

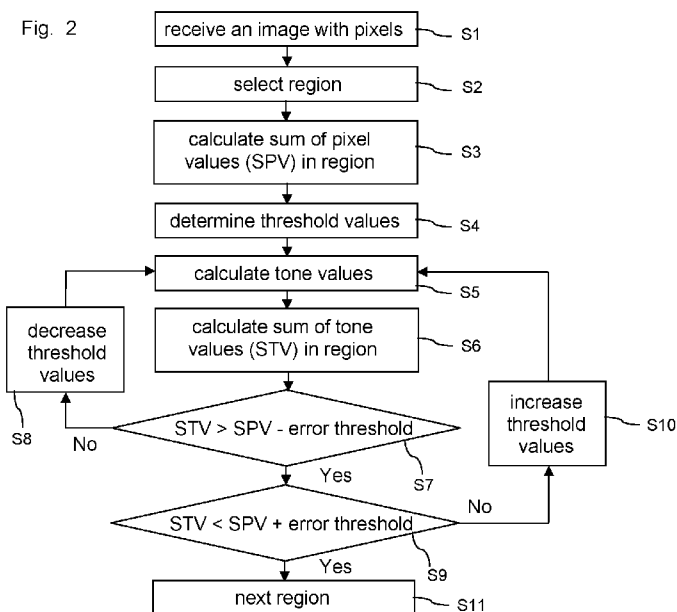


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(54) Title: METHOD FOR MULTILEVEL HALFTONING



(57) Abstract: A method is described for multilevel halftoning an image having pixels. Herein a tone value is attributed to a pixel in the image, the pixel having a pixel value from a predefined number of pixel values. The tone value is taken from a number of tone values that is in general smaller than the number of pixel values. Each tone value is associated with a predetermined amount of marking material to be applied in a print process. A number of threshold values is associated with each pixel to determine a tone value corresponding to the pixel value. In the image a region of pixels is defined for which the tone values and pixel values are summed. If the difference between these sums is larger than a predetermined error threshold, the threshold values of the pixels in the region are adjusted and new tone values are calculated. This method reduces the extent Moire artefacts occur for images in which a screen is present that may interfere with a screen according to which the threshold values are arranged. Also the loss of detail information due to the distribution of the threshold values is reduced.

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Method for multilevel halftoning

5 FIELD OF THE INVENTION

The invention relates to a method for multilevel halftoning, wherein a tone value is attributed to a pixel in an image, the pixel having a pixel value from a number of pixel values and the tone value being taken from a number of tone values that is in general
10 smaller than the number of pixel values, the tone value being associated with a predetermined amount of marking material to be applied in a print process, and wherein a number of threshold values is associated with each pixel to select one of the number of the tone value corresponding to the pixel value. The invention is further related to a computer readable medium comprising computer executable instructions and to a
15 printer system comprising a controller for scheduling and interpreting print jobs and a print engine for marking support material.

BACKGROUND OF THE INVENTION

20 In order to print a digital image on a support material, the digital image is electronically converted by image processing comprising a step called digital halftoning. In this step the number of values that is available for each pixel of the image is adjusted to the number of tone levels that is available for each print pixel in a print process. A print pixel refers to a position on the support material on which the print process can apply
25 material. Many print processes employ two tone levels for a print pixel: either a dot is defined for applying a fixed amount of marking material on the position of the print pixel, or no dot is defined, causing the print process to omit applying marking material on the position of the print pixel. However, a number of newly developed print processes employ more than two tone levels, e.g. by applying a number of small dots on the
30 position of a print pixel. For these print processes multilevel halftoning is used to convert for each pixel of an image a pixel value to a tone value, the tone value representing a tone level associated with a predetermined amount of marking material that is applied by the print process. In a conventional black and white print process the only process colour comprises black marking material and the image comprises pixels for which a
35 pixel value indicates an optical density of the pixel in the image. In a full colour print

process at least three, but mostly four, process colours are employed. In that case, the conversion as described here applies to a digital separation image that is generated for a process colour, in which a pixel value indicates an optical density of the marking material of that process colour.

