

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
25 November 2004 (25.11.2004)

PCT

(10) International Publication Number
WO 2004/102951 A2

(51) International Patent Classification⁷: **H04N 5/00**

(21) International Application Number:
PCT/IB2004/001591

(22) International Filing Date: 3 May 2004 (03.05.2004)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/471,451 16 May 2003 (16.05.2003) US

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI,

GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

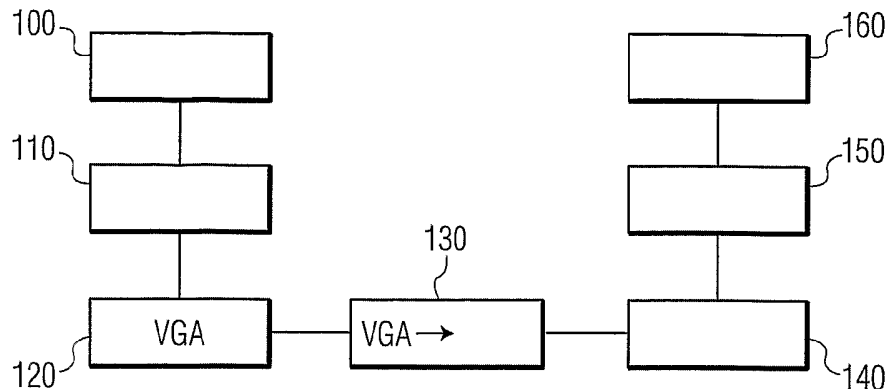
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)

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(54) Title: SYSTEM AND METHOD FOR DISCOURAGING COPYING BY RECURRING QUANTIZATION LOSS



(57) Abstract: The present invention alters a signal slightly after the decoding step so that the quantization loss is made recurring while not obvious to a human viewer of the decoded signal. The slightly altered signal, when re-encoded, is degraded enough to be annoying, without the measures being perceived in the first decoded signal. The present invention can be applied to a decoded digital signal if sufficient register space is available or to an analog signal after AD conversion.



— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*

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Published:

— *without international search report and to be republished upon receipt of that report*

SYSTEM AND METHOD FOR DISCOURAGING COPYING BY RECURRING QUANTIZATION LOSS

The present invention relates to a method and apparatus to prevent copying of a
5 video or audio signal by re-encoding the analog signal. More particularly, the present
invention is related to modifying the signal which results in cumulatively more obvious
recurring quantization loss in subsequent copies of the signal. Most particularly, the
present invention is a method and apparatus for modifying a de-coded signal such that
quantization loss is recurring and is not perceptible in the original decoding of the signal
10 but with each subsequent copy of the signal the quantization loss cumulatively degrades
the quality of the decoded signal so that the quality of the re-encoded signal is below an
acceptable level.

Many methods exist for preventing copying of digital video material. Direct digital-
to-digital copies are typically protected by using encryption and the Content Scrambling
15 System (CSS) for DVD. As long as the Digital Rights Management (DRM) system used is
not broken it effectively protects the content. Patented techniques include those directed to
preventing digital-to-analog copying by various methods that confuse the recorder, e.g.
sync manipulation (US Pat. No. 4,631,603 to Ryan, the entire contents of which are hereby
incorporated by reference) or color burst manipulation (US Pat. No. 5,883,959 to Kori, the
20 entire contents of which are hereby incorporated by reference). Generally this protection
works relatively well for copies to VHS, because the recording hardware cannot overcome
this manipulation scheme while TV sets can overcome it.

US Pat. No. 6,295,360 to Ryan et al., the entire contents of which are hereby
incorporated by reference, teaches a protecting against analog copying that does not work
25 well for VGA because many monitor types do not meet its requirements. Hence for PCs,
Ryan's protection cannot be implemented, allowing PC copying of the VGA signal. The
reduction in quality is relatively small if, for instance, a DVD is played on a PC and the
VGA signal is re-encoded to MPEG2 (see Philips National Laboratory Technical Note
427/99 issued March 2003, the entire contents of which are hereby incorporated by
30 reference). There are techniques that prevent re-encoding such as the protection provided

by watermarking techniques (see, e.g., US Pat. No. 6,314,518 to Linnartz, the entire contents of which are hereby incorporated by reference). However, on-the-fly embedding and detecting of watermarks is relatively expensive and it requires additional hardware. In addition, there is no standard for watermarking of digital video. Consequently, watermark
5 embedding and detection is not generally supported.

