Conversion of interlaced image signals into progressive scanned image signals.

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(54) **CONVERSION OF INTERLACED IMAGE SIGNALS INTO PROGRESSIVE SCANNED IMAGE SIGNALS**

UMSETZUNG VON MIT ZEILENSPRUNG ABGETASTETEN BILDSIGNALEN IN PROGRESSIV ABGETASTETE BILDSIGNALE

CONVERSION DE SIGNAUX-IMAGE ENTRELACES EN SIGNAUX-IMAGE BALAYEES PROGRESSIVEMENT PAR SCANNER

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- **PASI POHJALA ET AL: "LINE RATE UPCONVERSION IN IDTV APPLICATIONS" , PROCEEDINGS OF THE INTERNATIONAL CONFERENCE ON CONSUMER ELECTRONICS. (ICCE),US,NEW YORK, IEEE, VOL. CONF. 10, PAGE(S) 250-251 XP000289024 ISBN: 0-7803-0001-7 the whole document**

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Description

[0001] The invention relates to a method and device for de-interlacing image signals, and to a display apparatus comprising such a de-interlacing device.

[0002] De-interlacing is a basic requirement for practically all video scanning format conversions. Since perfection under all circumstances is impossible to achieve, many different algorithms have been proposed, ranging from simple spatial de-interlacing methods to the advanced motion compensated (MC) ones.

[0003] Many of the non-MC de-interlacing algorithms perform reasonably well on a limited set of sequences, but can suffer from annoying artifacts on another type of sequences. A nice overview is presented in [2]. For example the field insertion algorithm, is the best de-interlacer for stationary image parts, but is worst for non-stationary image parts. Motion compensation can provide better results on moving images, but the algorithm remains very fragile, i.e. the performance degrades rapidly to unacceptable levels if the motion compensation is not completely correct. A de-interlacer that can better cope with both stationarities and non-stationarities is the vertical-temporal median filter. This median filter de-interlacer inherently switches between field insertion and line repetition. However, due to its non-linear nature it introduces harmonics (and therefore alias) in image parts containing vertically high frequencies. The vertical-temporal linear filter, as also commercialized by Genesis [1], is better suited for sequences containing vertical high frequencies, but will not preserve edges as well as the median, while moving details may cause echoes in the image. In the literature, some proposals have been presented that explicitly switch or fade between multiple algorithms (see also [3-6]). The decision between the different algorithms is either determined by motion detection or edge detection. A very reliable detector is however difficult to design as also mentioned in [2]. A more robust alternative would provide an attractive option.

[0004] It is, inter alia, an object of the invention to provide an improved de-interlacing. To this end, the invention provides a de-interlacing method and device, as well as a display apparatus, as defined in the independent claims. Advantageous embodiments are defined in the dependent claims.

[0005] In a method of de-interlacing video data in accordance with a primary aspect of the present invention, at least three different de-interlacing algorithms are applied on the video date to obtain at least three de-interlaced signals, no majority of de-interlacing algorithms copying a single spatio-temporally neighboring pixel to the interpolated position, and the at least three de-interlaced signals are order statistical filtered to obtain an output signal.

[0006] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

[0007] In the drawings:

Fig. 1 illustrates the aperture of a three field de-interlacer;
Fig. 2 shows a general architecture of the method according to the invention; and
Fig. 3 shows a preferred embodiment of a display apparatus comprising a de-interlacing circuit in accordance with the present invention.

[0008] The current invention provides the required robust alternative. In a preferred embodiment, the current invention uses a set of (simple) de-interlacing algorithms, which is chosen such that a majority of the algorithms has a certain strength, e.g. robustness, another majority has a strength in e.g. edge preservation, and a third majority is strong in e.g. detail preservation. Although none of these algorithms is good in all aspects, the output of a median filter that selects between these alternatives is, simply because the majority wins. Unique in this new design is the fact that motion vectors can be applied to improve its performance, even if the reliability of these vectors is very poor. In case no vectors are being used, the method outperforms all known non-motion compensated methods. Next generation Trimedia will be designed to support this algorithm.

