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[Continued on next page]

(54) **Title:** METHOD AND SYSTEM FOR DETERRENCE OF UNAUTHORISED REUSE OF DISPLAY CONTENT
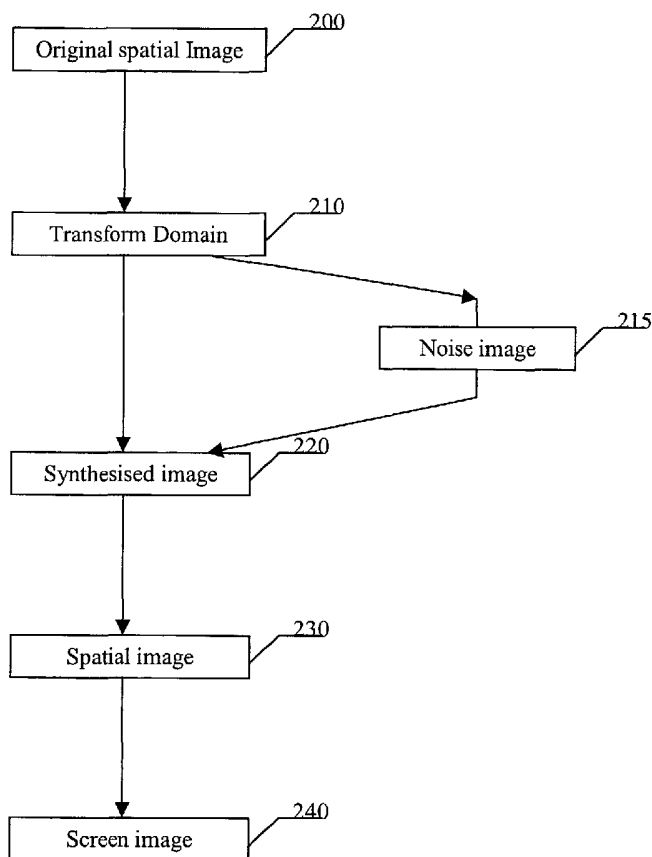
(57) **Abstract:** A system for generating a plurality of noise-deteriorated images from an image displayable on a computer display for deterring unauthorized reuse of the image is disclosed. The system relates to transforming an image displayable on a computer display into a plurality of frequency components, and generating a noise sequence for each frequency component in the plurality of frequency components, each noise sequence having a plurality of noise numbers. The system also relates to selecting, in relation to a first noise-deteriorated image, a first noise number from each noise sequence, and deteriorating each frequency component in the plurality of frequency components using the first noise number from each noise sequence corresponding to each frequency component in the plurality of frequency components to form a noise deteriorated frequency component in a first plurality of noise-deteriorated frequency components. The system further relates to transforming the first plurality of noisedeteriorated frequency components into the first noise-deteriorated image for displaying on the computer display.

METHOD AND SYSTEM FOR DETERRENCE OF UNAUTHORISED
REUSE OF DISPLAY CONTENT

Field of the invention

5   The invention relates generally to the field of content display. In particular, it relates to the deterrence of unauthorised reuse of display content for display on computer screens.

Background

10   With the rapid growth of the Internet, more and more images are accessible to Internet users. However, not all providers of images on the Internet are willing to permit users to keep the images provided and displayed on screens, much less allow the users to distribute the images at will. Present network protocols such as the HyperText Transfer Protocol (HTTP) do not address the issue of protecting images or other
15   display content such as text downloaded from websites or other remote resources. As a result, any user who has access to a website is able to save and reuse display content downloaded from that website. This is because a number of World Wide Web (WWW) browsers provide a save function allowing users to save a web page and a composer feature which the users can use to edit the saved display content. A user can
20   also type a Print Screen key typically found on the keyboard of a computer to perform screen dumps or capture snapshots of a series of images stored in the video buffer of the computer by duplicating the video buffer. Using programs that enable the user to create, view, and edit images, the user can then easily obtain the images by retrieving these snapshots.

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It is hence difficult to prevent unauthorised reuse of display content downloaded from or provided via a remote resource. A diligent pirate can reuse both text and images by re-typing the text and performing screen dumps of the images shown on the screen. It is therefore desirable to deter unauthorised reuse of display content by either forcing a
30   pirate to spend significant amounts of money and time to obtain display content, or degrading the quality of reused screen content. To this end, a number of patents and conventional technologies have been proposed which are described hereinafter.