There are techniques to cope with this situation also (see, e.g., US Pat. No. 6,345,099 to Alvarez, the entire contents of which are hereby incorporated by reference). However these techniques rely on the co-operation of the analog display device and, therefore, do not work on legacy devices. Most existing display devices can be considered
10 to be legacy devices with regard to these techniques.

Another approach is taught by Nguyen in US Pat. No. 6,272,283, the entire contents of which are hereby incorporated by reference, wherein the content is only allowed to be sent to an analog-out if copy protection is enforced. US Pat. No. 6,137,952 to Hogan, the entire contents of which are hereby incorporated by reference, teaches an apparatus and
15 method for degrading the quality of unauthorized copies of color images and video sequences. Hogan teaches a method of altering the analog output signal by introducing perceptively balanced artifacts in luminance and chrominance components resulting in degradation of the quality of unauthorized copies. However, Hogan teaches introducing artifacts during analog filtering and conversion (digital to analog copying) but does not
20 teach preventing re-encoding and recompression (digital to digital via analog).

It is possible to copy video, e.g. DVD video, by re-encoding the analog signal, e.g. VGA, as illustrated in FIG. 1. The existing techniques to remedy this situation are not effective because they do not cover every possible copying scenario and/or are not generally supported. Copy protection measures are taken at the video output signal of a
25 PC's DVD ROM drives. These measures can easily be circumvented by using the VGA signal of the personal computer (PC) instead of the video signal of the DVD drive. Measures are needed in the PC that prevent re-encoding or degrade the quality of the re-encoded VGA signal below an acceptable level, and these measures must not only be directed to the digital version of the media content but must also encompass the analog
30 version of the media content.

The system and method of the present invention modulate and manipulate the actual video or audio content of an analog signal to degrade the quality of any re-encoded signal below an acceptable level. When analog video is encoded, the signal is sampled and a quantization step transforms the analog signal into discrete values that are compressed and stored digitally. When the digital signal is decoded the original analog signal is recreated as best as possible. But, the reproduction is not perfect because there are quantization and compression losses at the encoding side, i.e. the difference between the recreated analog value after decoding and the original analog value. This cannot be prevented because by nature the analog signal is continuous whereas the digital signal is discrete. Still, if the resulting analog signal is re-encoded the copy can be close to the original digital encoding with regard to picture quality. This is due to the fact that through a proper choice of re-encoding parameters, the quantization loss does not recur or is very limited.

In a preferred embodiment, the system and method of the present invention alter the analog signal slightly after the decoding step so that the quantization loss is made recurring. By striking the right balance between altering the decoded analog signal and approximating the original value, the re-encoded signal can be degraded enough to be annoying, without these measures being perceived by an observer of the first decoded analog signal. These measures can be applied to any parameter that is quantized, e.g. for video such measures comprise frame rate modulation, block shifting, color and luminance variations.

The effectiveness of the present invention does not rely on additional measures either on the recording side or on the display side. In addition, the cost of implementation is relatively small. It is a simple scheme that does not rely on the cooperation of any other part of an existing system, i.e., it does not require any changes to other parts of an existing system.

FIG. 1 illustrates copying a decoded video signal by re-encoding VGA.

FIG. 2 illustrates the location within a PC of an embodiment of the present invention that modifies the VGA to video signal derived from a decoded video signal output by the DVD-ROM of the PC.

FIG. 3 illustrates the location within a DVD video recorder (DVD-VR) of an embodiment of the present invention that modifies the VGA to video signal derived from a VGA signal of a decoded video signal output by the DVD-ROM of a PC.

FIG. 4 illustrates copying of a copy using two DVD-VRs that incorporate an
5 embodiment of the present invention.

FIG. 5 illustrates frame rate modulation of an output analog signal, according to an embodiment of the present invention.

FIG. 6 illustrates adding a noise frame to an output analog signal, according to an embodiment of the present invention.

FIG. 7 illustrates making a noise addition in the digital domain, according to an
10 embodiment of the present invention.

FIG. 8 illustrates sample re-encoding without measures where the frame rate of the re-encoded signal (b) is matched to the frame rate of the original (a).

FIG. 9 illustrates a re-encoding with frame rate modulation (b) of an original
15 signal (a).

FIG. 10 illustrates a re-encoding with luminance noise (b) added to the original signal (a).

The system and method of the present invention introduces recurring losses into a video stream by modulating the frame rate of the analog output of a video replay system.
20 The modulation employed by the present invention is low enough to allow the human brain correct for them, i.e. so they are not noticed by a human observer, while it is sufficient to cause discontinuities in the recorded signal.

