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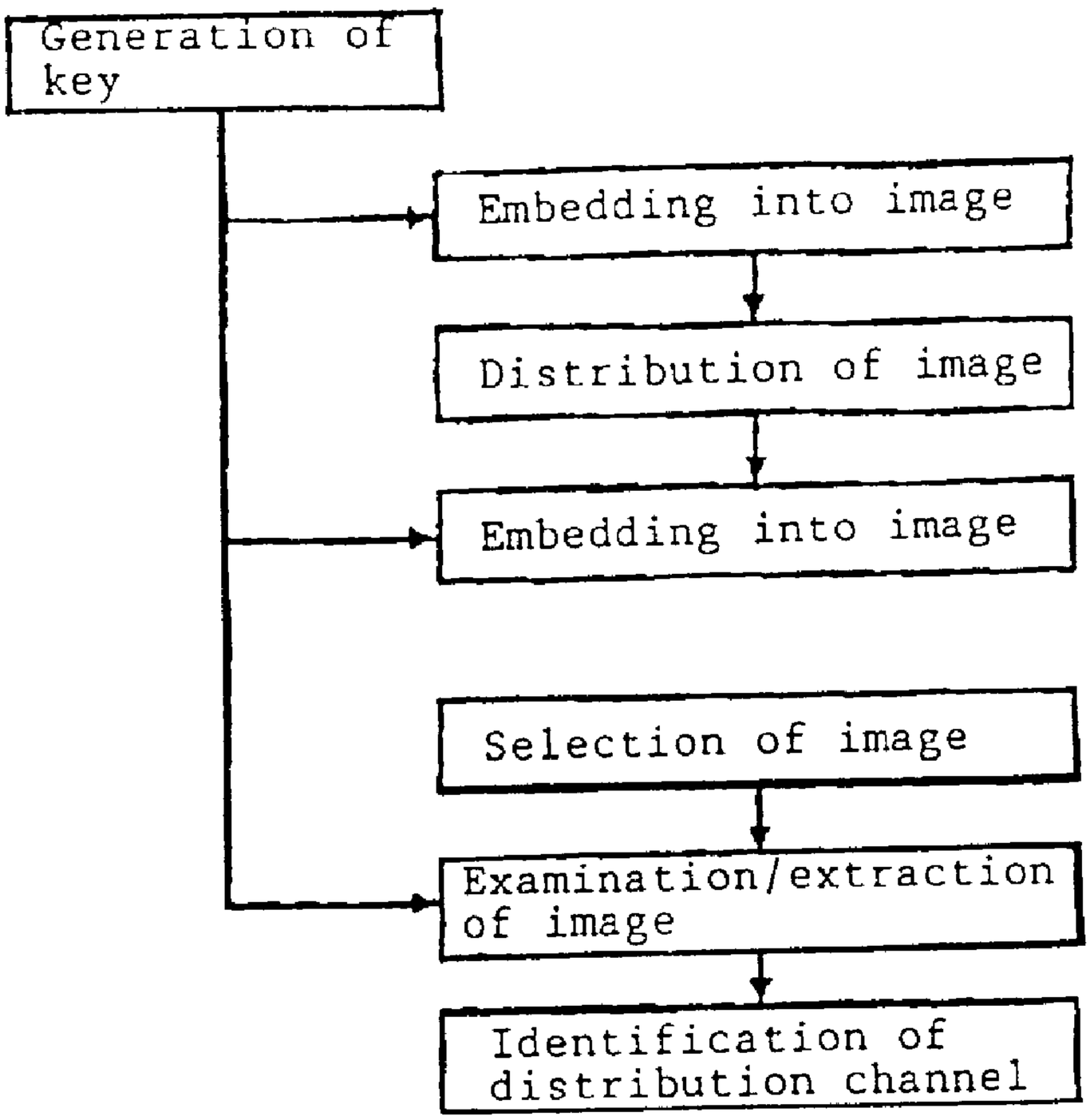


(57) Abrégé/Abstract:
It is intended to make it possible to properly certify who is a genuine owner, and to inhibit deterioration of image quality of media information to which the embedding operation is performed by adaptively determining amount of the operation for characteristic values such as pixel values. The invention provides a data hiding method for embedding message data into media data comprising

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(57) Abrégé(suite)/Abstract(continued):
the steps of obtaining a secondary key by inputting a key having a predetermined value to a specified function; determining hiding positions in which the message data will be embedded according to the obtained secondary key, and selecting one of plural hiding functions according to the secondary key so that the selected hiding function is used for each of the determined hiding positions; and embedding the message data into each of the determined hiding positions according to the selected hiding function corresponding to the hiding position.

# DATA HIDING METHOD AND DATA EXTRACTION METHOD USING STATISTICAL EXAMINATION

## ABSTRACT

It is intended to make it possible to properly certify who is a genuine owner, and to inhibit deterioration of image quality of media information to which the embedding operation is performed by adaptively determining amount of the operation for characteristic values such as pixel values. The invention provides a data hiding method for embedding message data into media data comprising the steps of obtaining a secondary key by inputting a key having a predetermined value to a specified function; determining hiding positions in which the message data will be embedded according to the obtained secondary key, and selecting one of plural hiding functions according to the secondary key so that the selected hiding function is used for each of the determined hiding positions; and embedding the message data into each of the determined hiding positions according to the selected hiding function corresponding to the hiding position.

# DATA HIDING METHOD AND DATA EXTRACTION METHOD USING STATISTICAL EXAMINATION

## Field of the Invention

The present invention relates to a data hiding method and a data extraction method to embed information on its owner or copyright (message information) into media information such as digital images, digital videos, or digital audio in an unperceptive manner. Particularly, it relates to a data hiding method to embed media information in an unperceptive manner while controlling the embedding operation for the information with statistical examination. It also relates to a data extraction method to determine with the statistical examination whether or not the media information is embedded, and to properly retrieve the embedded information based on the result of determination.

## Background Art

The following technique has been known as the data hiding method with statistical approach. First, two pixel point arrays (hereinafter called $\{a_n\}$ and $\{b_n\}$," respectively) are selected from the image data. The respective pixel point arrays are composed of a number of pixel points which is assumed to be "n." Then, the embedding operation is performed by adding a fixed value c to the value v ($a_n$) of n pixels in one point array $\{a_n\}$, while subtracting the fixed value c from the value v ($b_n$) of n pixels in the other point array $\{b_n\}$.

$$v_0 (a_n) = v (a_n) + c$$
$$v_0 (b_n) = v (b_n) - c \qquad \textbf{Equation 1}$$

Whether or not embedding is conducted in image data is determined by calculating and the average of difference between the values of n pixels in both point arrays, and based on its result, as represented in the following formula.

$$\frac{1}{N}\sum_{n=1}^{N}(v'(a_n))-v'(b_n))$$

**Equation 2**

That is, when an average is calculated for difference between values of pixels in the number as much as those where statistical property appears, it is expected that the average is converged to zero if no addition is conducted. On the other hand, if the addition is conducted, it is expected that the average becomes a fixed value of $2_c$. Accordingly, it is determined whether or not the embedding operation is performed on the basis of a fact whether the average is closer to 0 or $2_c$, with a threshold value being set.

