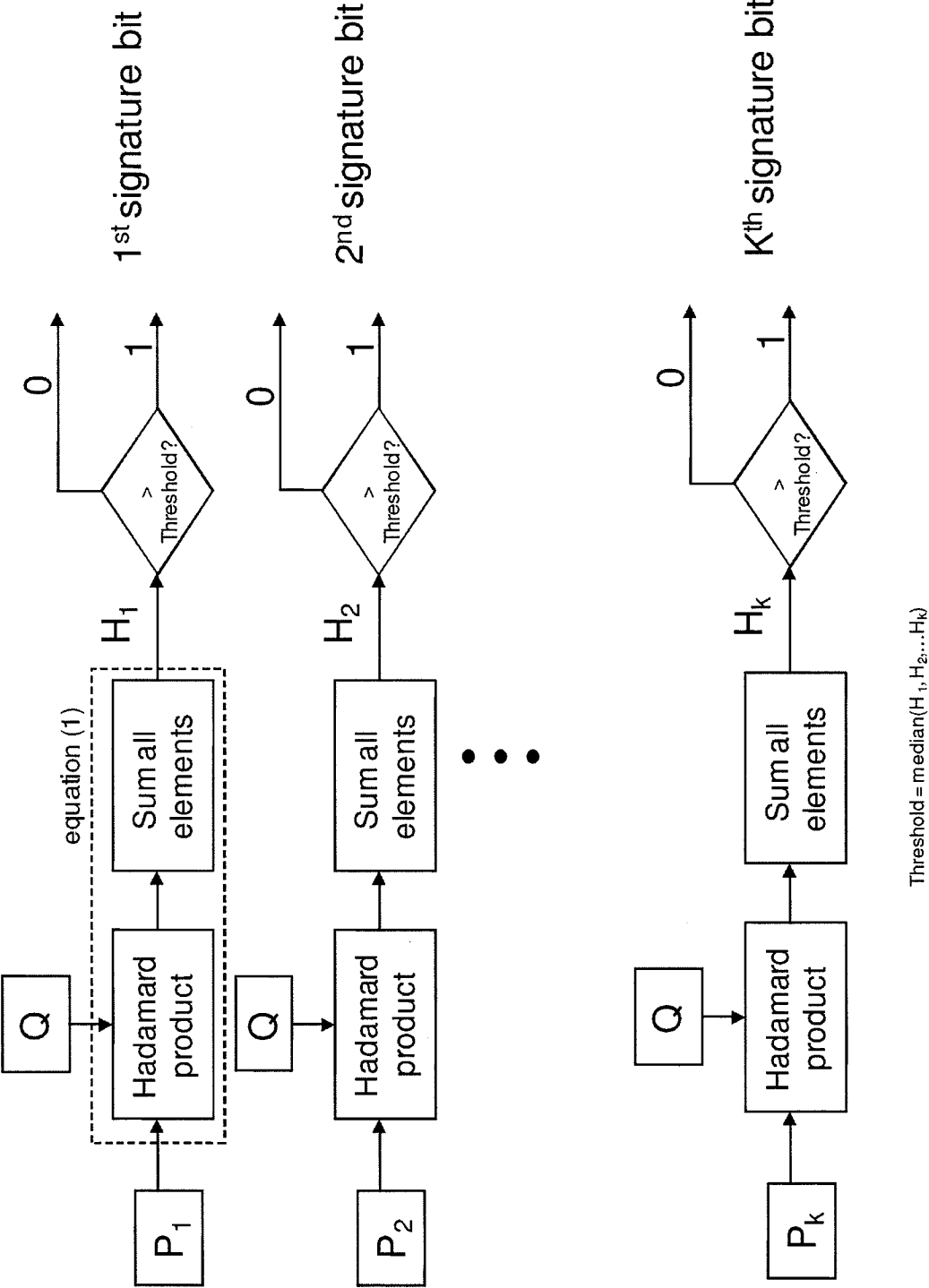


FIG. 6

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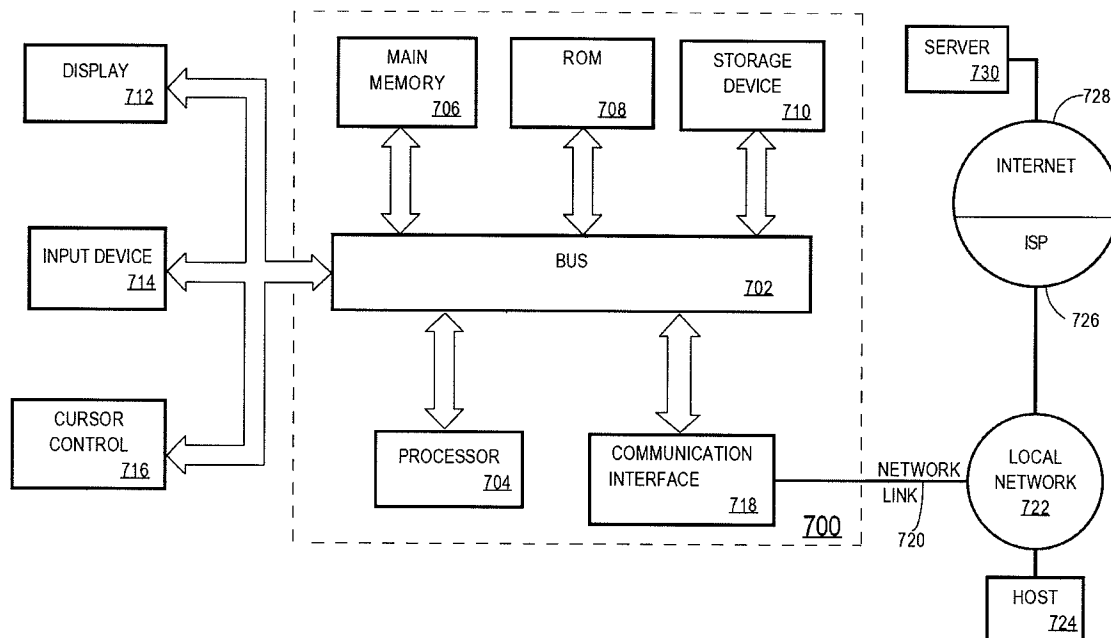