FIGs. 2 and 3 illustrate copying hardware configurations which when modified to accomplish the method of the present invention are embodiments of the present invention
25 that degrade a copy of a VGA signal derived from a PC's DVD-ROM drive. In FIG. 2 the signal modification, according to a preferred embodiment, takes place in the PC at location 230 so that there is recurring quantization loss in the output VGA signal and when the VGA->video 210 signal is re-encoded 220 and copied there results a noticeable degradation in the quality of a reproduced signal. In FIG. 3 the signal modification,
30 according to a preferred embodiment, also takes place in the PC at location 340 such that the quantization loss is recurring in the VGA->video 310 signal and re-encoding 320 and

copying in the DVD-video recorder (DVD-VR) 330 results in a noticeable degradation in the quality of a reproduced signal. FIG. 4 illustrates copying of a copy using DVD-VRs 400 and 410. The present invention can be incorporated into the DVD-VRs as well.

As illustrated in FIG. 5, a digital source 510, e.g., a DVD-video file, is input to a decoder 520 that decodes the content and calculates raw frames that are converted 530 to an analog signal 540. In a preferred embodiment, some of the frames are delayed and some are output early. The result is a frame rate modulation 550 in the resulting analog output 560. In an alternative embodiment, at the same location in the process 550 the pitch of sound can be modulated.

As illustrated in FIG. 6, a digital source 610, e.g., a DVD-video file, is input to a decoder 620 that decodes the content and calculates raw frames that are converted 630 to an analog signal 640. In a preferred embodiment, a noise frame is generated 650 and superimposed 660 on the frame coming from the AD converter such that each output frame 670 has its own noise frame superimposed. In an alternative embodiment, the noise frame can consist of a below threshold luminance modulation.

As illustrated in FIG. 7, when the registers used for the storage of digital frames are large enough, the noise addition can take place in the digital domain, before the AD conversion 750 where values can be added below the quantization level 730. Each output frame 760 has noise superimposed.

The effects of the present invention when the frame rate of a video signal is modulated, are illustrated in FIGs. 8 and 9. In FIG. 8, the frame rate of the re-encoded signal 810 matches the frame rate of the original signal 800. In a preferred embodiment, illustrated in FIG. 9, the differences in timing are very slight and are not perceivable by the viewer. The cumulative effect of these slight differences is that the re-encoded signal gets out of sync 910 at a certain point of time with the original 900. At this point, the re-encoder needs the next frame before it is available and a frame is skipped. This frame skipping can be perceived by a viewer. Existing encoding methods choose the frame rate so that the scene changes are perceived as gradual. The frame rate modulation of the present invention does not affect that perception. However, the frame skipping does.

Certain display systems cannot display a signal that has modulated frame rates. To address this problem, an alternative preferred embodiment of the present invention

introduces recurring losses by adding random noise to the luminance level where the noise is below the human perception threshold. The result of adding this random noise is illustrated in FIG. 10. An optimal compression scheme uses quantization steps that approximate the human perception threshold 1000. If over half of the value of the quantization step is added, i.e. half of the human perception threshold, then a viewer will not notice the difference. If a copy of this signal is re-encoded the recurring quantization loss makes the difference perceptible 1010.

In another alternative embodiment, random noise is added to the chrominance signal and has a similar effect. However, the sensitivity of the human eye to color information is much less than the sensitivity to changes in luminance.

Another embodiment introduces recurring quantization losses by modulating the pitch of sound. As humans mature, most lose the ability of absolute hearing, meaning that they are no longer able to determine the absolute pitch of a sound but can perceive only the pitch of a sound in relation to the pitch of another sound. Slight changes to the pitch, e.g. 10% of the detection threshold, are not perceived. Cumulative slight changes till they reach 100% of the perception threshold are not perceived if the change is made gradually. Re-encoding will make the quantization loss recurring so that any change in pitch becomes perceptible. This is illustrated in Table 1.

	(a)	(b)	(c)	(d)	(e)	(f)
1	75.0	0.10	75.1	75.0	75.1	75.0
2	75.0	0.20	75.2	75.0	75.2	75.0
3	75.0	0.30	75.3	75.0	75.3	75.0
4	75.0	0.40	75.4	75.0	75.4	75.0
5	75.0	0.50	75.5	76.0	76.5	77.0
6	75.0	0.60	75.6	76.0	76.6	77.0
7	75.0	0.70	75.7	76.0	76.7	77.0
8	75.0	0.80	75.8	76.0	76.8	77.0
9	75.0	0.90	75.9	76.0	76.9	77.0
10	75.0	1.00	76.0	76.0	77.0	77.0