In US Patent No. 5,905,505, a method and a system for copy protection of on-screen display of text are disclosed, in which embodiments described therein prevent screen dumps of text displayed on computer screens by first having the text transformed into a textual image. In a first embodiment, two random background images are generated and added to the textual image to produce two composite images. The two composite images are then alternately displayed on a screen to simulate the on-screen rendering of the textual image. In a second embodiment, the textual image is modified to produce two random bitmapped images. The two random bitmapped images are then alternately displayed for simulating the on-screen rendering of the textual image. Although in both cases the textual image is irretrievable by performing screen dumps, because only one of the pair of composite or random bitmapped images can be captured as a snapshot each instant, a user acquires a visual perception resembling the textual image by averaging each pair of composite or random bitmapped images as these are alternately displayed on the screen. However, the embodiments work adequately only for high contrast images such as textual images but not for display content with low contrast such as pictures.

In US Patent No. 6,209,103, a method and an apparatus for preventing reuse of text, images and software transmitted via networks are disclosed, which involve the transformation of textual information into images. In one embodiment, text is transformed into a textual image. In a further embodiment, an image is divided into multiple sub-images with each sub-image being a component of the image or an interference pattern is incorporated into different locations of the image to form multiple interference images with each interference image having a pattern at a unique location. An applet then displays these multiple images in succession over intervals. With these multiple images a user can only acquire a visual perception which resembles the original image but cannot obtain such an image from capturing snapshot of the video buffer once. Unfortunately, a pirate can still recover the image by capturing the video buffer several times to obtain all of the multiple images by trial. Generally, the number of attempts the pirate need to make to capture all of the multiple images is small because the number of sub-images is restricted by the screen's display refresh rate, which is usually less than 100Hz.

In US Patent No. 5,881,287, a method and an apparatus for copy protection of images in a computer system are disclosed which prevent unlicensed transfers of image data from a video adapter to other storage means. This is done by the interception of data transfer requests made to an operating system and identifying whether an image requested is one to be protected. If the image requested is one that is marked for protection, any data transfer incorporating the protected image is obscured, blacked out or replaced with another specified pattern or message. However, such a protection system can be easily bypassed. A pirate can load a hook program which intercepts the request before the protection system intercepts the request. For instance, when a user types the Print-Screen key on a computer keyboard, a hook program can intercept the Print-Screen request and copies the video buffer into another storage medium before the protection system can black out the snapshot.

In US Patent No. 6,208,735, a secure spread spectrum watermarking method for multimedia data is disclosed, which uses digital watermark technology to embed a watermark representing copyright into protected content so as to indicate ownership of the protected content. To remove the watermark, a pirate has to degrade the quality of the protected content. However, this method cannot prevent unauthorised reuse of the protected content.

In Microsoft's windows operating systems, an application program interface (API) such as the *sethook()* function is typically provided for intercepting a computer keyboard event. When a user types the Print-Screen key on a computer keyboard of a computer, the keyboard event can be intercepted by a hook application based on the *sethook()* function, which would prevent the default process of copying the content of the computer's video buffer onto a clipboard thus preventing reuse of information stored in the video buffer. The disadvantage of doing this is that the API *sethook()* function is a standalone application which has to be executed with a local user priority. This protection system is therefore not applicable to mobile codes such as Java applets.

There is therefore a need for a display content reuse deterrence system for addressing the foregoing problems.

Summary

An image is shown on a computer screen in the spatial domain. The human visual perception system, however, is sensitive to the frequency domain. To involve visual perception by the human visual perception system in the deterrence of reuse of display content, a system is disclosed in which an image is transformed into the frequency domain with corresponding frequency components. For every frequency component, a random number sequence is generated and a variant of the random number sequence is generated based on the value of the frequency component. The arithmetic mean value of any predefined length of segment of the random number sequence preferably tends to 0. A number is selected from every random number sequence and a noise image formed using the value of this number. The image in the frequency domain is combined with the noise image to generate a synthesised image known as a noise-deteriorated image, which is then transformed back to the spatial domain. From every random number sequence, multiple numbers are selected to generate multiple synthesised images for forming an image sequence. The image sequence is then displayed on the computer screen.

In such a system, an input such as an original image X, is processed into an output which consists of a sequence of noise-deteriorated images $\tilde{X}_k$ for rendering on the computer screen.

During preparation, the system transforms X into m components $f_1, f_2, \cdots, f_m$ in the frequency domain F. The system then generates a noise number sequence $r_i = \{ r_{i1}, r_{i2}, \cdots \}$ for each component f_i. $i=1,2, \cdots, m$ before generating the noise-deteriorated images. Alternatively, each number in the noise number sequences can be generated while generating the corresponding noise-deteriorated image.

To generate the noise-deteriorated images, the system performs the following operations:

for $k=1,2, \cdots$

 for $i=1,2, \cdots, m$

  $\tilde{f}_{ik} = f_i + r_{ik}$

5

                        end

                        where the kth noise-deteriorated image $\widetilde{F}_k$ in frequency domain

                has m components $\widetilde{f}_{ik}$. i=1,2, $\cdots$, m;

                inverse-transform $\widetilde{F}_k$ into $\widetilde{X}_k$; and

        render $\widetilde{X}_k$ to the computer screen

        end.