The information to be embedded is one bit, and the positions of two pixel point arrays are confidential known only to the person who performs the embedding operation. Since the average $2_c$ cannot be retrieved by a person other than the person who performs the embedding operation unless the positions of pixel point arrays can be identified, the fact that this value can be extracted proves that the person is the owner of the data.

Problems to be solved by the invention

However, the first problem in the conventional technique using the statistical approach lies in that who is the owner of data can be easily made unclear by conducting new embedding operation. That is, even if a third party does not manipulate the pixel value in the pixel point array known only to the owner, the average $2_c$ can be newly produced in other two suitable pixel point arrays by selecting such pixel point arrays, and conducting the embedding operation on their pixel values. Therefore, when the third party who performed such operation falsely claims that he/she herself/herself is the owner based on the average that is calculated from the point array identified by him or her, the background art cannot prove who is the genuine owner.

The second problem lies in that sufficient consideration is not given to the embedding operation and deterioration of image quality caused by it. Even if the same value c is added or subtracted, significant difference may occur in deterioration of visual image quality because of certain characteristics of the image quality. Therefore, it is preferable to adaptively change amount of embedding operation depending on the characteristics of image quality. That is, it is preferable to adaptively select the fixed value c and the number of pixels N in the pixel point arrays.

Thus, an object of the present invention is to provide a data hiding method which enables it to properly prove who is the genuine owner.

Another object of the present invention is to inhibit deterioration of image quality by adaptively determining amount of operation for the characteristic values such as pixel values in the medium information on which the embedding processing is conducted.

**Summary of the Invention**

To attain the above objects, one of the features of the present invention is to use a key for selecting a pixel point array. This prevents false authentication of the owner. Another feature is to adaptively determine the size of selected pixel point array (N), and the magnitude of statistic amount (c) to be manipulated for the characteristic values. In retrieving the data, reliability is calculated for determining whether or not information is embedded in a region, that is, whether or not the arithmetic operation is conducted on the characteristic values in that region. These enable it to embed multi-bit information (author, distribution ID, and the like) in an image in an unperceptive manner, and to retrieve the embedded information from the image for claiming the ownership of the image or for identifying the distribution channel.

More specifically, the first aspect of the present invention is a data hiding method for embedding message into data comprising the steps of obtaining a secondary key by inputting a key having a predetermined value to a specified function; determining hiding

positions in which the message will be embedded according to the obtained secondary key, and selecting one of plural hiding functions according to the secondary key so that the selected hiding function is used for each of the determined hiding positions; and embedding the message into each of the determined hiding positions according to the selected hiding function corresponding to the hiding position.

The second aspect of the present invention is a data extraction method for extracting message from data in which the message is embedded comprising the steps of obtaining a secondary key by inputting a key having predetermined value to a specified function; determining hiding positions in which the message is embedded according to the obtained secondary key, and selecting one of plural hiding functions according to the secondary key so that the selected hiding function is used for each of the determined hiding positions; inputting information in the determined position to a detection basic function which is identified according to the determined hiding function; inputting an output of the detection basic function to a detection function; and determining whether the message is embedded according to an output of the detection function.

**Brief Description of the Drawings**

**Figure 1** is a diagram illustrating the relationship between distribution of an image and generation of a key in an embodiment; and

**Figure 2** is a table showing the result of characteristics of a detection basic function when they are applied to a test image.

**Figures 3-9** are linear filters used a detection basis functions.

**Figures 10-14** are formulae for obtaining detection basic functions.

**Preferred Embodiment**

Figure 1 is the relationship between distribution of an image and generation of a key. An image is distributed by first generating a key, and embedding multi-bit information in the image based on the key. If it is intended to encrypt and distribute an image, multi-bit information is additionally embedded in the decrypted image at the destination. Then, an

image being distributed is detected on the basis of the key to see whether or not it violates the copyright. If so, its distribution channel is identified from the extracted bit information. In the following, first, a system is generally described for detecting whether or not embedding is performed in a digital content, and retrieving the bit information. Then, a system is generally described for detecting/embedding the multi-bit information. Furthermore, important concepts of the embodiment, the detection basic function and overwriting, a feature for calculating the detection function, false embedded certificate, and embedding utilizing a unidirectional function are described in detail.

(1) Detection/retrieval system

The detection/retrieval system comprises:

- a mechanism for determining a point array and a detection basic function from a given key;
- a mechanism for obtaining a value at each point from the point array and the detection basic function, and for calculating their sum;
- a mechanism for determining a detection function; and
- a mechanism for determining bit information and its probable reliability by applying the detection function to the calculated sum.

The point array is for determining a position where the digital content is embedded. It is an array of one-dimensional coordinates if the digital content is one dimensional, while it is an array of two-dimensional coordinates if the digital content is two dimensional. The point array is divided into a plurality of groups into each of which one-bit information is embedded. Information of bit length corresponding to the number of groups is retrieved from the embedded digital content. Each point in the point array is represented as xna. The double suffix is conveniently appended to indicate that the point array is divided into a plurality of groups, in which a represents the group to which it belongs.

The detection basic function is a feature for calculating a value by using digital data near a specified point. Specific examples of the detection basic function will be described later. A common detection basic function may be used for all points in the point array, while a different detection basic function may be selected on the basis of the key for each point from a plurality of detection basic functions. To prevent a malicious third party from erasing the embedded information, it is arranged to selecting one of a plurality of detection basic functions for each point based on the key so that each point has a different one. The detection basic function at a point $x_{na}$ is represented as $f_{na}$ in the following.

A value is determined for each point based on the point array and the detection basic function to calculate the sum $s_a$ of them in each group (suffix a).

$$s_a = \sum_{n=1}^{N_a} f_{na}(x_{na})$$

**Equation 3**

where $N_a$ is the number of points belonging to the group a, and may differ from one group to another. It is not necessary to maintain the point array and the detection basic function. It is sufficient to generate keys one after another and to destroy them as soon as the sum is added in an accumulation memory.

A detection function is defined, assuming that point arrays and the detection basic function are randomly selected, to provide a probabilities where its sum is larger and lower than a certain value. The probability where the sum of point arrays of N is larger than s is represented as E± (N: s), while the probability where the sum is smaller than s is represented as E-(N: s). In this case, the bit information and its probable reliability are found from the calculated sum $s_a$ as follows:

$$E+ (N_a, s_a) > E- (N_a, s_a)$$

**Equation 4**

It is determined that bit 0 is embedded if the above is satisfied, and $E+ (N_a, s_a)$ is determined to be its reliability. On the contrary, if

$$E+ (N_a, s_a) < E- (N_a, s_a), \qquad \textbf{Equation 5}$$

it is determined that bit 1 is embedded, and $E- (N_a, s_a)$ is determined to be its reliability. If equality is established, the probability is the same for bits 0 and 1. That is, the bit information cannot be detected. If the detection function is arranged to satisfy the following, then the above mechanism may be more simplified for determining the bit information and its probable reliability.

$$E+ (N, s) + E- (N, s) = 1 \qquad \textbf{Equation 6}$$

In this case, if

$$E+ (N_a, s_a) > 0.5, \qquad \textbf{Equation 7}$$

then it is determined that bit 0 is embedded, and $E+ (N_a, s_a)$ is determined to be its reliability. On the contrary, if

$$E+ (N_a, s_a) < 0.5, \qquad \textbf{Equation 8}$$

then it is determined that bit 1 is embedded, and $1 - E+ (N_a, s_a)$ is determined to be its reliability. Here, the detection rule for bit 0 and bit 1 may be reversed.