[0009] In a first embodiment, the output of the de-interlacer is defined by:

$$F_0(\vec{x},n)=\begin{cases}F(\vec{x},n) & ,(y \bmod 2 = n \bmod 2)\\ MED\{D, MED\{B,A,C\}, F_{VT}(\vec{x},n)\} & ,(otherwise)\end{cases} \qquad (1)$$

with $\vec{x}=\begin{pmatrix}x\\y\end{pmatrix}$ the spatial position, n the field number, $F(\vec{x}, n)$ the input field defined for 'y mod 2 = n mod 2' only,

$\vec{u}_Y = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$ the vertical unity vector, and A, *B*, *C* and D defined by (see also Fig. 1):

$$\begin{aligned} A &= F(\vec{x}, n+1) \\ B &= F(\vec{x} - \vec{u}_Y, n) \\ C &= F(\vec{x} + \vec{u}_Y, n) \\ D &= F(\vec{x}, n-1) \end{aligned} \qquad (2)$$

[0010] Fig. 1 illustrates the aperture of a three field de-interlacer. The vertical position VP is indicated on the vertical axis, while the field number FN is indicated on the horizontal axis. The black dots A-D indicate original samples, while the open circle E indicates an interpolated sample to be obtained in accordance with the lower expressions in formulae 1, 6 or 7.

[0011] The median filter operator *MED(A, B, C)* is defined by:

$$MED\{A, B, C,\} = \begin{cases} A, & (B \langle A \langle C) \vee (C \langle A \langle B) \\ B, & (A \le B \le C) \vee (C \le B \le A) \\ C, & (otherwise) \end{cases} \qquad (3)$$

[0012] The output of the vertical-temporal filter F_{VT} is defined by:

$$F_{IT}(\vec{x}, n) = \begin{cases} F(\vec{x}, n) & ,(y \bmod 2 = n \bmod 2) \\ \sum_m \sum_k F(\vec{x} + k\vec{u}_Y, n+m) h(k, m) & ,(otherwise) \end{cases} \qquad (4)$$

with (k, m $\in$ Z, $(k + m) \bmod 2 = 1$) Λ ($|Max(k)|>0$) Λ ($|Max(m)|>0$).

[0013] The *Max(x)* operator determines the maximum value of the variable *x*. In our experiments, the vertical-temporal filter was defined by:

$$18h(k, m) = \begin{cases} 1,8,8,1 & ,(k = -3,-1,1,3) \wedge (m = 0) \\ -5,10,-5 & ,(k = -2,0,2) \wedge (m = -1) \\ 0, & ,(otherwise) \end{cases} \qquad (5)$$

[0014] A possible architecture of this invention is presented in Fig. 3. For stationary image parts containing dominant vertical edges or low frequencies, the output of the VT median is likely to be equal to the sample $F(\vec{x}, n-1)$, and therefore, either of the two is selected as the output. For stationary image parts containing high vertical frequencies, the VT median introduces alias by resulting in either $F(\vec{x} - u_Y, n)$ *or* $F(\vec{x} + \bar{u}_Y, n)$. However, the output of the linear vertical-temporal filter, $F_{VT}(\vec{x}, n)$,will resemble $F(\vec{x}, n + 1)$. Therefore, either of these two samples is selected as the output sample, preserving vertical detail.

[0015] For moving image parts $F(\vec{x}, n - 1)$ will generally be an outlier in the VT median. Since the linear vertical-temporal filter applies a weighted filtering of the neighboring samples also, it is likely that $F_{VT}(\vec{x}, n)$ and the output of the inner median have about similar sample values. Therefore, in case of motion, either line repetition or linear vertical temporal filtering results.

[0016] A somewhat simplified variant of the de-interlacer as mentioned in equation 1 uses two fields only, and is defined by:

$$F_0(\bar{x},n)=\begin{cases}F(\bar{x},n) & ,(y \bmod 2 = n \bmod 2)\\ MED\{A, MED\{B,A,C\}, F_{VT}(\bar{x},n)\} & ,(otherwise)\end{cases} \quad (6)$$

The quality performance of this algorithm is somewhat less compared to the one of equation 1. The main difference can be observed for vertical moving objects containing vertical detail.