Table 1

Ten samples are listed in Table 1 having constant pitch (a) (assumed to vary from 0 to 100) the quantization step is 1 as is the perception threshold. Over time the pitch is changed by 10% of the threshold value compared to the previous sample (b). The resulting output has a gradually changing pitch (c), which is not noticed by a human observer. When this output is quantized upon re-encoding, at a certain point in time a sudden jump in pitch is observed. (from 75.0 to 76.0 (d)). If the process is repeated (copy from a copy (e)), the jump in pitch is amplified resulting in a change in pitch of twice the perception threshold (75.0 to 77.0 (f)). Repeated re-encoding, i.e., repeated copying of a copy, amplifies the effect.

In alternative embodiments, parameters that are quantized are modulated such that the actual modulation is not perceived but the effect after re-encoding is perceived. These embodiments modulate quantized parameters comprising time, color, luminance, pitch and position (pixel, block or picture shifting). The effect is further illustrated in Tables 2 and 3.

(a)	(b)	(c)	(d)	(e)	(f)
90.0629278445819	90.0	89.4313980987747	89.0	89.99786288	90.0
13.1726840675944	13.0	12.5926102903547	13.0	13.63147732	14.0
36.9200733106677	37.0	37.7581152182808	38.0	38.70949927	39.0
11.9555836852979	12.0	11.0356283704219	11.0	11.4244593	11.0
52.8042788803264	53.0	52.0598751550741	52.0	51.25829538	51.0

Table 2

In Table 2, analog values ranging from 0 to 100 (a) are quantized with a step of 1 (b). On the reproduced analog signal a random noise below the quantization step, i.e. perception threshold is superimposed (c). This makes the quantization loss recurring, amplifying the noise (d). This effect is repeated if the copy is copied (e), amplifying the effect (f).

(a)	(b)	(c)	(d)	(e)	(f)
71.3197914243845	71.0	71.5100000000000	72.0	72.5100000000000	73.0
47.9533842878958	48.0	47.4900000000000	47.0	46.4900000000000	46.0
77.2555565303215	77.0	77.5100000000000	78.0	78.5100000000000	79.0
36.9200733106677	37.0	36.4900000000000	36.0	35.4900000000000	35.0
62.7278837145204	63.0	63.5100000000000	64.0	64.5100000000000	65.0

Table 3

In Table 3 analog values ranging from 0 to 100 (a) are quantized with a step of 1 (b). On the reproduced analog signal a fixed modulation of half the quantization step, i.e. perception threshold, is superimposed (c). This makes the quantization loss recurring, amplifying the noise (d). This effect is repeated if the copy is copied (e), amplifying the effect again (f).

The foregoing description is a method along with an exemplary apparatus for modifying a video signal so that the original decoding contains artifacts that are not perceptible but that are increasingly perceptible in each subsequent copy. Many different forms of the apparatus are possible for practicing the method of this invention and all such variation which would occur to one of ordinary skill in the art are included within the true spirit and scope of the present invention, which is stated more particularly in the appended claims.

I claim:

1. A method of processing a decoded input signal, comprising the steps of:
analyzing the input signal;
selecting a type of signal modification based on the analysis of the input signal; and
altering the input signal with the selected type of signal modification such that
resulting quantization loss is recurring.
2. The method of claim 1, wherein:
the signal is an analog video signal; and
the type of signal modification is selected from the group consisting of frame rate
modulation, adding random noise to the luminance level, and adding random noise to the
chrominance level.
3. The method of claim 2, wherein the signal modification is below the human
perception threshold.
4. The method of claim 2 wherein the signal modification is between 50-100 percent
of the human perception threshold.
5. The method of claim 1, wherein:
the signal is an analog audio signal; and
the type of signal modification is changing a pitch of the audio signal.
6. The method of claim 5, wherein the signal modification is below the human
perception threshold.
7. The method of claim 6 wherein the signal modification is 10 percent of the human
perception threshold.
8. The method of claim 1, wherein:
the signal is a digital video signal; and

the type of signal modification is selected from the group consisting of adding random noise to the luminance level and adding random noise to the chrominance level.