Whether or not bit information is embedded in a digital content is determined by the fact whether or not reliability determined by an actual user of the subsystem for his or her purpose is exceeded. While the detection/extraction system requires random access to digital content data, the system may be configures as follows to process the digital content data as a stream instead of holding it in the memory region:

- a mechanism for determining which detection basic function f is used for the stream data of digital content from its position (point) and a given key, and to which sum sa its value is added;
- a mechanism for temporarily obtain the value of detection basic function f, and adding it to the sum sa for accumulation;
- a mechanism for accumulating data necessary for obtaining a detection function from the stream data; and
- a mechanism for obtaining a detection function after all stream data are processed, and applying the detection function to the accumulated sum sa to determine bit information and its probable reliability.

(2) Overview of embedding system

The embedding system comprises:

- a mechanism for determining a point array and a detection basic function form the given key;
- a mechanism for obtaining a detection function;
- a mechanism for determining magnitude of the sum necessary to be embedded in the bit information from the probable reliability and the detection function; and
- a mechanism for manipulating digital data near each point in the point array while maintaining unperceptivity so that the sum of detection basic function exceeds a predetermined value.

The point array and the detection basic function are represented as $x_{na}$ and $f_{na}$, respectively. The number of point array groups generated by the embedding system from the key should be generally arranged to be larger than the number used in the detection/extraction system so that important statistical characteristics of the digital content is not changed by the manipulation, while the number of points $N_a$ belonging to individual groups a should be arranged to be larger for a group for which the bit information is desired to be embedded with higher reliability. The detection function is represented as E+ (N, s) or E- (N, s). When the bit information is embedded in the group a with reliability $p_a$ or higher, embedding is performed for bit 0 so that the sum $s_a$ of the detection function becomes

$$E+ (N_a, s_a) > p_a. \qquad \textbf{Equation 9}$$

Embedding is performed for bit 1 so that the sum $s_a$ of the detection function becomes

$$E- (N_a, s_a) > p_a. \qquad \textbf{Equation 10}$$

Here, the reliability $p_a$ is assumed to be larger than 0.5. That is, the reliability is arranged for bit 0 to be smaller than the sum of detection basic function which is $s_a$ where $E+ (N_a, s_a) = p_a$, and for bit 1 to be larger than the sum of detection basic function which is $s_a$ where $E- (N_a, s_a) = p_a$. Here, the embedding rule for bits 0 and 1 may be reversed in the above bit embedding.

Since the detection function depends on the statistical characteristics of digital content, the number of point array groups in the embedding system is arranged to be larger than that in the detection/extraction system, and surplus groups are manipulated to cancel change in the statistical characteristics. Particularly, the embedding is performed by setting a target value of the sum of detection basic functions for surplus groups so that the average of detection basic functions for entire digital content is not changed from that before the

manipulation. The number of surplus group for cancellation may be one or more. Every time one bit is embedded, embedding is performed to cancel it so that the number of bit embedding groups are made equal to that of surplus groups.

The embedding operation is performed by manipulating values of points near each point $x_{na}$ in the point array while maintaining unperceptivity. When the sum of detection basic functions is assumed to be $s_a^0$, $\Delta s_a = s_a - s_a^0$ is the target change range for each group. If the change range is made equal for each point in the point array, $\Delta s_a/N_a$ is the target change range for the value of detection basic function at each point.

In order to provide tampering resistance while maintaining unperceptivity, embedding is performed by manipulating values of points near each point $x_{na}$ in the point array with a narrower change range for a region where the embedding is conspicuous, and with a wider change range for a region where the embedding is inconspicuous, instead of equal change range. An index of unperceptivity is calculated for each point in a point array for embedding into the digital content, and a target change range is determined for the detection basic function to manipulate values of points near that point.

The index of unperceptivity is a value calculated from the values of digital content at points near a given point x, and includes the following types:

- Proportion index: an index for providing perceptivity in a similar magnitude if the change range at each point x is proportional to the index g (x)
- Recognition threshold index: an index for providing perceptivity in a similar magnitude if the change range at each point x is smaller than the index g (x)
- Mixed index: an index combining the above

For the proportional index, a proportional constant r is determined as follows, and rg ($x_{na}$) is made a target change range at each point $x_{na}$.

$$r=\Delta S_a / \sum_{n=1}^{N_a} g(x_{na})$$

**Equation 11**

For the recognition threshold index, if

$$|\Delta S_a| \leq \sum_{n=1}^{N_a} g(x_{na})$$

**Equation 12**

manipulation is sequentially conducted for each point $x_{na}$ with a change range ($x_{na}$) in the direction of sign of $\Delta s_a$ until $|\Delta s_a|$ is exceeded. Then, the change manipulation is stopped at the point where it is exceeded, or the following manipulation is conducted for all points $x_{na}$.

$$g(X_{na}) \Delta S_a / \sum_{n=1}^{N_a} g(x_{na})$$

**Equation 13**

In addition, if

$$|\Delta S_a| \geq \sum_{n=1}^{N_a} g(x_{na})$$

**Equation 14**

the manipulation with the change range

$$g(X_{na}) + (|\Delta S_a| - \sum_{n=1}^{N_a} g(x_{na}) / N_a$$

**Equation 15**

is performed for each point $x_{na}$ according to the sign of ($s_a$. For the mixed index, the embedding is performed by combining the above.

(3) Detection basic function and overwriting

The key specifies a point array and a detection basic function. Here, description is given on the detection basic function, and the associated embedding operation, and the overwriting technique. The detection basic function is a mechanism for calculating values by using digital data at points near a specified point. The detection basic function is represented as $f_\alpha$, where $\alpha$ is a suffix for distinguishing a plurality of detection basic functions.

First, description is given on a linear filter for which the sum of coefficients is zero. Although, in principle, the detection basic function may take any form, since a digital content is typically provided in an array of integer values, it is desirable to be a one that receives an integer value as input and outputs another integer value, and that, to efficiently satisfy the unperceptivity, values of the detection basic function are concentrated around their average with the change range of value being small at nearby points necessary for changing the values of detection basic function. More specifically, for the latter condition, when $\sigma$ is assumed to be the standard deviation of detection basic function for the entire digital content, the detection basic function is desirable to be a one in which the average of change range of values at nearby points necessary for increasing/decreasing the detection basic function by $\sigma$ is smaller than the standard deviation of values of every points for the entire digital content.

