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(54) **COPY PROTECTION VIA REDUNDANT WATERMARK ENCODING**

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G06K 9/00 (2006.01)

(52) **U.S. Cl.** **382/100**

(58) **Field of Classification Search** ..... None
See application file for complete search history.

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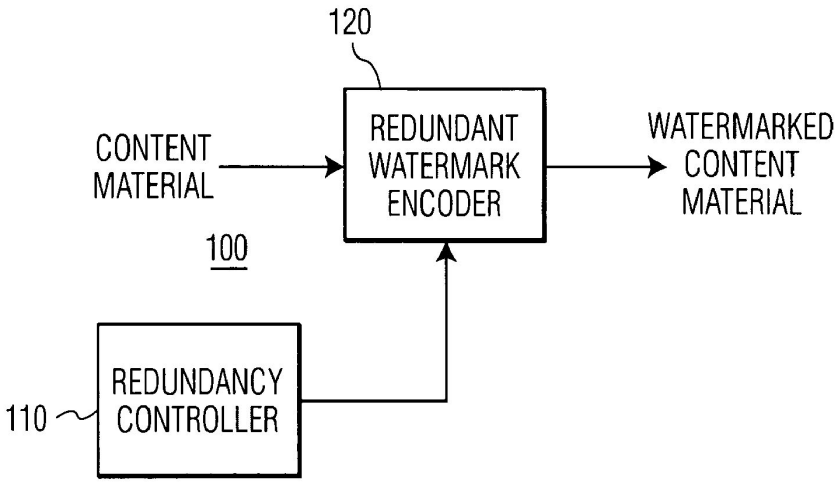
(57) **ABSTRACT**

A watermark is encoded redundantly so as to provide effective copy protection. To assure a reliable detection of the watermark in the presence of a potentially faulty watermark detection process, some or all of the watermark is redundantly encoded. The number of redundant encodings of the watermark is selected so that upon modification of the watermarked material, sufficient redundancy exists so that the material can be identified as watermarked material, and the number of detected copies of the watermark is used to detect the modification. Statistical processes are employed to determine the presence or absence of the watermarks in the presence of a potentially faulty watermark detection process. Different criteria may be applied to the watermark detection process for the verification of the watermarked portions, based on the desired degree of confidence for determining whether the appropriate watermark is present or absent, and the desired degree of confidence for determining whether a modification has occurred.