So far, the result is a non-MC de-interlacing method, however, the proposed algorithm can easily be adapted to apply motion compensation, e.g.:

$$F_0(\bar{x},n)=\begin{cases}F(\bar{x},n), & (y \bmod 2 = n \bmod 2)\\ MED\{F(\bar{x}+\bar{d}(\bar{x},n),n+1), & \\ \quad MED\{B,A,C\}, & \\ \quad F_{VT}(\bar{x},n)\ \}, & otherwise\end{cases} \quad (7)$$

with $\bar{d}$ the motion vector. Since the motion compensated sample is part of the "fragile" de-interlacing algorithm, the result need not be robust. In other words, since the majority of methods that are input to the median filter are robust, the result will be robust even though motion vectors are being used.

[0017] If we generalize the examples shown above, the proposed de-interlacing algorithm is an order statistical filter with multiple inputs from different de-interlacing methods as shown in Fig. 2. Fig. 2 shows a general architecture of the method according to the invention. An ordered statistical filter OSF supplies an interpolated line Fo based on n different de-interlaced outputs DIO-1, DIO-2, ..., DIO-n obtained by n different de-interlacing methods. If n>3, the de-interlacing methods need not be all different. A majority of the de-interlacing methods is strong on a first quality aspect (e.g. edge preservation). Another majority is strong on a second quality aspect (e.g. detail preservation), and so on. Since the order statistical filter selects the input belonging to the overall majority, the resulting de-interlacing algorithm combines the strengths of the input algorithms.

[0018] Fig. 3 shows a preferred embodiment of a display apparatus comprising a de-interlacing circuit in accordance with the present invention. An input image signal F is applied to a first field memory FM1, an output of which is coupled to a second field memory FM2. Inputs of cache memories CM1, CM2 and CM3 are connected to the input of the field memory FM1 and to the outputs of the field memories FM1 and FM2, respectively. The cache memory CM1 supplies the sample A from field n+1 to a first median filter MED I, while the cache memory CM2 supplies the samples B and C to the first median filter MED1. Outputs of the cache memories CM1 and CM2 are coupled to respective inputs of a vertical-temporal filter VTF. A second median filter MED2 receives the sample D from field n-1 from the cache memory CM3, the median of A, B and C from the first median filter MED1, and a filter output F_{VT} from the vertical-temporal filter FVT, to supply the interpolated line E. The cache memory CM2 outputs the original line F. An insertion circuit IC inserts the interpolated lines E between the original lines F to obtain a display signal Fo that is displayed by a display device DD.

[0019] A preferred aspect of the invention can be summarized as follows. De-interlacing is the process required to convert interlaced video into a progressive format. Many algorithms, including high performance motion compensated methods and low cost solutions are available from the literature. Preferably, a set of simple de-interlacing algorithms is used, which is chosen in such a manner, that a majority of the algorithms is robust, another majority is good in edge preservation, and a third majority is strong in detail preservation. Although non of these algorithms is good in all aspects, the output of a median filter that selects between these alternatives is, simply because the majority wins. Unique in this new design is the fact that motion vectors can be applied to improve its performance, even if the reliability of these vectors is very poor. In case no vectors are being used the method outperforms all known non-motion compensated methods.

[0020] Preferred aspects of the invention provide a method, and an apparatus realizing this method, for de-interlacing video data, characterized in that the interpolated pixels are calculated with an order statistical filter using at its input the N outputs of a number of N de-interlacers, where different majorities of these algorithms share individual strengths, and there exist no majority of de-interlacing algorithms that copy a single spatio-temporally neighboring pixel to the interpolated position.

[0021] Preferably, N = 3 and the order statistical filter has the following inputs: the output of a first de-interlacing algorithm that is strong on a first and a second criterion (e.g. robustness and edge preservation), but weak on a third criterion (e.g. detail preservation), and the output of a second de-interlacing algorithm that is strong on the first and the third criterion (e.g. robustness and detail preservation), and weak on the second criterion the output of third de-interlacing algorithm that is strong on the second and the third criterion, but weak on the first.

[0022] Advantageously, the order statistical filter is a median filter.

[0023] Preferably, the first de-interlacing algorithm is a vertical-temporal median filter.

[0024] Preferably, the third de-interlacing algorithm is a (motion compensated) field insertion, inserting either a pixel from the previous or from the next input video field.