A detection basic function with such features includes a linear filter represented by the following equation:

$$f_a(x) = \sum_y F_\alpha(y)\, v(x+y)$$

**Equation 16**

where v (x + y) is the value of digital content at a point moved from the point x by y, and the coefficient of filter $F_\alpha(y)$ is an integer expressed by

$$0 = \sum_y F_\alpha(y)$$

**Equation 17**

X and y are two-dimensional vectors for digital images and digital videos. The reason why the sum of coefficient is made zero is to make the embedded information not to depend on an absolute value of digital data at that point, but to depend on behavior of digital data around that point, or a relative value. For example, consider the following as the simplest linear filter for digital image. The coefficient of the detection basic function $F_{S0}$ is given by

$$(F_{S0}(0, 0); F_{S0}(1, 0)) = (1, -1),$$

**Equation 18**

and the coefficient of the detection basic function $F_{S1}$ is given by

$$(F_{S1}(0, 0); F_{S1}(0, 1) = (1, -1).$$

**Equation 19**

Figure 2 is a table where the characteristics of detection basic function are applied to test images. The standard deviation of each detection basic function is considerably smaller than the standard deviation of pixel values. Therefore, it is expected that a narrower change range can be employed by using $F_{S0}$ and $F_{S1}$ as the detection basic function, instead of using the pixel values themselves as the detection basic functions.

To meet JPEG and MPEG, used as the detection basic functions are linear filters with width and height matching with an 8 × 8 block for DCT conversion, that is, linear filters of 4 × 4, 4 × 8, 8 × 4, 8 × 8, 16 × 8, 8 × 16, or 16 × 16. For example, the following 8 × 8 filters $F_{J0}$, $F_{J1}$, $F_{J2}$, and $F_{J3}$ are used:

**Equation 20 shown in Figure 3**

**Equation 21 shown in Figure 4**

**Equation 22 shown in Figure 5**

**Equation 23 shown in Figure 6**

The target change value $\Delta f_\alpha (X) = f_\alpha (x)' - f_\alpha (x)$ is determined for the value of detection basic function at each point in a point array by using the unperceptivity index. Here, detailed description in the case of a linear filter is given on the operation on digital data at each point near points in the embedding point array to attain such target value. In the following, a change value is represented as w (x, y) for each point (x + y) near a point x in the embedding point array. That is, the value of digital data v (x + y) at a point (x + y) is converted into v (x + y) + w (x, y).

A coefficient $G_\alpha (y)$,

$$\sum_{y} F_\alpha (y)\, G_\alpha (y) = D_\alpha > 0$$

**Equation 24**

is defined for the coefficient $F_\alpha (y)$ of linear filter for the detection basic function $f_\alpha$. Then, d (x) is obtained from

$$d(x) = \Delta F_\alpha (x) / D_\alpha$$

**Equation 25**

The change value is obtained from

$$w(x,y) = d(x)\, G_{\alpha}(y)$$

**Equation 26**

A selected simplest coefficient $G_{\alpha}$ (y) is $G_{\alpha}$ (y) = $F_{\alpha}$ (y). If the absolute value of d (x) is larger than 1, the unperceptivity is enhanced by slightly changing and averaging the value of d (x) $G_{\alpha}$ (y) so that the value gradually changes. For example, if d (x) = 4 for $G_{J1}$ (j, k) = $F_{J1}$ (j, k), instead of using

**Equation 27 shown in Figure 7**

its average,

**Equation 28 shown in Figure 8**

is used.

The following approaches are used for embedding a plurality of messages with overwriting:

- Orthogonal embedding; and
- Layered embedding.

Here, the orthogonal embedding is to overwrite bits by using detection basic functions which are highly independent of each other. In the case of the linear filter, it is performed using a set of orthogonal coefficients:

$$\sum_{y} F_{\alpha}(y)\, G_{\beta}(y) = D_{\alpha} \neq 0 \quad if\ \alpha = \beta$$
$$= 0 \quad otherwise$$

**Equation 29**

If α and ß differ each other, the embedding performed with w (x, y) = d (x) $G_{ß}$ (y) is not detected by the detection basic function $f_{\alpha}$ given by the coefficient $F_{\alpha}$ (y).

In addition, the layered embedding means a case where, when, between detection basic functions having different sizes for the regions to which they are applied, the smaller region to which one detection function is applied is enlarged in the form to the larger region to which the other function is applied, they have high independence. For example, a linear filter $f_{S0}$ with a 2 × 1 size can be enlarged to the following linear filter with a 2 × 2 size:

**Equation 30 shown in Figure 9**

**Equation 31 shown in Figure 9**

They are orthogonal with the following linear filter in term of the above orthogonal embedding. Accordingly, $f_{SS}$ and $f_{S0}$ can be overwritten.

Here, calculation of the detection function is described. When a digital content is determined, the frequency that the detection basic function $f_\alpha$ has a value f is counted for the entire content to produce a frequency distribution (histogram) h (f). It is calculated for a probability p (f) where the detection basic function $f_\alpha$ is the value f as follows:

$$p(f) = h(f) / \sum_f h(f)$$

**Equation 32**

Even if a histogram is produced by calculating the value of detection basic function fα for randomly selected points, rather than calculating it for all points in the content, there is no problem in practical use if sufficiently large number of points are selected. A probability PN (s) where the sum of N detection basic functions is s is found from the resulting probability p (f) according to the following equation:

$$P_N(s) = \sum_{f_1} \sum_{f_2} \cdots \sum_{f_{N-1}} p(f_1)p(f_2)\cdots p(f_{N-1})p(s-f_1-f_2\cdots-f_{N-1})$$

**Equation 33**

The detection function can be obtained by using this as follows:

**Equation 34 as shown in Figure 10**

Approximate calculation of detection function

In the following, a method for approximately obtaining a detection function from a statistical moment of a detection basic function or average of powers $<f_n>$ is described as a method for efficiently obtaining the detection function. Here, the statistical moment is assumed to be calculated from

$$<f^n>=\sum_x \sum_\alpha f_\alpha(x)^n / \sum_x \sum_\alpha 1$$

**Equation 35**

As described below, since it is not necessary to calculate the probability PN (s) from the histogram h (f), amount of memory and calculation can be maintained at a low level. The equation $<f^m>^c = <(f - <fi>)^n>$ simplifies the equation, shown in Figure 11, Equation 36.

Here, it is possible to approximate as

**Equation 37, shown in Figure 12**

for sufficiently large N. Thus, the detection function can be given by:

**Equation 38, shown in Figure 13**

Correction terms $E+ (N, s)^{(n)}$ and $E- (N, s)^{(n)}$ in the approximated detection function are calculated as follows:

$$E_{+}(N,s)^{(n)} = -Q_n(N,s)\,P_N(s)^{(0)}$$

$$E_{-}(N,s)^{(n)} = Q_n(N,s)\,P_N(s)^{(0)}$$

**Equation 39**

For simplicity, if

$$v = s - N\langle f\rangle$$

**Equation 40**

and

$$w = \frac{(s - N\langle f\rangle)^2}{N\langle f^2\rangle_c}$$

**Equation 41**

Qn (N, s) is given by the following:

$$Q_1(N,s) = \frac{\langle f\rangle^3{}_c}{3!\langle f^2\rangle_c}(w-1)$$

**Equation 42**

and $Q_1$(N,S) by Equation 43 of Figure 14.