14 Claims, 2 Drawing Sheets



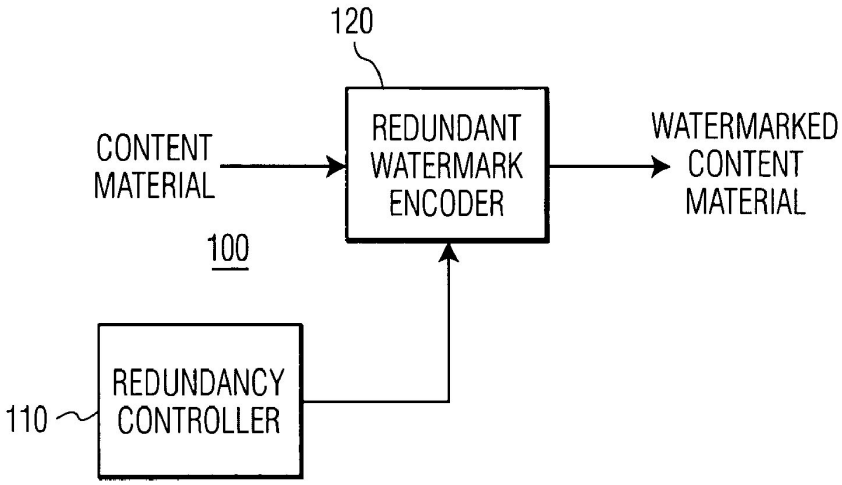


FIG. 1

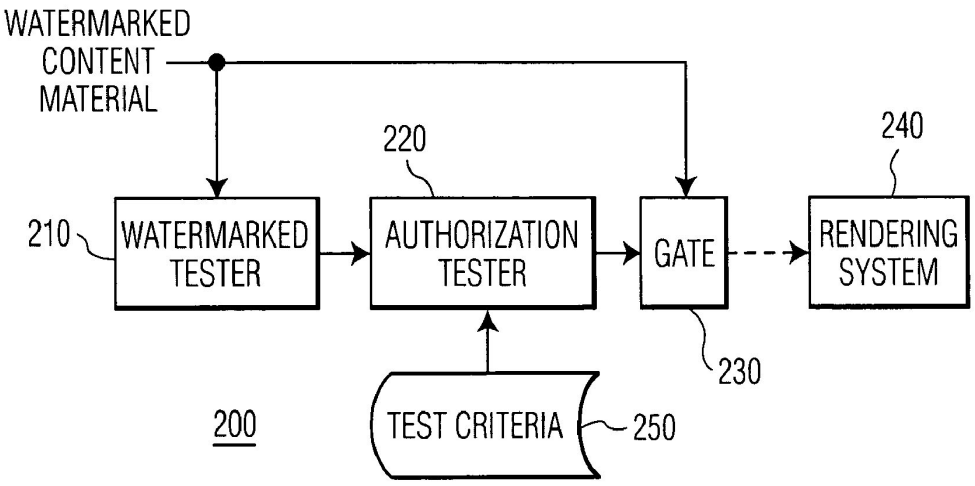


FIG. 2

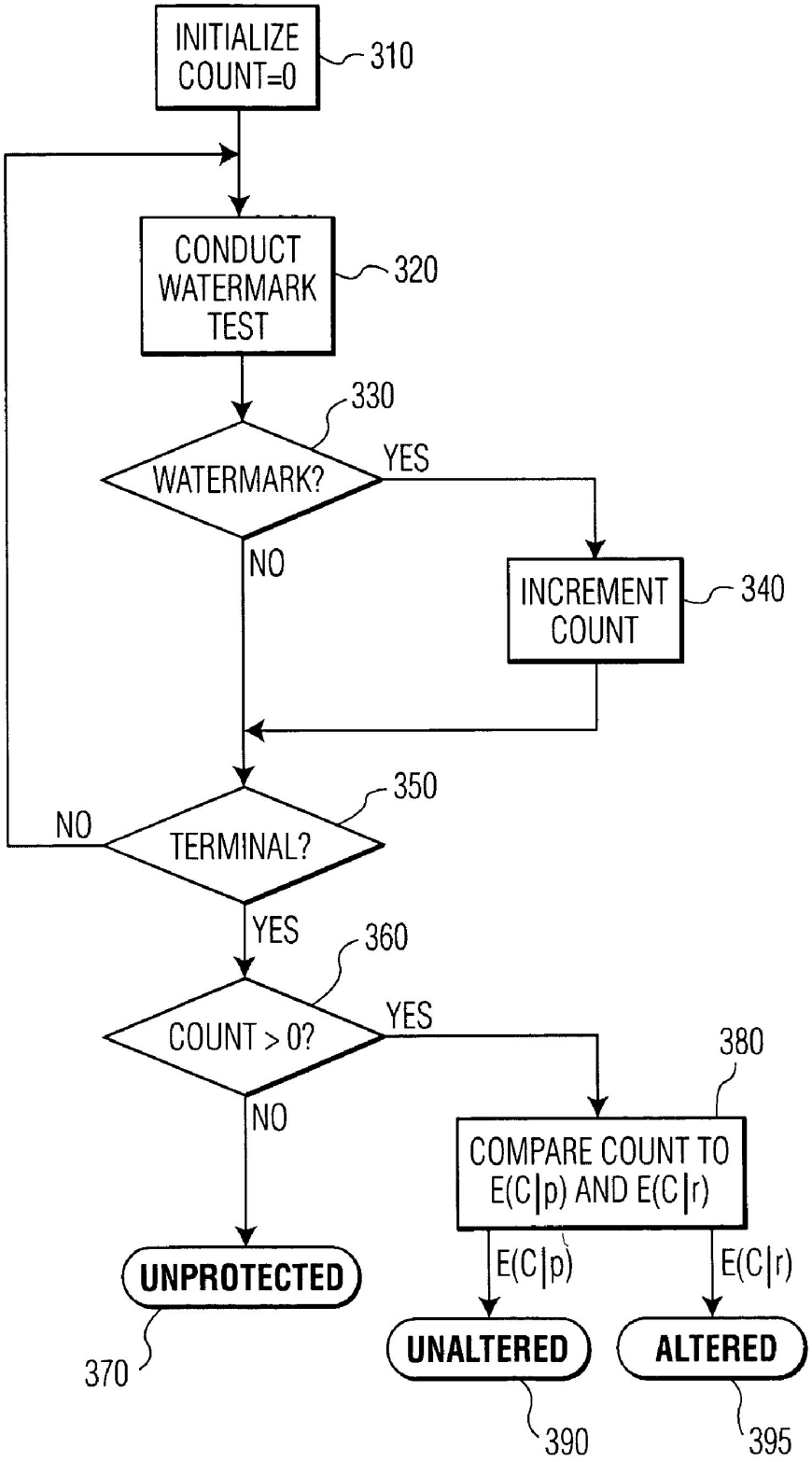


FIG. 3

COPY PROTECTION VIA REDUNDANT WATERMARK ENCODING

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the field of data protection, and in particular to protecting data from illicit copying from a remote source.

2. Description of Related Art

The protection of data is becoming an increasingly important area of security. In many situations, the authority to copy or otherwise process information is verified by evaluating the encoding of copy-protected material for particular characteristics. For example, on copy-protected material may contain watermarks or other encodings that identify the material as being copy-protected, and also contains other encodings that identify whether this particular copy of the material is an authorized copy, and whether it can be copied again. For example, an authorized copy of content material may contain a robust watermark and a fragile watermark. The robust watermark is intended to be irremovable from the encoding of the content material. Attempting to remove the watermark causes damage to the content material. The fragile watermark is intended to be damaged when the content material is illicitly copied. For example, common fragile watermarks are damaged if the content material is compressed or otherwise altered. In this manner, content material that is compressed in order to be efficiently communicated via the Internet will be received with a robust watermark and a damaged fragile watermark. A content-processing device that is configured to enforce copy protection rights in this example will be configured to detect the presence of a robust watermark, and prevent the processing of the content material containing this robust watermark unless an appropriate fragile watermark is also present. The assumption being that compressed content represents an unauthorized transfer of copyrighted material.

The design of a watermarking encoding process and corresponding watermark detection involves a tradeoff among conflicting requirements. An ideal watermark should be undetectable during a conventional rendering of the content material, yet easily detectable by the watermark detector. As the watermark's detectability by the watermark detector increases, so too does its detectability during a conventional rendering; similarly, as the watermark's undetectability during a convention rendering decreases, so too does its undetectability by the watermark detector. Conventional watermarking processes are biased to assure that the watermarking process does not affect the quality of the rendering of the content material, often at the cost of reduced detectability by a watermark detector. That is, the likelihood of a watermark detector producing an erroneous decoding of a watermark, or failing to detect the watermark, is not insubstantial.

In the aforementioned use of both a robust watermark and a fragile watermark, each watermarking process must be designed within these conflicting tradeoff requirements, and each watermarking process must be configured to have a different susceptibility to damage. The robust watermark must be substantially undetectable by the conventional rendering process, yet also be robust enough to be recognizable after the watermarked material has been compressed and reformulated into a decompressed form. The fragile watermark must also be substantially undetectable by the con-

watermark. Additionally, each of the watermark processes must be configured so that they do not interfere with each other.