FIG. 7

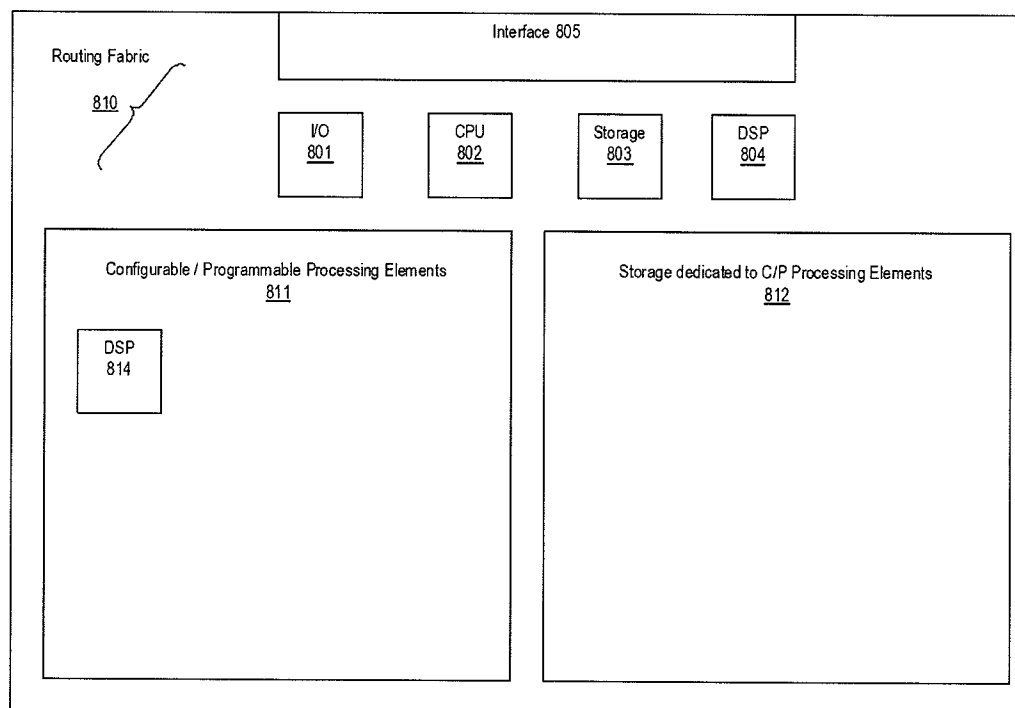


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/053988

A. CLASSIFICATION OF SUBJECT MATTER

INV. G06T1/00

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)

G06T H04L G06K G06F H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	WO 2008/143768 A (DOLBY LABORATORIES LICENSING CO [US]; RADHAKRISHNAN REGUNATHAN [US]; BA) 27 November 2008 (2008-11-27) abstract page 3, line 32 - page 4, line 12 page 5, line 30 - page 6, line 4 page 7, line 23 - page 10, line 4 page 11, line 23 - page 12, line 31 ----- -/--	1, 2, 4-8, 10-13, 16-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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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

23 October 2009

Date of mailing of the international search report

04/11/2009

Name and mailing address of the ISA/

 European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040,
 Fax: (+31-70) 340-3016

Authorized officer

Zamuner, Umberto

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/053988

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	RADHAKRISHNAN R ET AL: "Content-based Video Signatures based on Projections of Difference Images" MULTIMEDIA SIGNAL PROCESSING, 2007. MMSP 2007. IEEE 9TH WORKSHOP ON, IEEE, PISCATAWAY, NJ, USA, 1 October 2007 (2007-10-01), pages 341-344, XP031224845 ISBN: 978-1-4244-1274-7	1-4,6-8, 10-13, 16-20
Y	the whole document	5,9
X	US 6 532 541 B1 (CHANG SHIH-FU [US] ET AL) 11 March 2003 (2003-03-11) column 3, lines 17-52 column 7, line 49 - column 8, line 6	1,2,10, 12,13, 16-20
X	WO 2008/066930 A (DOLBY LAB LICENSING CORP [US]; RADHAKRISHNAN REGUNATHAN [US]; BAUER CL) 5 June 2008 (2008-06-05)	1-4,7,8, 11-13, 16-20
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International application No

PCT/US2009/053988

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