[0025] Preferably, the second de-interlacing algorithm is a linear vertical-temporal filter.

[0026] It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word "comprising" does not exclude the presence of elements or steps other than those listed in a claim. The word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention can be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer. In the device claim enumerating several means, several of these means can be embodied by one and the same item of hardware.

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[0027]

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Claims

1. A method of de-interlacing video data (F), the method comprising the steps of:

   applying at least three different de-interlacing algorithms (VTF, MED1, CM3) on the video data to obtain at least three de-interlaced signals (DIO-1, DIO-2, DIO-3), no majority of de-interlacing algorithms copying pixels from a single spatio-temporally neighboring pixel position (A, B, C, D) to an interpolated position (E); and
   order statistical filtering (OSF, MED2) the at least three de-interlaced signals (DIO-1, DIO-2, DIO-3) to obtain an output signal (E) for said interpolated position.

2. A method as claimed in claim 1, wherein the order statistical filtering step (OSF) uses a median filter (MED2).

3. A method as claimed in claim 1, wherein at least one of said de-interlacing algorithms uses a vertical-temporal median filter (FM1, MED1).

4. A method as claimed in claim 1, wherein one of said de-interlacing algorithms is a field insertion, inserting either a pixel (D) from a previous field (n-1) or a pixel (A) from a next input video field (n+1).

5. A method as claimed in claim 4, wherein said field insertion is motion-compensated.

6. A method as claimed in claim 1, wherein at least one of said de-interlacing algorithms uses a linear vertical-temporal filter (VTF).

7. A method as claimed in claim 1, wherein at least one of said de-interlaced signals (DIO-1, DIO-2, DIO-3) is motion-compensated.

8. A device for de-interlacing video data (F), the device comprising:

means for applying at least three different de-interlacing algorithms (VTF, MED 1, CM3) on the video data (F) to obtain at least three de-interlaced signals (DIO-1, DIO-2, DIO-3), no majority of de-interlacing algorithms copying pixels from a single spatio-temporally neighboring pixel position (A, B, C, D) to the interpolated position (E); and
means for order statistical filtering (OSF, MED2) the at least three de-interlaced signals (DIO-1, DIO-2, DIO-3) to obtain an output signal (E) for said interpolated pixel position.

9. A display apparatus, comprising:

a device for de-interlacing video data as claimed in claim 8, to obtain interpolated data (E);
an insertion circuit (IC) for inserting the interpolated data (E) into the video data (F) to obtain a display signal; and
a display device (DD) for displaying the display signal (Fo).

Patentansprüche

1. Verfahren zum Zeilenentflechten (de-interlacing) von Videodaten (F), umfassend die Schritte:

Anwenden mindestens dreier unterschiedlicher Zeilenentflechtungsalgorithmen (VTF, MED1, CM3) auf die Videodaten, um mindestens drei zeilenentflochtene Signale (DIO-1, DIO-2, DIO-3) zu erhalten, wobei keine Mehrheit von Zeilenentflechtungsalgorithmen Pixel von einer einzelnen räumlich-zeitlich benachbarten Pixelposition (A, B, C, D) an eine interpolierte Position (E) kopiert; und
Anwenden eines Order-Statistic-Filters (OSF, MED2) auf die mindestens drei zeilenentflochtenen Signale (DIO-1, DIO-2, DIO-3), um ein Ausgangssignal (E) für die interpolierte Position zu erhalten.

2. Verfahren nach Anspruch 1, bei dem der Schritt der Anwendung des Order-Statistic-Filters (OSF) einen Medianfilter (MED2) verwendet.

3. Verfahren nach Anspruch 1, bei dem mindestens einer der Zeilenentflechtungsalgorithmen einen vertikal-zeitlichen Medianfilter (FM1, MED1) verwendet.

4. Verfahren nach Anspruch 1, bei dem einer der Zeilenentflechtungsalgorithmen eine Feldeinfügung ist, wobei entweder ein Pixel (D) aus einem früheren Feld (n-1) oder ein Pixel (A) aus einem nächsten Eingangsvideofeld (n+1) einfügt.