9. The method of claim 8, wherein the signal modification is below the human perception threshold.
10. The method of claim 8 wherein the signal modification is between 50-100 percent of the human perception threshold.
11. A method for processing a decoded video signal so as to inhibit the making of acceptable DVD copies therefrom while producing a normal picture on a display, wherein the video signal has a frame modulation rate, said method comprising the step of changing the frame rate by an amount such that a re-encoded video signal gets out of sync at a certain point of time with the original, wherein frame skipping occurs that results in an unacceptable DVD copy.
12. The method of claim 11, wherein the amount of the change is less than the human perception threshold.
13. A method for processing a decoded video signal so as to inhibit the making of acceptable DVD copies therefrom while producing a normal picture on a display, wherein the video signal has a luminance level and a chrominance level, said method comprising the step of adding random noise to one of the luminance level and the chrominance level in an amount such that in a re-encoded video signal the addition exceeds the human perception threshold, wherein perception of the addition occurs that results in an unacceptable DVD copy.
14. The method of claim 13, wherein the amount of the addition is less than the human perception threshold.

15. The method of claim 13 wherein the modulation is between 50-100 per cent of the human perception threshold.
16. A method for processing a decoded audio signal so as to inhibit the making of acceptable copies therefrom while producing a normal sound on an audio player, wherein the audio signal has at least one pitch level, said method comprising the step of adding random noise to the at least one pitch level in an amount such that in a re-encoded audio signal the addition exceeds the human perception threshold, wherein perception of the addition occurs that results in an unacceptable audio copy.
17. The method of claim 16, wherein the amount of the change is less than the human perception threshold.
18. The method of claim 16 wherein the amount of the addition is 10 percent of the human perception threshold.
19. An apparatus for introducing quantization loss into a decoded signal, comprising a means for modifying the signal such that resultant quantization loss is recurring.
20. The apparatus of claim 19, wherein the decoded signal is a digital video signal and the means is selected from the group consisting of superimposition of an amount of random noise on the luminance level and superimposition of an amount of random noise on the chrominance level.
21. The apparatus of claim 20, wherein the amount is below the human perception threshold.
22. The apparatus of claim 20, wherein the amount is between 50-100 percent of the human perception threshold.

23. The apparatus of claim 19, wherein the decoded signal is an analog video signal and the means is selected from the group consisting of amount of frame rate modulation, superimposition of an amount of random noise on the luminance level and superimposition of an amount of random noise on the chrominance level.

24. The apparatus of claim 23, wherein the amount is below the human perception threshold.

25. The apparatus of claim 23, wherein the amount is between 50-100 percent of the human perception level.

26. The apparatus of claim 19, wherein the decoded signal is an analog audio signal and the means is changing a pitch of the audio signal by an amount.