When the detection function including the correction items is evaluated by $E+^{(0)} + E+^{(1)}$, $E+^{(0)} + E^{(1)} + E+^{(2)}$, $E-^{(0)} + E-^{(1)}$, and $E-^{(0)} + E-^{(1)} + E-^{(2)}$, if it provide a negative value, it is replaced with zero.

Strict calculation of detection function

To efficiently obtain the probability PN (s) without approximation, a recurrence formula

$$P_{N+N'}(s) = \sum_{s'} P_N(s')\, P_{N'}(s-s')$$

**Equation 44**

is used. For example, for N = 2M, it is sufficient to repeat the above recurrence formula M times. Its disadvantage is memory size. It is used in a trial or the like where approximation is undesired.

False certificate of embedding

When a digital content is determined, the following point array is obtained by counting the frequency where the detection basic function $f_\alpha$ has the value f for the entire content, producing a frequency distribution (histogram) h (f), manipulating the frequency distribution h (f) to produce a frequency distribution $h_a$ (f) corresponding to the point array:

- causing the sum of detection basic function on the point array to exceed a target value;
- causing the sum of detection basic function on the point array to be close to the target value; and
- causing the sum of detection basic function on two point arrays to be close to the target value.

If there is no key system with a unidirectional function, it is possible to produce false certificate that embedding has been performed in a digital content into which bit information is not embedded with this system. The present invention is described in detail in the following.

When it is assumed that the frequency distribution of detection basic function values over the entire digital content is h (f), and that the frequency distribution of detection basic function values for the point array group a is $h_a$ (f),

$$0 \leq h_a(f) \leq h(f) \qquad \textbf{Equation 45}$$

is satisfied for all f, the sum of detection basic function values in the point array group a is given by

$$s_a = \sum_f f h_a(f) \qquad \textbf{Equation 46}$$

and the number of points in the point array group a is given by

$$N_a = \sum_f h_a(f) \qquad \textbf{Equation 47}$$

In this case,

$$s_a/N_a = -s_b/N_b = c \qquad \textbf{Equation 48}$$

is substantially established for the bit extraction condition formula (Equation 1) described for the background art to obtain $h_a(f)$ and $h_b(f)$ with

$$N_a = N_b = N \text{ and } h_a(f) + h_b(f) \leq h(f) \qquad \textbf{Equation 49}$$

In addition, when it is noticed that the bit extraction condition with the detection function according to the present invention is approximately close to normal distribution if $N_a$ for the detection function is large, the following equation is established for bit 1:

$$s_a/\sqrt{N_a} \geq c \qquad \textbf{Equation 50}$$

On the other hand, the following equation is established for bit 0:

$$s_a/\sqrt{N_a} \geq -c \qquad \textbf{Equation 51}$$

$$\sum_a = h_a(f) \leq h(f) \qquad \textbf{Equation 52}$$

Thus, $h_a$ (f) is obtained.

A system for creating a certificate of false embedding produces a frequency distribution h from the digital content with the first scanning, then, produces a frequency distribution ha satisfying the above from h (f), and selects $h_a$ (f) of points f = f (x) from the digital content with the second scanning, thereby their aggregation being made a point array for false embedding.

The frequency distribution $h_a$ is produced from the entire frequency distribution h by repeating for all a the basic operation which calculates f under the predetermined rule described later until the sum Σfha (f) reaches a value $N_a$ with $h_a$ (f) = 0 as the initial value, decrements h (f) by 1 and increments $h_a$ (f) by 1 if h (f) is positive. The loop for a is inside.

To produce the frequency distribution $h_a$ for the bit extraction condition with the detection function, the basic operation is performed in the descending order of f for the frequency distribution used for embedding bit 1, and in the ascending order of f for the frequency distribution used for embedding bit 0.

The bit extraction condition formula (Equation 1) described for the background art is operated as follows. With Δ0 (+) = 0, Δ(-) = 0 as the initial value, $f_{na}$ close to

$$f_{na} = c + \Delta_n (+) \qquad \textbf{Equation 53}$$

is found, and the basic operation is conducted on $h_a$ to obtain

$$\Delta_{n+1}(+) = c + \Delta_n (+) - f_{na} \qquad \textbf{Equation 54}$$

Then, $f_{nb}$ close to

$$f_{nb} = -c + \Delta_n (-) \qquad \textbf{Equation 55}$$

is found, and the basic operation is conducted on $h_b$ to obtain

$$\Delta_{n+1}(-) = -c + \Delta_n (-) - f_{nb} \qquad \textbf{Equation 56}$$

The final error is given by $\Delta N (+) = N$ and $\Delta N (-) = N$.

Embedding utilizing bidirectional function

As described above, predetermined bit information can be extracted from a non-embedded digital content with selection of a point array as if it is embedded. Therefore, it cannot be determined whether or not a person is the owner of the digital content only by the fact that the point array for extracting the predetermined bit information from the digital content is known. While, as a solution to this problem, it is contemplated to previously register with a fair third party organization the fact that bit information is embedded in a specific digital content with a specific point array, this solution has the following shortcomings:

- Registration should be performed for every embedding so that cost is required for the registration.

- Since the embedded point array is registered with the third party organization, the risk that the secret of embedded point array is exposed is increased, and the embedded information is exposed to the risk that it is erased.

Thus, it is claimed as our inventions a method and system for embedding bit information as a solution of the problem of false certificate of owner which publishes an approach for determining an embedding position from an integer value (hereinafter called a "key") with a unidirectional function, wherein the "key" is secret and is known only to an owner him/herself. As long as this method is employed, even if a point array for a false certificate of owner can be obtained from a specific digital content, because the "key" for deriving the point array cannot be calculated due to the characteristics of unidirectional function, it is impossible to perform a false certificate of owner from knowing a private key.

The method for producing a point array for determining a position where embedding is performed from a key using a unidirectional function can be implemented by generating a "secondary key" using the unidirectional function, and producing the point array from the "secondary key." Since both the key and the "secondary key" are non-negative integer values, an ordinary unidirectional function may be used. A method is also implemented for determining a position into which embedding is performed from a key using the unidirectional function through production of a "secondary key" from the key using the unidirectional function.

Now, detailed description is given on a method for generating a point array from a "secondary key." A digital content is divided into N regions to each of which a number is assigned. Here, the number is represented as n. Each region n is divided into M sub-regions to which a detection base function is applied, and to each of which a number is assigned. In addition, it is assumed that the detection basic function is selected L detection basic functions. In this case, the secondary key selects the number mn of a sub-region from each sub-region n, and the detection basic function fln which is applied to this sub-

region. That is, it is assumed that the secondary key (non-negative integer) k generates an integer

$$j=\sum_{n=0}^{N-1} L^{n}M^{n}(m_{n}+Ml_{n})$$

**Equation 57**

for determining the sub-region and the detection basic function. A possible range (bit length of k) for the secondary key is usually shorter than a possible range (bit length of j) for an integer j. Accordingly, if $k_0$ is assumed to be the secondary key, the sub-region and the detection basic function are determined by sequentially calculating $k_i + 1$ from $k_i$, and then calculating

$$j=\sum_{i=0} K^{i}k_{i}$$

**Equation 58**

Here, K is the upper limit of non-negative integer $k_i$. The mechanism for calculating $k_i + 1$ from $k_i$ may be a unidirectional function or an ordinary arithmetic operation. It is desirable to be a one-to-one function. Mn and In from the integer j can be bit calculated by taking the number M of sub-regions and the number L of detection basic functions as powers of 2.