BRIEF SUMMARY OF THE INVENTION

It is an object of this invention to provide a robust and reliable copy protection scheme that accommodates a detection of a modification to the watermarked material, but does not require the use of multiple watermarking processes. It is a further object of this invention to provide a copy protection scheme that is fault tolerant.

These objects and others are achieved by the use of a watermark that has multiple degrees of redundancy. To assure a reliable detection of the watermark in the presence of a potentially faulty watermark detection process, some or all of the watermark is redundantly encoded. Whenever the watermarked material is modified, the quality of the watermark decreases, and the likelihood of each redundant copy of the watermark being detected by a watermark detector decreases. The number of redundant encodings of the watermark is selected so that upon modification of the watermarked material, sufficient redundancy exists so that the material can be identified as watermarked material, and the number of detected or undetected copies of the watermark is used to detect the modification. Statistical processes are employed to determine the presence or absence of the watermarks in the presence of a potentially faulty watermark detection process. Different criteria may be applied to the watermark detection process for the verification of the watermarked portions, based on the desired degree of confidence for determining whether the appropriate watermark is present or absent, and the desired degree of confidence for determining whether a modification has occurred.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is explained in further detail, and by way of example, with reference to the accompanying drawings wherein:

FIG. **1** illustrates an example block diagram of a watermark encoding system in accordance with this invention.

FIG. **2** illustrates an example block diagram of a copy protection system in accordance with this invention.

FIG. **3** illustrates an example flow diagram of an authorization test process in accordance with this invention.

Throughout the drawings, the same reference numerals indicate similar or corresponding features or functions.

DETAILED DESCRIPTION OF THE INVENTION

U.S. Pat. No. 6,252,972 "METHOD AND ARRANGEMENT FOR DETECTING A WATERMARK USING STATISTICAL CHARACTERISTICS OF THE INFORMATION SIGNAL IN WHICH THE WATERMARK IS EMBEDDED", issued Jun. 26, 2001 to Johan P. M. G. Linnartz, and incorporated by reference herein, teaches an encoding process wherein a particular binary pattern of +1 and −1 is added to each element of the content material. At the detector, the same binary pattern is applied to the received input signal to determine whether a sufficient correlation exists to decide that the received input contains this pattern. U.S. Pat. No. 6,208,735 "SECURE SPREAD SPECTRUM WATERMARKING FOR MULTIMEDIA

technique wherein a spread spectrum encoding of the watermark is applied to the content material, wherein the spread spectrum information is particularly targeted to the significant frequency components of the content material.

Because common watermark detection processes are not 100% reliable, a fault in the detection process may be interpreted by a security process as an erroneous watermark, and the rendering of the content material may be inappropriately terminated. That is, the content material may be authorized for rendering, and contain a proper watermark, but the fault in the detection process may indicate an improper watermark, or no watermark.

In accordance with this invention, the watermark is redundantly encoded such that the amount of redundancy determines the likelihood of the watermark being detected, assuming a potentially faulty watermarking detection process, and such that the number of proper detections of the watermark determines whether the material has been modified. In each of the above referenced encoding techniques, for example, the same pattern of +1 and −1 additions, or the same spread spectrum encoding is repeatedly applied to the content material.

During the detection process, the redundantly watermarked content material is scanned until a corresponding +1/−1 pattern, or a corresponding spread spectrum encoding is detected. Assuming that the watermark detection process is potentially faulty, the number of times that the same pattern is encoded will determine the likelihood of the watermark being detected. If, for example, the watermark is only singly encoded, the likelihood of the watermark being detected will be (1−p), where p is the inherent probability of the watermark detector not properly detecting the watermark. If the watermark is encoded twice, the likelihood of detection is $(1-p^2)$; if the watermark is encoded three times, the likelihood of detection is $(1-p^3)$; etc.