In accordance with a first aspect of the invention, a method for generating a plurality
of noise-deteriorated images from an image displayable on a computer display for
deterring unauthorised reuse of the image is disclosed, in which the method
comprising the steps of:

        transforming an image displayable on a computer display into a plurality of
frequency components;

        generating a noise sequence for each frequency component in the plurality of
frequency components, each noise sequence having a plurality of noise numbers;

        selecting, in relation to a first noise-deteriorated image, a first noise number
from each noise sequence;

        deteriorating each frequency component in the plurality of frequency
components using the first noise number from each noise sequence corresponding to
each frequency component in the plurality of frequency components to form a noise-
deteriorated frequency component in a first plurality of noise-deteriorated frequency
components; and

        transforming the first plurality of noise-deteriorated frequency components
into the first noise deteriorated image for displaying on the computer display.

In accordance with a second aspect of the invention, a system for generating a
plurality of noise-deteriorated images from an image displayable on a computer
display for deterring unauthorised reuse of the image, in which the system comprises:

        means for transforming an image displayable on a computer display into a
plurality of frequency components;

means for generating a noise sequence for each frequency component in the plurality of frequency components, each noise sequence having a plurality of noise numbers;

means for selecting, in relation to a first noise-deteriorated image, a first noise number from each noise sequence;

means for deteriorating each frequency component in the plurality of frequency components using the first noise number from each noise sequence corresponding to each frequency component in the plurality of frequency components to form a noise-deteriorated frequency component in a first plurality of noise-deteriorated frequency components; and

means for transforming the first plurality of noise-deteriorated frequency components into the first noise deteriorated image for displaying on the computer display.

Brief Description of Drawings

Embodiments of the invention are described hereinafter in detail with reference to the drawings, in which:

Fig. 1 is block diagram of a computer system for displaying an image according to an embodiment of the invention;

Fig. 2 is a flowchart of an image transformation process according to the embodiment of Fig. 1;

Fig. 3 is a flowchart of a process for the generation of interference images according to the embodiment of Fig. 1; and

Fig. 4 is a block diagram of the image transformation and interference image generation processes of Figs. 2 and 3 for processing a two-by-two (2×2) pixels image for display.

Detailed Description

Embodiments of the invention are disclosed hereinafter for addressing the need for a display content reuse deterrence system.

5   In the field of vision sciences, the Talbot-Plateau Law states that the brightness of intermittent light is equal to the brightness of steady light with the same time-averaged luminance. For the Talbot-Plateau Law to apply, the intermittent light must illuminate at a rate beyond the Critical Flicker Frequency (CFF), which is the frequency at which flicker induced by intermittent illumination disappears. The

10 Talbot-Plateau Law holds because when the human eye is presented with images changing at a rate above 24 frames per second, the human eye averages the images to visually perceive an averaged representation of the images rather than perceive the images separately.

15 The embodiments described hereinafter aim to prevent reuse of display content while providing good visual perception quality. Measurements of vision perception quality vary because of different criteria for vision perceptual. The embodiments primarily focus on the criterion of screen flicker.

20 Assume X is the original image, and X_k is an image at a kth frame shown on the screen in a sequence of T images which can be copied from a video buffer of a computer on which X is displayed by performing a screen dump. Generally, any display content reuse deterrence system should satisfy the following requirements:

(1) Reduce to a minimum the arithmetic mean value of the difference $X_k - X$, i.e.

25 $$\frac{1}{T} \sum_{k=k_0}^{k_0+T} X_k - X \text{ tends to zero;}$$

(2) At any frame k, the difference $X_k - X$ should be at a maximum

(3) If the screen display refresh rate is fast enough, the difference $X_k - X$ should be global, i.e., distributed throughout the images.

30 The first requirement aims to reduce screen flicker to a minimum so as to display an image of high quality to authorised users. The other requirements aim to introduce interference into the video buffer so that any screen dump cannot result in a high

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quality image. The first requirement appears to contradict the others and a trade-off is therefore necessary for a display content reuse deterrence system to perform adequately.

5   To meet all three requirements by the embodiments, a series of interference or noise images is added to the original image to generate a sequence of degraded or noise-deteriorated images which are rendered in succession and repeatedly in place of the original image. Although the noise-deteriorated images are displayed, an authorised user can visually perceive the original image with high quality.

10

All the pixels in an image are affected when the image is modified in the frequency domain. Applying interference to an image in the frequency domain can therefore satisfy the third requirement.