Advantages of the invention

As described, the present invention can properly certify who is the genuine owner, and can inhibit deterioration of image quality of media information to which the embedding operation is performed by adaptively determining amount of the operation for characteristic values such as pixel values.

## Claims:

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A data hiding method for embedding a message comprising one or more digital data bits into an array of data, said method comprising the steps of:

obtaining a secondary key by inputting a secret first key to a specified public unidirectional function, said second key specifying said array of data and detection basic functions for calculating values based on data near points in said array;

determining a plurality of point array groups from said array of data in which said message is to be embedded according to said secondary key, an amount of point array groups corresponding in number to an amount of digital data bits in said message, and selecting one corresponding detection basic function from a plurality of detection basic functions according to said secondary key so that said detection basic function is applied to each point of said point array groups at a time of detection; and

embedding each bit into its corresponding point array group by manipulating digital data near each point in the point array group to achieve a desired sum of detection basic function values over the point array group.

2. A method as recited in claim 1, wherein said array of data is comprised of pixel data or an image.

3. A method as recited in claim 2, wherein each of the hiding positions is comprised of a pixel point array of pixels, each of the pixels having at least one characteristic value.

4. A method as recited in claim 3, wherein the step of embedding is comprised of adaptively ascertaining a size of each pixel point array and a magnitude for manipulating said characteristic value.

5. A method as recited in claim 4, wherein said step of ascertaining the magnitude employs statistics of a plurality of characteristic values for the pixel point array.

6. A method as recited in claim 1, wherein said message is a fixed constant.

7. A method as recited in claim 1, further comprising the steps of generating the first key in a random fashion.

8. A data extraction method for extracting a message comprising one or more digital data bits from an array of data in which the message is embedded, said method comprising the steps of:

specifying said array of data and detection basic functions for calculating values based on data near points in said array according to a secondary key;

determining a plurality of point array groups from said array of data in which said message is embedded according to said secondary key, an amount of point array groups corresponding in number to an amount of digital data bits in said message, and selecting one corresponding detection basic function at each point of point array groups from a plurality of detection basic functions according to said secondary key;

inputting neighboring array data of each point in said point array group to the selected detection basic function for that point, calculating a function value for each point in said point array group and accumulating a sum of values calculated for each point array group;

inputting said accumulated sum of output values for each group to a detection function; and

determining with probable reliability whether a digital data bit is embedded in each of said point array groups according to an output of said detection function.

9. A method as in claim 8, further comprising a step of ascertaining whether or not information is embedded in a subset of the array of data.

10. A method as in claim 9, wherein said step of ascertaining includes determining whether or not an arithmetic operation was conducted on the subset.

11. A method as in claim 8, wherein said array of data is comprised of an array of pixels of an image.

12. A method as in claim 8, wherein said message is comprised of multi-bit information.

13. A method as in claim 12, wherein said multi-bit information is not perceived by a normal eye.

14. A data hiding method for embedding a message comprising one or more digital data bits into an array of data comprising the steps of:

obtaining a secondary key by inputting a secret first key to a specified public unidirectional function;

determining a plurality of point array groups in which said message will be embedded according to said obtained secondary key, an amount of point array groups corresponding the number to an amount of digital data bits in said message, and selecting one of plural detection basic functions for a corresponding hiding position in point array groups according to said secondary key so that said selected detected basic function is used for each of said determined hiding positions at a time of detection; and

embedding each bit of the message into its corresponding point array group by manipulating neighborhoods of said hiding positions according to said selected detection basic function, wherein each neighborhood comprises a group of pixels for computing a function value, said embedding step including adaptively determining a function value to be modified in said group of pixels according to values of surrounding pixels for each pixel in said group in order to achieve a desired unperceptivity and statistical characteristic.

15. A data extraction method for extracting message comprising one or more digital data bits from data in which the message is embedded comprising the steps of:

determining a plurality of point array groups in which said message is embedded according to a key, an amount of point array groups corresponding in number to an amount of digital data bits in said message, and selecting one of plural detection basic functions according to said key so that said selected detection basic function is used for a determined hiding positions in each said point array group;

inputting neighboring array data of each point in said point array group to said detection basic function and generating an output of said detection basic function;

calculating a function value for each point in said point array group and accumulating a sum of values calculated for each group;

inputting said accumulated sum to a detection function; and

determining with probable reliability whether a digital data bit is embedded according to an output of said detection function.

16. The method as claimed in claim 1, wherein performance of said embedding step according to said detection basic function further includes:

applying said detection basic function at each point in a point array group to determine a point value; and,

accumulating a sum of point values for each group to obtain a point array sum, said step of manipulating data being performed such that said sum exceeds a predetermined value based on a detection function for determining bit information and its probable reliability.

17. The method as claimed in claim 16, wherein said embedding step further includes the step of specifying a target change range for each point during application of said detection

basic function to enable said accumulated sum to exceed said predetermined value.

18. The method as claimed in claim 17, wherein said step of specifying a target change range includes the step of calculating an index of unperceptivity for each point in said point array group, said index being of a value calculated from the values of points near a given point in said array.