27. The apparatus of claim 26, wherein the amount is below the human perception threshold.

28. The apparatus of claim 26, wherein the amount is between 50-100 percent of the human perception level.

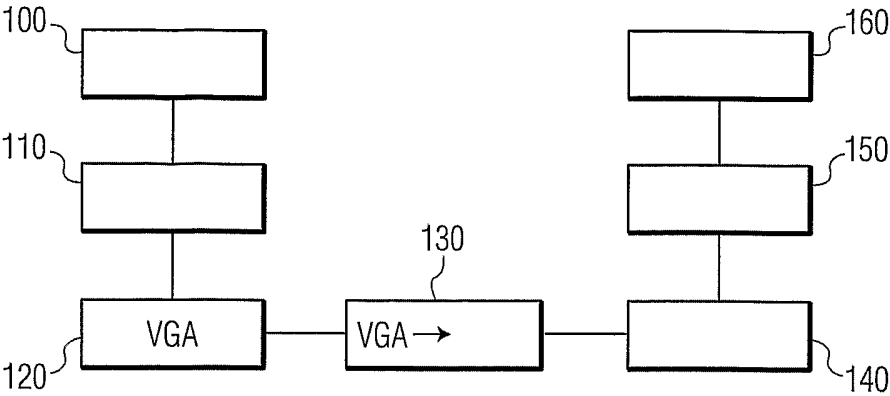


FIG. 1

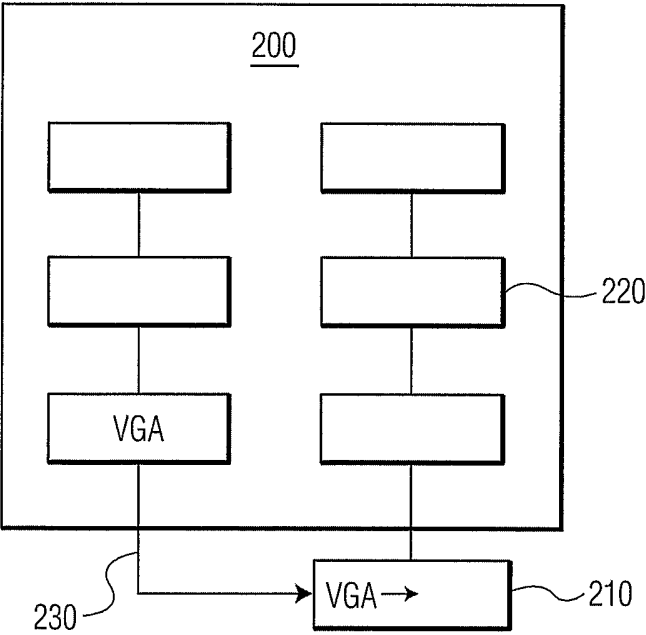


FIG. 2

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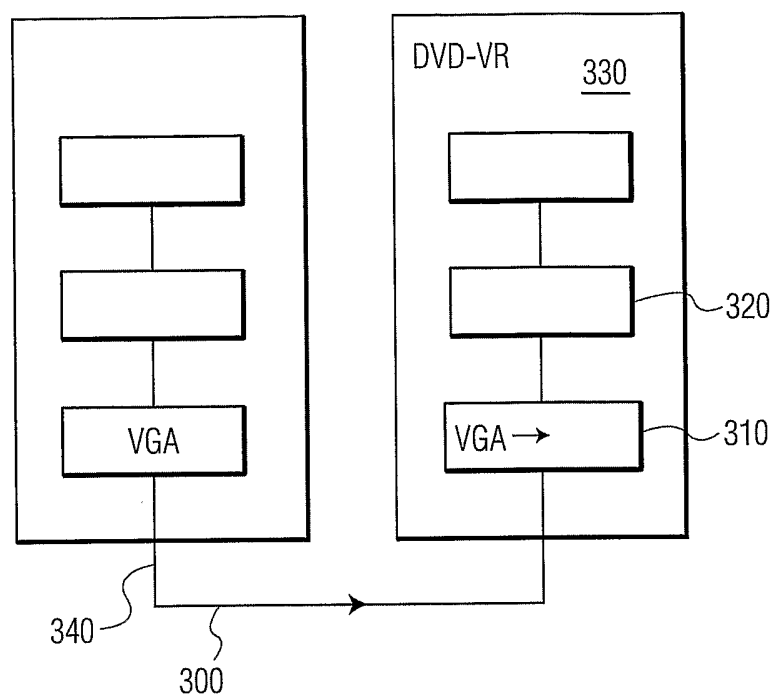