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A known method for multilevel halftoning is an extension of a commonly known dithering process. In a usual dithering process each pixel is associated with a threshold, which is compared to the pixel value to determine whether or not a dot is to be placed. The extension to multilevel halftoning comprises a number of predetermined thresholds for each pixel to determine a tone value that is selected from a number of tone values. The number of thresholds is the number of tone values minus one. Similarly to pixel values, tone values are discretely distributed between a minimum and a maximum value. Expressed numerically, for pixel and tone values a scale from 0 and 1 is used, wherein 0 corresponds to the minimum and 1 to the maximum value of the range. The number of tone values is in general smaller than the number of pixel values. The usual dithering process may be construed as a multilevel halftoning process with two tone values. In all these halftoning processes a pattern of dots emerges for image parts in which all pixels have the same pixel value and the pixel values have been calibrated to make the optical density of the marking material corresponding to the patterns match the pixel values. A pattern may have repetitive features, depending on the distribution of the threshold values over the pixels, which is adapted to the print process involved.

A problem that frequently occurs in these halftoning processes, is that the interaction of the repetitive elements in the dot patterns with image features that have a spatial frequency close to the frequency in the dot patterns, appears in the printed image as Moiré. Another way this interaction is visible, is in staggered edges of lines. An object of the present invention is to diminish the amount of Moiré and reduce the visibility of staggered lines.

30 SUMMARY OF THE INVENTION

According to the present invention the method for multilevel halftoning an image is improved by the steps of :

- a) defining a region comprising a number of pixels of the image;
- 35 b) determining a tone value for each pixel in the region using threshold values that are

associated with the pixel;

c) determining a difference between a sum of tone values of the pixels in the region and a sum of pixel values of the pixels in the region;

d) adapting the associated threshold values of the pixels in the region and repeating
5 steps b) to d), if an absolute value of the difference determined in step c) is larger than an error threshold,

wherein the associated threshold values are lowered if the sum of tone values is lower than the sum of pixel values and wherein the associated threshold values are raised if the sum of tone values is higher than the sum of pixel values.

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By lowering the threshold values of the pixels in the region and recalculating the tone values, the sum of the tone values rises. Inversely by raising the threshold values of the pixels in the region and recalculating the tone values, the sum of the tone values goes down. Therefore by the iteration steps the sum of the tone values will move towards the
15 sum of the pixel values within the selected region. In areas of pixels having all the same value, the iteration in the steps above is carried out only once, because the pixel values are already calibrated. If they are not calibrated, the iteration may be repeated, but in areas of pixels having all the same value, this only has the same effect as a calibration. However, if the pixel value varies within an element of the image, such as at the edge of
20 a line or when the image feature shows a modulation, the iteration to equalise the sums within a region of pixels has the effect of making the optical density of the marking material within the printed image better represent the average of the pixel values. This is found to have a strongly damping effect on the visibility of Moiré patterns and staggered edges. It is well understood that equivalently the pixel values within the selected region
25 may be changed to bring the sum of the pixel values towards the sum of the tone values.

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In an embodiment the region comprises at least 64 pixels. The minimum number of pixels makes the sum of tone values accurately represent an average density in the involved region.

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In an embodiment the error threshold is determined to be approximately the difference between two consecutive pixel values times the number of pixels in the region. This defines the accuracy that is used for matching the sum of the pixel values to the sum of the tone values.

In an embodiment the number of pixel values comprises 256 values and the number of tone values comprises two values. The multilevel halftoning process in this embodiment reduces to the ordinary halftoning process with one threshold for each pixel. The
5 reduction of Moiré is significant due to the big difference in optical density between the amount of marking material associated with the two tone levels.

In an embodiment the number of times the steps b) to d) are repeated, is smaller than a predefined number of times. This limits the processing time that is needed for the step
10 of halftoning. Especially in the case of complex pages which contain many regions with image features that show interaction with the repetitive elements of the dot patterns, it may be beneficial to have an upper limit for the processing time.

The invention encompasses also a software product and a printer system implementing
15 the method that has been described above.

BRIEF DESCRIPTION OF THE DRAWINGS

Hereinafter the present invention is further elucidated with references to the appended
20 drawings showing non-limiting embodiments and wherein

Fig. 1 shows a printer system;

Fig. 2 is a flow diagram of an embodiment of the invented method; and

Fig. 3 is a diagram of a controller connected to a printer.

25 DETAILED DESCRIPTION OF EMBODIMENTS

A number of embodiments will now be described in conjunction with the drawings, in which same reference numerals refer to like elements.