FIG. 1

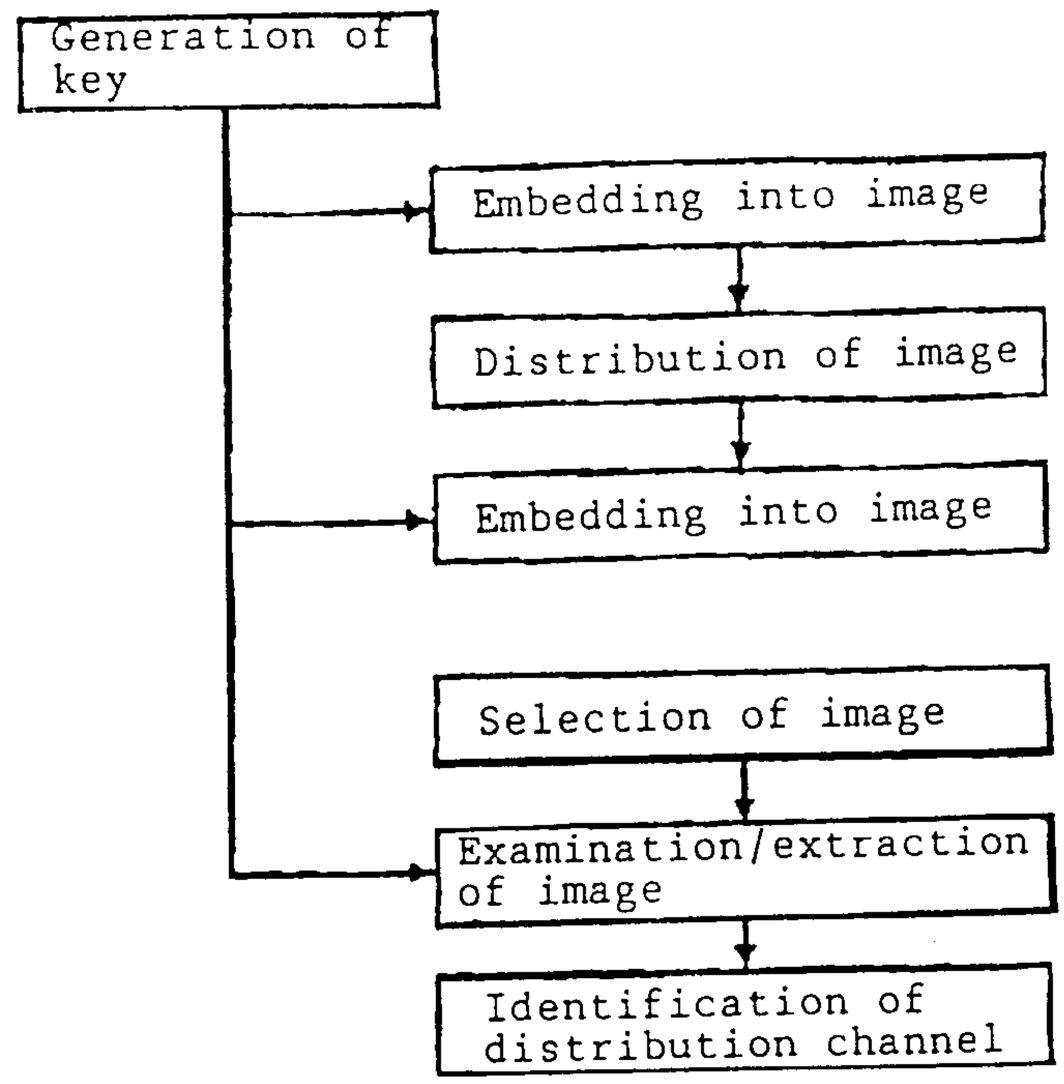



FIG. 2

| Sample image | Standard deviation of pixel values | Standard deviation of $f_{S0}$ | Standard deviation of $f_{S1}$ |
|---|---|---|---|
| 200000 RED | 68.3396 | 9.4510 | 9.0329 |
| 200000 GREEN | 59.6419 | 9.5007 | 9.0248 |
| 200000 BLUE | 60.9283 | 9.7633 | 9.2070 |
| 200001 RED | 58.7429 | 16.2642 | 17.1555 |
| 200001 GREEN | 54.6655 | 16.3756 | 17.1682 |
| 200001 BLUE | 53.0666 | 15.9594 | 16.8779 |
| 200002 RED | 52.5882 | 4.4696 | 8.5511 |
| 200002 GREEN | 45.1880 | 4.1811 | 8.1316 |
| 200002 BLUE | 37.9568 | 4.0256 | 7.8376 |
| 200011 RED | 16.0885 | 3.2931 | 3.4074 |
| 200011 GREEN | 18.8486 | 3.3313 | 3.4857 |
| 200011 BLUE | 21.4928 | 3.4299 | 3.6075 |

$$F_{J0}(j, k) = \begin{Bmatrix} 1 & 1 & 0 & 0 & -1 & -1 & 0 & 0 \\ 1 & 1 & 0 & 0 & -1 & -1 & 0 & 0 \\ 0 & 0 & -1 & -1 & 0 & 0 & 1 & 1 \\ 0 & 0 & -1 & -1 & 0 & 0 & 1 & 1 \\ -1 & -1 & 0 & 0 & 1 & 1 & 0 & 0 \\ -1 & -1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & -1 & -1 \\ 0 & 0 & 1 & 1 & 0 & 0 & -1 & -1 \end{Bmatrix}$$

**Equation 20**

# Figure 3

$$F_{J1}(j, k) = \begin{Bmatrix} 0 & 0 & -1 & -1 & 0 & 0 & 1 & 1 \\ 0 & 0 & -1 & -1 & 0 & 0 & 1 & 1 \\ -1 & -1 & 0 & 0 & 1 & 1 & 0 & 0 \\ -1 & -1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & -1 & -1 \\ 0 & 0 & 1 & 1 & 0 & 0 & -1 & -1 \\ 1 & 1 & 0 & 0 & -1 & -1 & 0 & 0 \\ 1 & 1 & 0 & 0 & -1 & -1 & 0 & 0 \end{Bmatrix}$$

**Equation 21**

# Figure 4

$$F_{J2}(j, k) = \begin{pmatrix} 1 & 1 & 0 & 0 & -1 & -1 & 0 & 0 \\ 1 & 1 & 0 & 0 & -1 & -1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & -1 & -1 \\ 0 & 0 & 1 & 1 & 0 & 0 & -1 & -1 \\ -1 & -1 & 0 & 0 & 1 & 1 & 0 & 0 \\ -1 & -1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & -1 & -1 & 0 & 0 & 1 & 1 \\ 0 & 0 & -1 & -1 & 0 & 0 & 1 & 1 \end{pmatrix}$$

**Equation 22**

# Figure 5

$$F_{J3}(j, k) = \begin{pmatrix} 0 & 0 & -1 & -1 & 0 & 0 & 1 & 1 \\ 0 & 0 & -1 & -1 & 0 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 & -1 & -1 & 0 & 0 \\ 1 & 1 & 0 & 0 & -1 & -1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & -1 & -1 \\ 0 & 0 & 1 & 1 & 0 & 0 & -1 & -1 \\ -1 & -1 & 0 & 0 & 1 & 1 & 0 & 0 \\ -1 & -1 & 0 & 0 & 1 & 1 & 0 & 0 \end{pmatrix}$$

**Equation 23**

# Figure 6

$$d(x)G_{JI}(j,k) = \begin{pmatrix} 0 & 0 & -4 & -4 & 0 & 0 & 4 & 4 \\ 0 & 0 & -4 & -4 & 0 & 0 & 4 & 4 \\ -4 & -4 & 0 & 0 & 4 & 4 & 0 & 0 \\ -4 & -4 & 0 & 0 & 4 & 4 & 0 & 0 \\ 0 & 0 & 4 & 4 & 0 & 0 & -4 & -4 \\ 0 & 0 & 4 & 4 & 0 & 0 & -4 & -4 \\ 4 & 4 & 0 & 0 & -4 & -4 & 0 & 0 \\ 4 & 4 & 0 & 0 & -4 & -4 & 0 & 0 \end{pmatrix}$$