15   There are two types of frequency components in an image, namely high and low frequency components. The high frequency components represent sharp or abrupt changes in the image while the low frequency components represent smooth or slow changes such as those found in a uniform region in the image. To meet the second requirement, high amplitude noise can be added to the high frequency components of

20   the image to increase interference or noise in the image.

The embodiments are described in detail hereinafter with reference to Figs. 1 to 4. In Fig. 1, a computer system in which embodiments may be implemented is shown. The computer system comprises of a Central Process Unit (CPU) 100, a keyboard 110

25   with a key for activating screen dump, a video card 130 having a video buffer and a corresponding computer screen monitor 120, a storage unit 140 to store the program and data. Optionally, a network interface 150 is used to access to a network 160 to which the computer system is connected.

30   Fig. 2 is a flowchart of an image transformation process according to an embodiment of the invention, whereby in a step 200, an original image is introduced into a reuse deterrence system consisting of the computer system shown in Fig. 1 and an appropriate reuse deterrence software application. In this process, the original image is to be transformed into a series of synthesised or noise-deteriorated images which

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when displayed in succession give an authorised viewer a visual perception of the original image. The original image is first transformed into a series of frequency components in the frequency domain by a transformation process, such as Fast Fourier Transformation (FFT) or Discrete Cosine Transformation (DCT), in a step 210. All frequency components are denoted as f_i. For purposes of illustration, it is assumed that there are m frequency components where $i = 1, 2, \cdots, m$.

Corresponding to each frequency component f_i, a random number sequence $r_i = \{r_{ij},$ where $j = 1, 2, \cdots \}$ is generated. In order to generate a kth synthesised image as display content for the kth display frame on the monitor 120 in a sequence of synthesised images, a corresponding k^{th} interference or noise image is generated by using r_{ik} ($i = 1, 2, \cdots, m$) in a step 215. Alternatively, a random number resource may be used in this step 215 to generate the kth interference image. Thus the kth synthesised image can then be generated by $f_i + r_{ik}$, where $i = 1, 2, \cdots, m$, in a step 220.

In a step 230, the kth synthesised image is transformed back to the spatial domain by reverse transformation. In a step 240, the spatial domain image of the kth synthesised image is provided as output to the monitor 160 for display as the kth display frame in the sequence of display frames.

In order to obtain a stable and flicker free image and prevent unauthorised reuse of the original image, the foregoing steps are preferably iterated indefinitely. Additionally, the random number sequence for each frequency component is preferably generated with the arithmetic mean value of each segment of the random number sequence of predefined length T tending to zero. This is because the predefined length T of each segment of the random number sequence for each frequency component is related to the noise amplitude, the frequency and perception tolerance of flicker. However, the smaller T is, the better the quality of the visual perception of the original image.

There are a number of ways to generate the interference images. Fig. 3 is a flowchart of an exemplifying process for the generation of the interference images. After receiving the original image in a step 300, a hash value v representing the original

image is calculated in a step 310. The hash value is a pseudo-random resource and can be obtained using SHA or MD5 hashing.

In a step 320, a uniform-distribution random number sequence within interval (-1.0, 1.0) is generated from the seed of the hash value v by using a random function such as $rand(\ )$. In a step 330, for each ith frequency component a new hash value $h(v|i)$ is calculated, this new hash value marking the start position of a new random number sequence for the ith frequency component, where $h(\ )$ is a hash function.

In a step 340, based on the amplitude of the ith frequency component and properties of the human visual perception system, the amplitude of the new random number sequence for the ith frequency component is adjusted to a suitable level. In a step 350, all noise components for the frequency components relating to the kth display frame are combined, forming the kth noise image in the frequency domain.

The foregoing processes are more clearly described using an example shown in Fig. 4, which is a block diagram of the foregoing processes for processing a two-by-two (2×2) pixels image 410 for display on the monitor 160.

Given the 2 × 2 pixels original image 410, a noise number sequence is generated as follows:

$$\{R\}=\{R_1, R_2, R_3, R_4, R_5, R_6, \cdots\}, \text{ where } \sum_{i=k}^{k+T} R_i = 0.$$

The noise number sequence is then truncated into sub-sequences 420 and adjusted to appropriate amplitudes using a parameter $\{\alpha_i\}$. Each of the sub-sequences 420 also tends to zero if it is of sufficient length. These sub-sequences 420 are denoted as $\{r_1\}$, $\{r_2\}$, $\{r_3\}$ and $\{r_4\}$,

$$\{r_1\}= \alpha_1\{R_1, R_2, R_3, R_4, R_5, \cdots\}= \{\ r_{11}, r_{12}, r_{13}, r_{14}, r_{15}, r_{16}, \cdots\ \}$$

$$\{r_2\}= \alpha_2\{R_2, R_3, R_4, R_5, R_6, \cdots\} = \{\ r_{21}, r_{22}, r_{23}, r_{24}, r_{25}, r_{26}, \cdots\ \}$$

$$\{r_3\}= \alpha_3\{R_3, R_4, R_5, R_6, R_7, \cdots\} = \{\ r_{31}, r_{32}, r_{33}, r_{34}, r_{35}, r_{36}, \cdots\ \}$$

$$\{r_4\} = \alpha_4\{R_4, R_5, R_6, R_7, R_8, \cdots\} = \{r_{41}, r_{42}, r_{43}, r_{44}, r_{45}, r_{46}, \cdots\}$$