FIG. 3

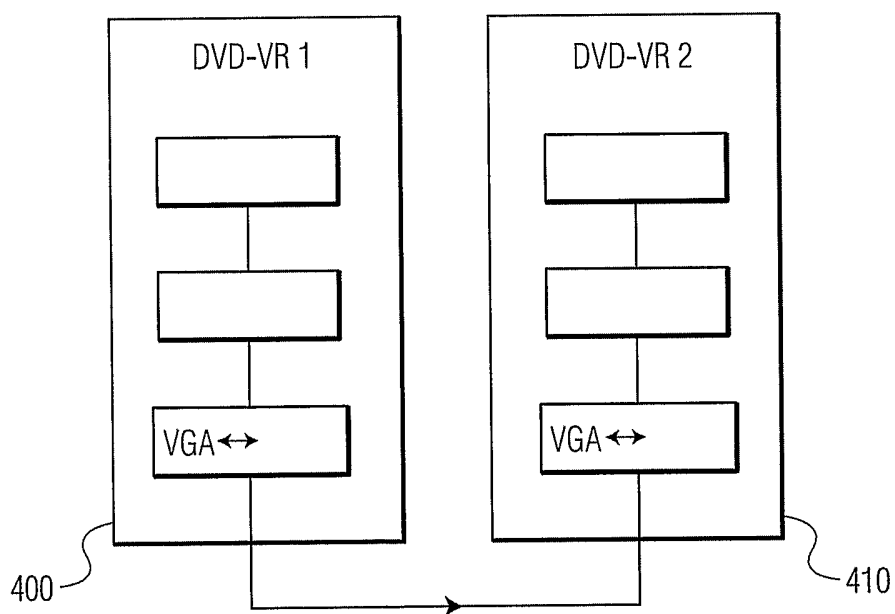


FIG. 4

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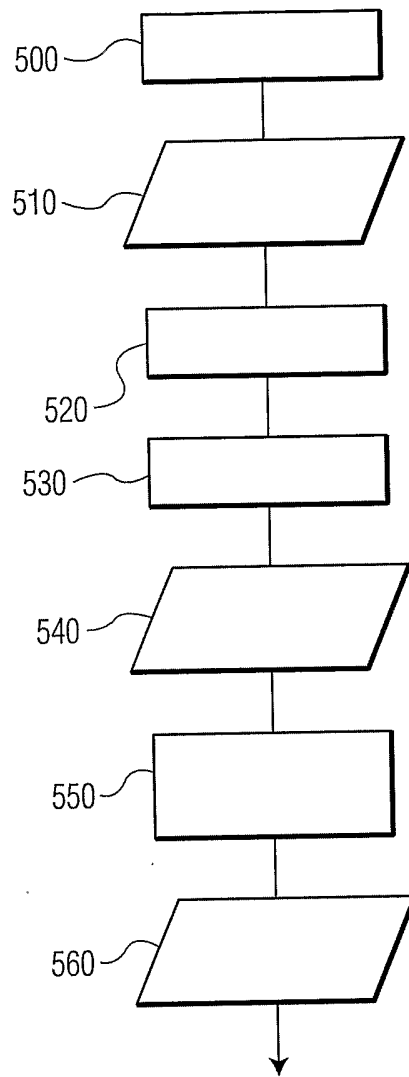


FIG. 5

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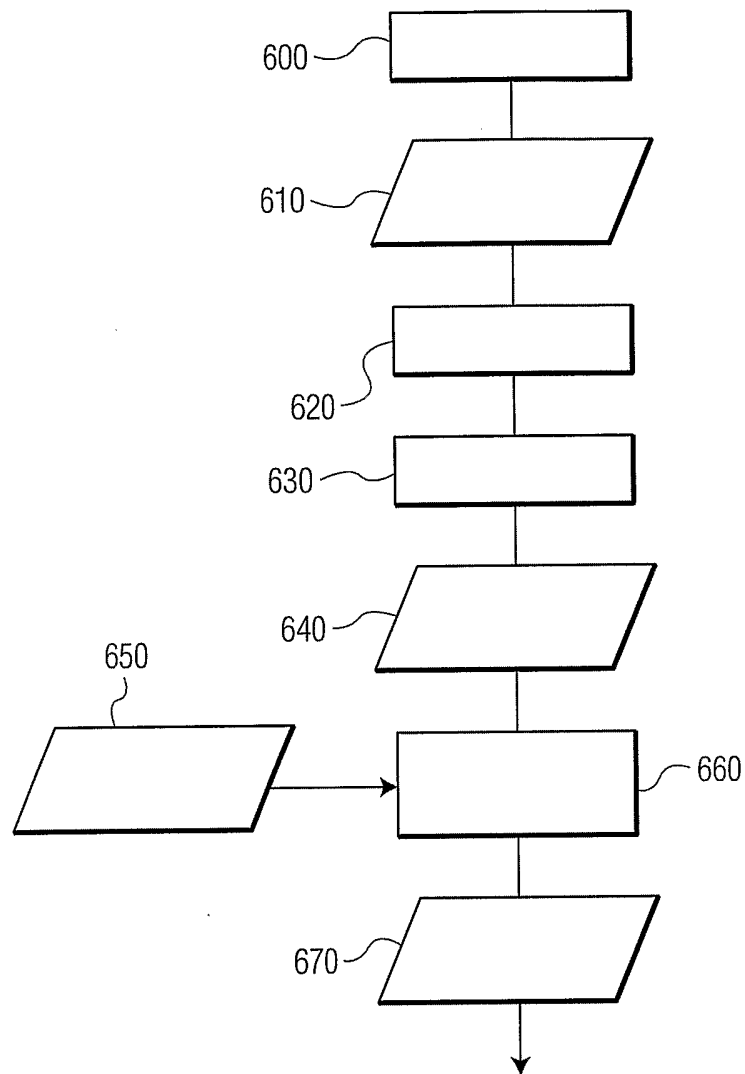