5. Verfahren nach Anspruch 4, bei dem die Feldeinfügung bewegungskompensiert ist.

6. Verfahren nach Anspruch 1, bei dem mindestens einer der Zeilenentflechtungsalgorithmen einen linear vertikal-zeitlichen Filter (VTF) verwendet.

7. Verfahren nach Anspruch 1, bei dem mindestens eines der zeilenentflochtenen Signale (DIO-1, DIO-2, DIO-3) bewegungskompensiert ist.

8. Vorrichtung zum Zeilenentflechten (de-interlacing) von Videodaten (F), umfassend:

Mittel zum Anwenden mindestens dreier unterschiedlicher Zeilenentflechtungsalgorithmen (VTF, MED1, CM3) auf die Videodaten (F), um mindestens drei zeilenentflochtene Signale (DIO-1, DIO-2, DIO-3) zu erhalten, wobei keine Mehrheit von Zeilenentflechtungsalgorithmen Pixel von einer einzelnen räumlich-zeitlich benachbarten Pixelposition (A, B, C, D) an eine interpolierte Position (E) kopiert; und
Mittel zum Anwenden eines Order-Statistic-Filters (OSF, MED2) auf die mindestens drei zeilenentflochtenen Signale (DIO-1, DIO-2, DIO-3), um ein Ausgangssignal (E) für die interpolierte Pixelposition zu erhalten.

9. Anzeigegerät, umfassend:

eine Vorrichtung zum Zeilenentflechten von Videodaten nach Anspruch 8, um interpolierte Daten (E) zu erhalten;
eine Einfügeschaltung (IC) zum Einfügen der interpolierten Daten (E) in die Videodaten (F), um ein Anzeigesignal

zu erhalten; und
eine Anzeigevorrichtung (DD) zum Anzeigen des Anzeigesignals (Fo).

Revendications

1. Procédé de conversion d'entrelacement de données vidéo (F), le procédé comprenant les étapes consistant à :

   appliquer au moins trois algorithmes de conversion d'entrelacement différents (VTF, MED1, CM3) sur les données vidéo en vue d'obtenir au moins trois signaux entrelacés convertis (DIO-l, DIO-2, DIO-3), aucune majorité d'algorithmes de conversion d'entrelacement ne copiant seul un pixel de voisinage de façon spatio-temporelle (A, B, C, D) à une position de pixel interpolée (E) ; et
   filtrer selon une statistique d'ordre (OSF, MED2) les au moins trois signaux entrelacés convertis (DIO-1, DIO-2, DIO-3) pour obtenir un signal de sortie (E) pour ladite position de pixel interpolée.

2. Procédé selon la revendication 1, dans lequel l'étape de filtrage selon une statistique d'ordre (OSF) utilise un filtre médian (MED2).

3. Procédé selon la revendication 1, dans lequel au moins l'un desdits algorithmes de conversion d'entrelacement utilise un filtre médian vertical-temporel (FM1, MED1).

4. Procédé selon la revendication 1, dans lequel l'un desdits algorithmes de conversion d'entrelacement correspond à une insertion de trame, insérant soit un pixel (D) à partir d'une trame précédente (n-1), soit un pixel (A) à partir d'une trame vidéo d'entrée suivante (n+1).

5. Procédé selon la revendication 4, dans lequel ladite insertion de trame est à compensation de mouvement.

6. Procédé selon la revendication 1, dans lequel au moins l'un desdits algorithmes de conversion d'entrelacement utilise un filtre vertical-temporel linéaire (VTF).

7. Procédé selon la revendication 1, dans lequel au moins l'un desdits signaux entrelacés convertis (DIO-1, DIO-2, DIO-3) est à compensation de mouvement.

8. Dispositif pour convertir des données vidéo entrelacées (F), le dispositif comportant :

   des moyens pour appliquer au moins trois algorithmes différents de conversion d'entrelacement (VTF, MED 1, CM3) sur les données vidéo (F) en vue d'obtenir au moins trois signaux entrelacés convertis (DIO-1, DIO-2, DIO-3), aucune majorité d'algorithmes de conversion d'entrelacement ne copiant un seul pixel de voisinage de façon spatio-temporelle (A, B, C, D) à une position de pixel interpolée (E) ; et
   des moyens pour filtrer selon une statistique d'ordre (OSF, MED2) les au moins trois signaux entrelacés convertis (DIO-1, DIO-2, DIO-3) pour obtenir un signal de sortie (E) destiné à ladite position de pixel interpolée.