If the watermarked content material is altered, the quality of the watermark decreases, and the inherent probability of the watermark detector not properly detecting the watermark, using conventional watermark encoding and decoding techniques, increases. Defining this new inherent probability as q, the likelihood of a watermark detector not properly detecting a redundantly encoded watermark is expressed as $(1-q^n)$, where n is the number of encodings of the same watermark.

In accordance with this invention, the parameter n is selected to provide a very high likelihood of detection, regardless of whether the material is altered. In accordance with a second aspect of this invention, the detection process includes a statistical procedure that further provides a control over the likelihood of detecting altered watermarked content material, based on the probabilities of detection p and q, for unaltered and altered content material, respectively, discussed further below.

FIG. **1** illustrates an example block diagram of a watermark encoding system **100** in accordance with this invention. The encoding system **100** includes a redundancy controller **110** that controls a redundant watermark encoder **120**. As noted above, any of a variety of watermark encoding techniques may be included in the watermark encoder **120**, provided that the technique allows for a repetition of the watermark within the same content material. In accordance with this invention, the redundancy controller **110** controls the redundant watermark encoder **120** such that the likelihood of detecting at least one copy of the watermark is high, encoder **120** such that the number of properly detected watermarks can be used to distinguish between altered and unaltered content material.

FIG. **2** illustrates an example block diagram of a security system **200** that is configured to control the rendering of content material, based on the presence or absence of proper watermarks. The security system **200** includes a watermark tester **210** that is configured to detect a watermark and an authorization tester **220** that is configured to control the rendering of the content material, via rendering system **240**, based on the output of the watermark tester **210**, and based on a set of test criteria **250**, via a gate **230**. For the purposes of this invention, the term rendering is intended to include any subsequent processing, recording, modification, or translation of the content material.

In accordance with this invention, the authorization tester **220** is configured to determine whether the content material is protected, based on whether any watermark is present in the content material. If the material is determined to be protected, the authorization tester **220** is further configured to determine whether the watermarked content material has been altered, based on a measure of the quality of a detected watermark.

Consider, for example, an illicit attempt to remove a watermark from the watermarked content material that reduces the likelihood of a watermark being detected from a nominal 95% (1−p) to as low as 10% (1−q), and an encoding and detection process that is configured to detect the presence of the watermark at least 99% of the time. Using the equations presented above, in order to assure a 99% detection rate with an increased non-detection rate of q, this equates to:

$$(1-q^n)<=0.01.$$

In this example, with q=0.90, the number of redundant encodings, n, must be at least 42. Thus, the redundancy controller **110** of FIG. **1** would be configured to control the redundant watermark encoder **120** to produce at least 42 redundant encodings of the watermark within the content material, and the authorization tester **220** of FIG. **2** would be configured to determine that the content material is protected if the watermark tester **210** detects at least one of these encodings. Because the watermark is redundantly encoded at least 42 times, at least one of these watermarks is likely to be detected, even if the likelihood of detecting each watermark is reduced to as low as 10%. Thus, the highly redundant encoding of the watermark allows for the detection of the watermark even after a purposeful attempt to substantially reduce the likelihood of the watermark being detected.

FIG. **3** illustrates an example flow diagram of an authorization test process in accordance with this invention. At **310**, a count of the number of detected watermarks is initialized to zero. At **320**, a watermark tester (**210** in FIG. **2**) determines whether a watermark is present in the content material. If a watermark is detected, at **330**, the count is incremented, at **340**. This process continues until terminated, at **350**, typically by reaching the end of the content material, or the end of a predetermined segment of the content material that is expected to contain the watermarks. Upon termination, at **360**, if no watermarks were detected, the content material is determined to be unprotected, at **370**.

In accordance with the second aspect of this invention, the authorization tester **220** is further configured to determine whether the content material has been altered, based upon

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