FIG. 6

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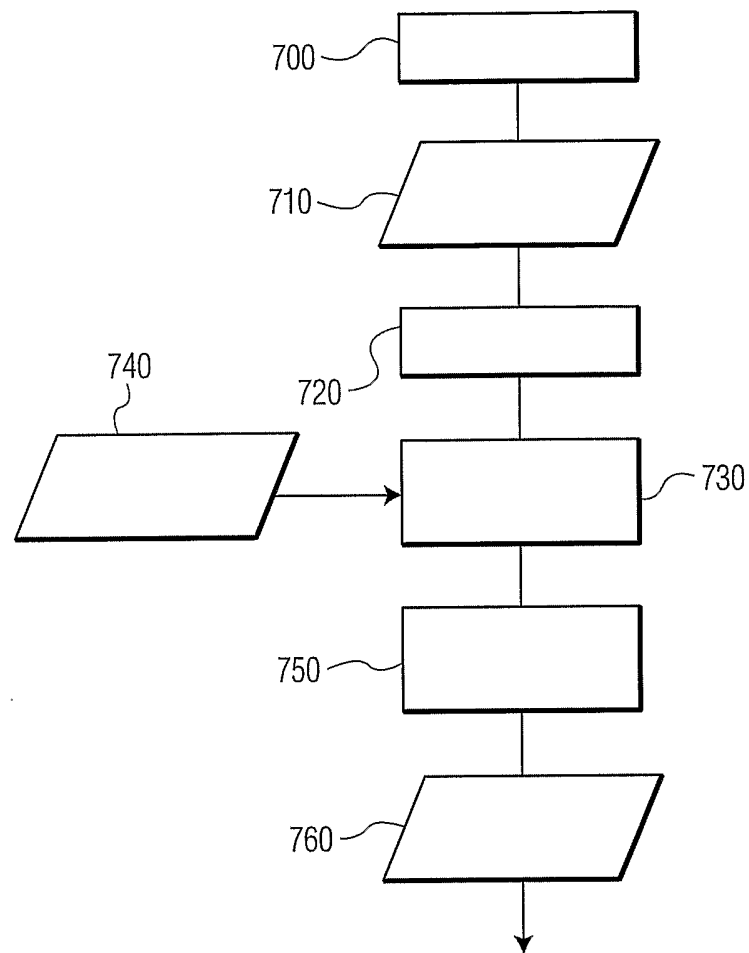


FIG. 7

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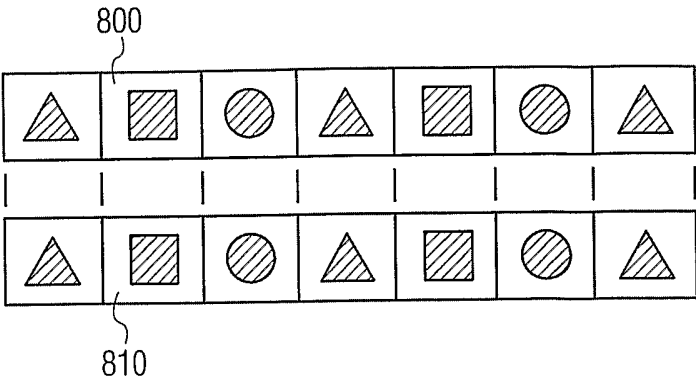


FIG. 8

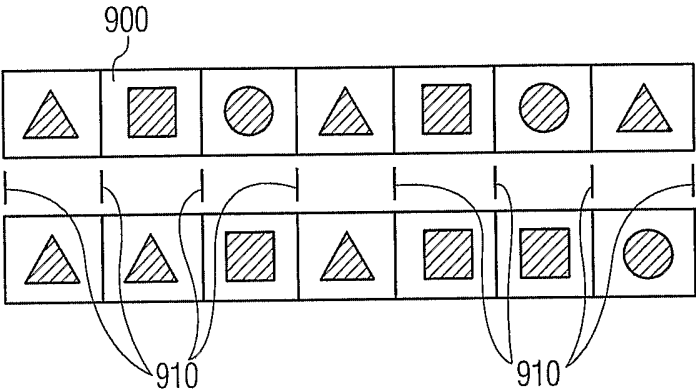


FIG. 9

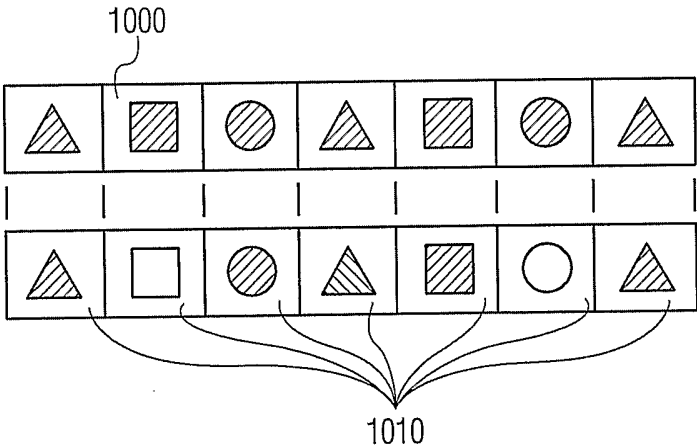


FIG. 10