9. Appareil de visualisation comprenant :

   un dispositif pour convertir des données vidéo entrelacées selon la revendication 8, en vue d'obtenir des données interpolées (E) ;
   un circuit d'insertion (IC) pour insérer les données interpolées (E) dans les données vidéo (F) en vue d'obtenir un signal d'affichage ; et
   un dispositif d'affichage (DD) pour afficher le signal d'affichage (Fo).

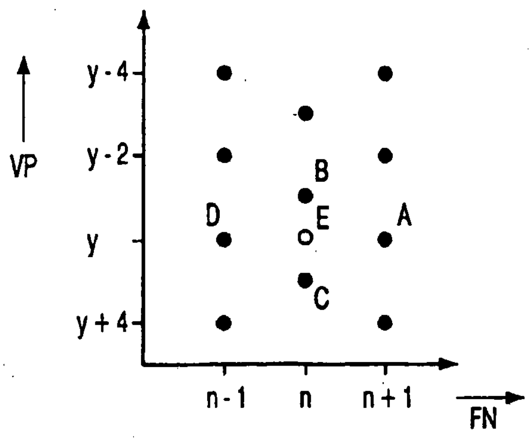

FIG. 1

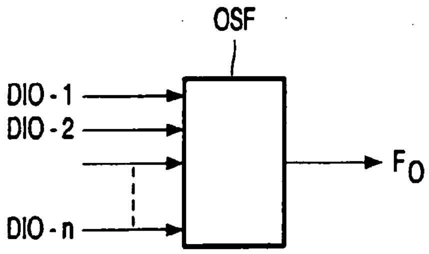

FIG. 2

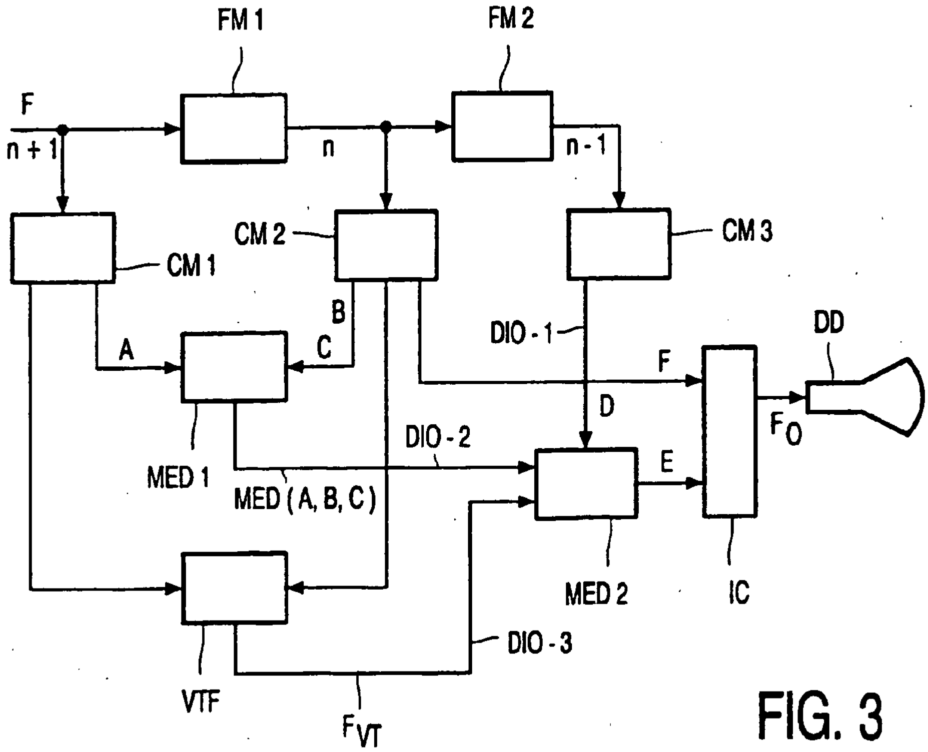

FIG. 3

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