For purposes of illustration, it is assumed that the 5th (*i.e.*, $k=5$) frame is to be rendered. A noise image 430 is created with elements from the sub-sequences 420 corresponding to the kth display frame. The noise image 430 is added to the original image in the frequency domain 440 to form the kth synthesised 450 image which is then transformed into the spatial domain. The kth synthesised image in the spatial domain 460 can then be rendered on the monitor 160 during the kth display frame.

In the foregoing manner, a display content reuse deterrence system is disclosed. Although only a number of embodiments are described, it will be apparent to one skilled in the art in view of this disclosure that numerous changes and/or modifications can be made to such a system without departing from the scope and spirit of the invention.

In this system, an input such as an original image X, is processed into an output which consists of a sequence of noise-deteriorated images $\tilde{X}_k$ for rendering on the computer screen.

During preparation, the system transforms X into m components $f_1, f_2, \cdots, f_m$ in the frequency domain F. The system then generates a noise number sequence $r_i = \{r_{i1}, r_{i2}, \cdots\}$ for each component f_i. $i=1, 2, \cdots, m$ before generating the noise-deteriorated images. Alternatively, each number in the noise number sequences can be generated while generating the corresponding noise-deteriorated image.

To generate the noise-deteriorated images, the system then performs the following operations:

for $k=1, 2, \cdots$

    for $i=1, 2, \cdots, m$

        $\tilde{f}_{ik} = f_i + r_{ik}$

    end

where the kth noise-deteriorated image $\widetilde{F}_k$ in frequency domain

has m components $\widetilde{f}_{ik}$. $i=1,2,\cdots,m$;

inverse-transform $\widetilde{F}_k$ into $\widetilde{X}_k$; and

render $\widetilde{X}_k$ to the computer screen

5   end.

Claims

1. A method for generating a plurality of noise-deteriorated images from an image displayable on a computer display for deterring unauthorised reuse of the image, the method comprising the steps of:

   transforming an image displayable on a computer display into a plurality of frequency components;

   generating a noise sequence for each frequency component in the plurality of frequency components, each noise sequence having a plurality of noise numbers;

   selecting, in relation to a first noise-deteriorated image, a first noise number from each noise sequence;

   deteriorating each frequency component in the plurality of frequency components using the first noise number from each noise sequence corresponding to each frequency component in the plurality of frequency components to form a noise-deteriorated frequency component in a first plurality of noise-deteriorated frequency components; and

   transforming the first plurality of noise-deteriorated frequency components into the first noise deteriorated image for displaying on the computer display.

2. The method as in claim 1, further comprising the steps of:

   selecting, in relation to a second noise-deteriorated image, a second noise number from each noise sequence;

   deteriorating each frequency component in the plurality of frequency components using the second noise number from each noise sequence corresponding to each frequency component in the plurality of frequency components to form a noise-deteriorated frequency component in a second plurality of noise-deteriorated frequency components; and

   transforming the second plurality of noise-deteriorated frequency components into the second noise deteriorated image for displaying on the computer display.

3. The method as in claim 2, further comprising the step of displaying consecutively the first and second noise-deteriorated images.

4. The method as in claim 3, wherein the step of displaying consecutively the first and second noise-deteriorated images comprises the step of repeating the consecutive display of the first and second noise-deteriorated images.

5. The method as in claim 4, wherein the step of displaying consecutively the first and second noise-deteriorated images further comprises the step of displaying consecutively the first and second noise-deteriorated images in accordance with the display refresh rate of the computer display.

6. The method as in claim 1, wherein the step of generating the noise sequence for each frequency component in the plurality of frequency components comprises the step of generating the noise sequence with a plurality of segments for each frequency component in the plurality of frequency components wherein the arithmetic mean value of each of the plurality of segments tends to zero.

7. The method as in claim 1, wherein the step of transforming the image comprises the step of performing Fast-Fourier Transformation on the image.

8. The method as in claim 7, wherein the steps of transforming the first and second pluralities of noise-deteriorated frequency components comprise the steps of performing Inverse Fast-Fourier Transformation on the first and second pluralities of noise-deteriorated frequency components.