**Equation 27**

# Figure 7

$$w(x,y) = \begin{pmatrix} 0 & 0 & -3 & -4 & 0 & 0 & 4 & 3 \\ 0 & 0 & -4 & -4 & 0 & 1 & 3 & 4 \\ -3 & -4 & 0 & 0 & 4 & 3 & 1 & 0 \\ -4 & -4 & 0 & 0 & 4 & 4 & 0 & 0 \\ 0 & 0 & 4 & 4 & 0 & 0 & -4 & -4 \\ 0 & 1 & 3 & 4 & 0 & 0 & -4 & -3 \\ 4 & 3 & 1 & 0 & -4 & -4 & 0 & 0 \\ 3 & 4 & 0 & 0 & -4 & -3 & 0 & 0 \end{pmatrix}$$

**Equation 28**

# Figure 8

$$F_{S0.0}(i,j)=\begin{pmatrix}1 & -1\\ 0 & 0\end{pmatrix}$$

$$F_{S0.1}(i,j)=\begin{pmatrix}0 & 0\\ 1 & -1\end{pmatrix}$$

**Equation 30**

$$F_{SS}(i,j)=\begin{pmatrix}1 & 1\\ -1 & -1\end{pmatrix}$$

**Equation 31**

# Figure 9

$$E_{+}(N,s)=\sum_{s'>s}P_N(s')$$

$$E_{-}(N,s)=\sum_{s'<s}P_N(s')$$

**Equation 34**

# Figure 10

$$\begin{aligned}\langle f\rangle_c &= 0\\ \langle f^2\rangle_c &= \langle f^2\rangle-\langle f\rangle^2\\ \langle f^3\rangle_c &= \langle f^4\rangle-3\langle f^2\rangle\langle f\rangle+2\langle f\rangle^3\\ \langle f^4\rangle_c &= \langle f^4\rangle-4\langle f^3\rangle\langle f\rangle+6\langle f^2\rangle\langle f\rangle^2-3\langle f\rangle^4\end{aligned}$$

**Equation 36**

# Figure 11

$$P_N(s)^{(0)} = \frac{1}{\sqrt{2\pi N\langle f^2\rangle_c}} \exp\left(-\frac{(s - N\langle f\rangle)^2}{2N\langle f^2\rangle_c}\right)$$

**Equation 37**

# Figure 12

$$E_+(N, s)^{(0)} = \frac{1}{\sqrt{2\pi N\langle f^2\rangle_c}} \int_s^\infty ds' \exp\left(-\frac{(s' - N\langle f\rangle)^2}{2N\langle f^2\rangle_c}\right)$$

$$E_-(N, s)^{(0)} = \frac{1}{\sqrt{2\pi N\langle f^2\rangle_c}} \int_\infty^s ds' \exp\left(-\frac{(s' - N\langle f\rangle)^2}{2N\langle f^2\rangle_c}\right)$$

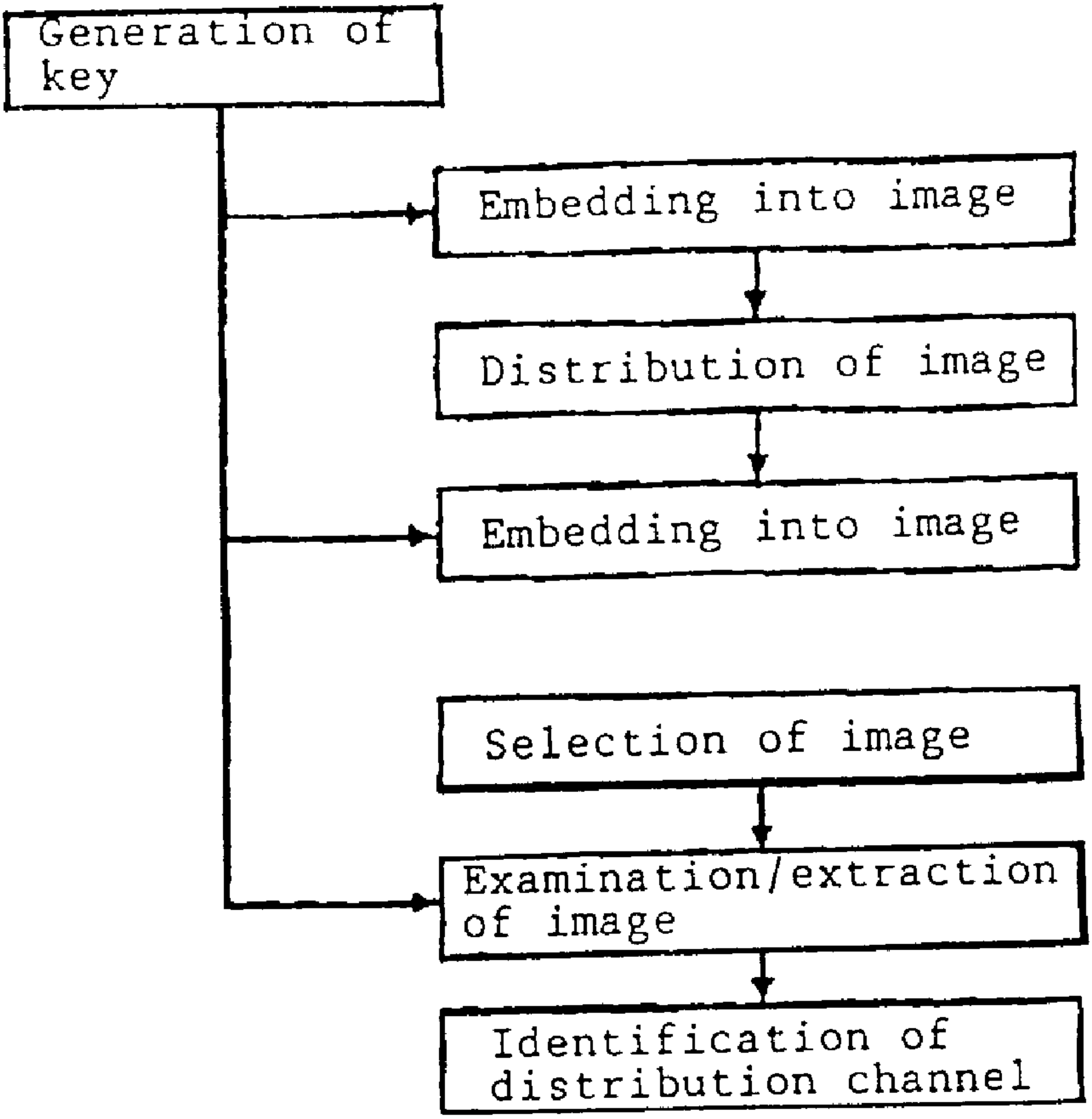
**Equation 38**

# Figure 13

$$Q_2(N, s) = \frac{u}{N}\left[\frac{(\langle f^4\rangle_c - 3\langle f^2\rangle_c^2)}{4!\langle f^2\rangle_c^2}(w - 3) + \frac{\langle f^3\rangle_c^2}{2!3!3!\langle f^2\rangle_c^3}(w^2 - 10w + 15)\right]$$

**Equation 43**

# Figure 14


Generation of key
Embedding into image
Distribution of image
Embedding into image
Selection of image
Examination/extraction of image
Identification of distribution channel