9. The method as in claim 1, further comprising the step of generating a first noise sequence having a first plurality of noise numbers prior to the step of generating the noise sequence for each frequency component in the plurality of frequency component.

10. The method as in claim 9, wherein the step of generating the noise sequence for each frequency component in the plurality of frequency components comprises the step of truncating and modifying the amplitude of the first noise sequence having the first plurality of noise numbers to generate the noise sequence for each frequency component in the plurality of frequency components.

11. A system for generating a plurality of noise-deteriorated images from an image displayable on a computer display for deterring unauthorised reuse of the image, comprising:

means for transforming an image displayable on a computer display into a plurality of frequency components;

means for generating a noise sequence for each frequency component in the plurality of frequency components, each noise sequence having a plurality of noise numbers;

means for selecting, in relation to a first noise-deteriorated image, a first noise number from each noise sequence;

means for deteriorating each frequency component in the plurality of frequency components using the first noise number from each noise sequence corresponding to each frequency component in the plurality of frequency components to form a noise-deteriorated frequency component in a first plurality of noise-deteriorated frequency components; and

means for transforming the first plurality of noise-deteriorated frequency components into the first noise deteriorated image for displaying on the computer display.

12. The system as in claim 11, further comprising:

means for selecting, in relation to a second noise-deteriorated image, a second noise number from each noise sequence;

means for deteriorating each frequency component in the plurality of frequency components using the second noise number from each noise sequence corresponding to each frequency component in the plurality of frequency components to form a noise-deteriorated frequency component in a second plurality of noise-deteriorated frequency components; and

means for transforming the second plurality of noise-deteriorated frequency components into the second noise deteriorated image for displaying on the computer display.

13. The system as in claim 12, further comprising means for displaying consecutively the first and second noise-deteriorated images.

5   14. The system as in claim 13, wherein the means for displaying consecutively the first and second noise-deteriorated images comprises means for repeating the consecutive display of the first and second noise-deteriorated images.

15. The system as in claim 14, wherein the means for displaying consecutively the
10   first and second noise-deteriorated images further comprises means for displaying consecutively the first and second noise-deteriorated images in accordance with the display refresh rate of the computer display.

16. The system as in claim 11, wherein the means for generating the noise sequence
15   for each frequency component in the plurality of frequency components comprises means for generating the noise sequence with a plurality of segments for each frequency component in the plurality of frequency components wherein the arithmetic mean value of each of the plurality of segments tends to zero.

20   17. The system as in claim 11, wherein the means for transforming the image comprises means for performing Fast-Fourier Transformation on the image.

18. The system as in claim 17, wherein the means for transforming the first and second pluralities of noise-deteriorated frequency components comprise means for
25   performing Inverse Fast-Fourier Transformation on the first and second pluralities of noise-deteriorated frequency components.

19. The system as in claim 11, further comprising means for generating a first noise sequence having a first plurality of noise numbers prior to the generation of the
30   noise sequence for each frequency component in the plurality of frequency component.

20. The method as in claim 19, wherein the means for generating the noise sequence for each frequency component in the plurality of frequency components comprises means for truncating and modifying the amplitude of the first noise sequence having the first plurality of noise numbers to generate the noise sequence for each frequency component in the plurality of frequency components.
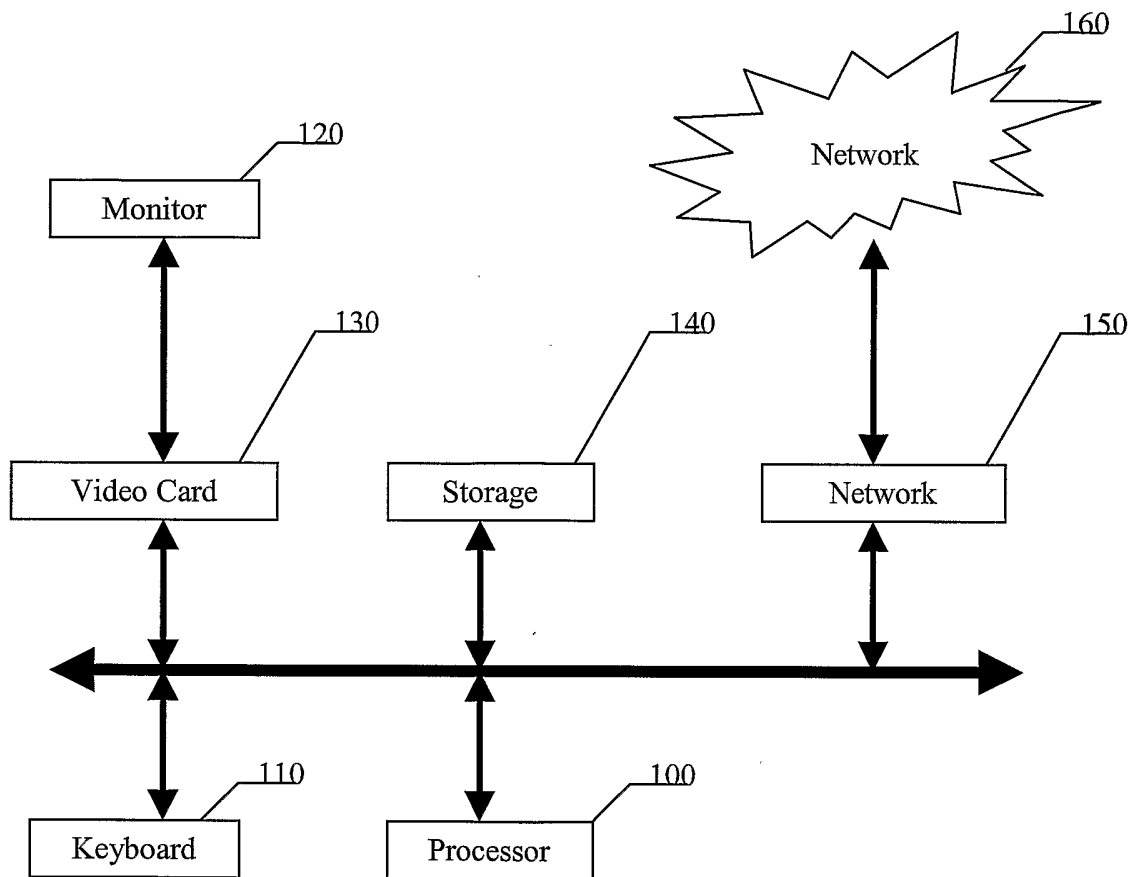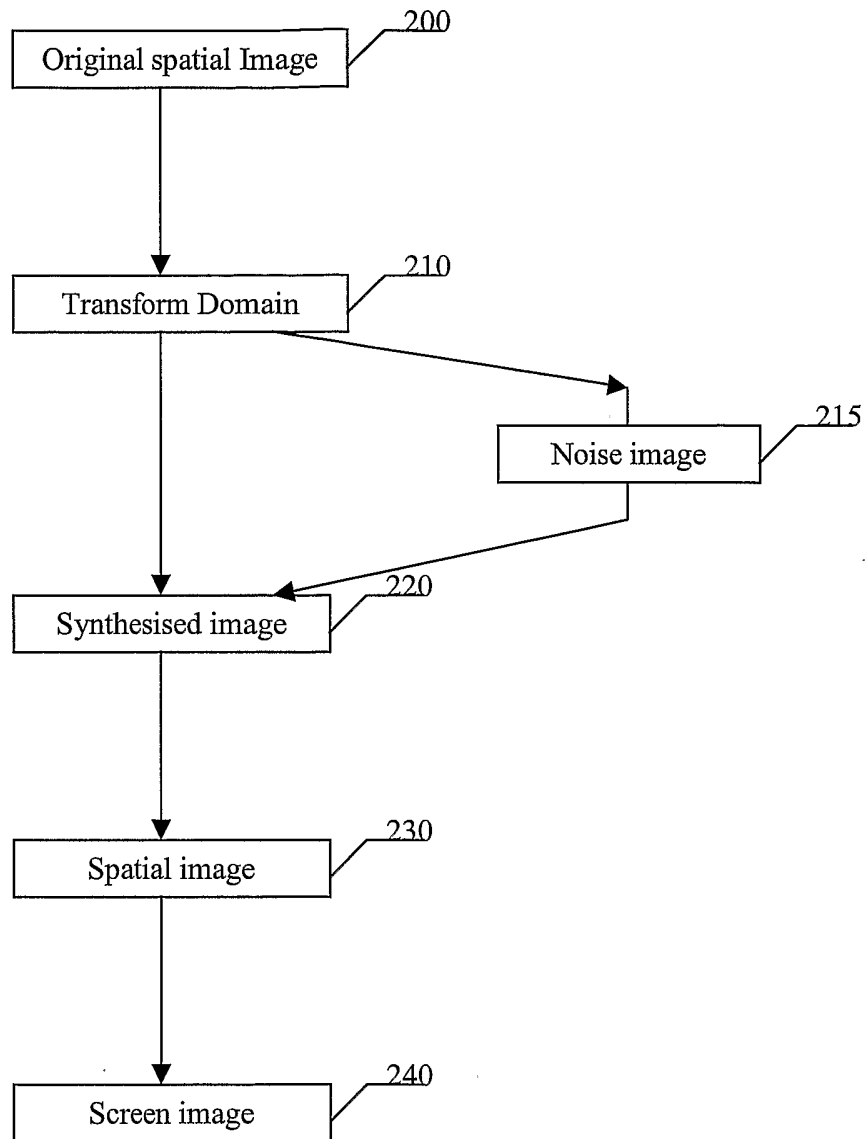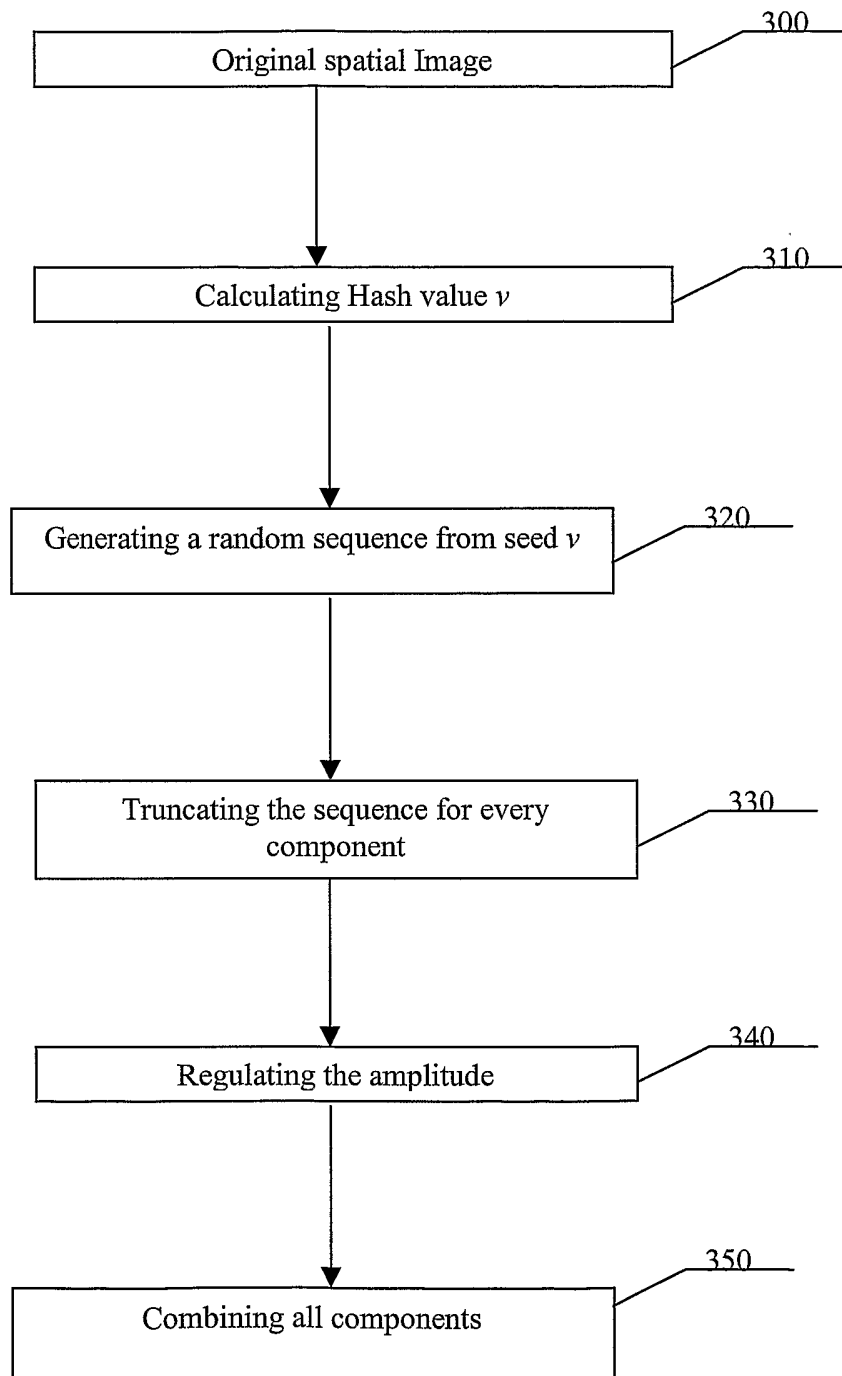
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                                                     ___160
         ___120                         _____
   _____                         /  Network  \
   |  Monitor  |                        _____/
   |_____|                              ↕
        ↕
   ___130          ___140          ___150
   _____     _____     _____
   | Video Card|   |  Storage  |   |  Network  |
   |_____|   |_____|   |_____|
        ↕               ↕               ↕
   ←————————————————————————————————————————————→
        ↕               ↕
   ___110          ___100
   _____     _____
   | Keyboard  |   | Processor |
   |_____|   |_____|
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Figure 1

Figure 2

Figure 3

Figure 4