30 The printer system in Fig. 1 comprises a number of workstations (2, 4, 6) that are connected to a controller computer 16 through a network N. On the workstations print jobs are prepared involving documents in various formats and various sizes. The data in these documents originate from different sources, such as scanners, digital camera's and computer applications. The print jobs may be sent to the controller computer where
35 the jobs are analyzed and the documents converted into image data that are

appropriate to be accepted by one of the printers connected to the controller computer. In the present embodiment a printer 14 for large size documents, such as CAD drawings and banners, is available and a printer 18 for office size documents, such as A4 and A3 sized support sheets of paper, connected to the controller computer by a means for data transfer 15. In the process of converting, the documents are rasterized and rendered for the marking process of the printer to be used. In this process also a number of methods may be applied that improve the appearance of the image on the support material that is used in the printer. The image data are compressed before being sent to the printer and possibly saved on a non-volatile memory in the controller, such as a hard disk.

The steps of an embodiment of the method according to the invention have been summarized in Fig. 2. It will be understood that the method may be carried out, for example, by an image processor that forms part of a digital printer. As an alternative, the method may be carried out on a multi-purpose computer loaded with suitable software so as to process an image file that will then be sent to a digital printer for being printed. In step S1 a digital image is received by a computer with an image processor. In step S2 a region in the digital image is selected comprising a number of pixels. Depending on the resolution this number is between 20 and 200, a higher number with a higher resolution. For a resolution of 600 pixels per inch, a region may comprise 64 pixels. A sum of the pixel values, SPV of the pixels within this region is calculated in step S3. Pixel values are discrete values indicating an optical density of a part of the image between a minimum and a maximum value in a predetermined range. In this embodiment they are numerically scaled to lie in a range from 0 to 1. In step S4 the threshold values that correspond to the pixels in the selected region are derived from the repetitive application of an array of thresholds to the pixels in the image, as is usual for dithering processes. In step S5 tone values are calculated for all pixels within the region, by comparing each pixel value to the thresholds associated with the pixel. This is a common procedure for multilevel halftoning processes in the form of dithering. The tone values are also discrete values indicating an amount of marking material between a minimum and a maximum value in a predetermined range. In this embodiment they are numerically scaled to lie in a range from 0 to 1. For each pixel, first a comparison is made to the lowest threshold. If the pixel value is lower, the minimum tone value is associated with the pixel, otherwise a comparison to the next threshold is made and the tone value is raised to the next tone value. This process is repeated until the pixel has a

tone value that corresponds to the situation of the pixel value being between two thresholds or to the situation that the pixel value is lower than the lowest threshold or higher than the highest threshold. Subsequently in step S6 a sum of tone values, STV, is calculated. In step S7 the value STV is compared to SPV minus an error threshold. If STV is lower ("No"), all threshold values of the pixels in the region are decreased in step S8 and new tone values are calculated in step S5. By making the thresholds lower, the new tone values will be equal or higher than the previous ones, making a new STV in step S6 higher and thus making it possible that the new STV will be larger than SPV minus the error threshold in step S7. If so ("Yes") a comparison between STV and SPV plus the error threshold is made in step S8. If STV is smaller ("No"), all threshold values of the pixels in the region are increased in step S10 and new tone values are calculated in step S5. By making the thresholds higher, the new tone values will be equal or lower than the previous ones, making a new STV in step S6 lower and thus making it possible that the new STV will be smaller than SPV minus the error threshold in step S8. The stepsize of increasing and decreasing the threshold values in steps S8 and S10 can conventionally be adjusted to reach a situation that both comparisons S7 and S9 are fulfilled ("Yes"). In that case a next region may be selected, which is step S11.

In Fig. 3 a diagram for a printer system is shown, comprising a controller computer 16, a printer 14 and a means for data transfer 15. The controller computer is connected to the network N and comprises a network connection module 40, a central processing unit 41, a volatile memory module 42, a non-volatile memory module 43 and a module for multilevel halftoning 50, all connected to a data-bus 44. The controller computer accepts print jobs through the network N, interprets the print jobs and transforms them to image data. The module for multilevel halftoning is configured to compare pixel values in the image data to predetermined threshold levels that are associated with each pixel. Thus the module gives tone values in response to pixel values and an array of thresholds. The central processing unit is configured to determine, according to the method indicated in Fig. 2, if the tone values in a region are matching the pixel values. If this is not the case, a new array of thresholds is used as input for the multilevel halftoning module. In another embodiment several arrays of thresholds are used in parallel for a set of pixel values of pixels in a region. The central processing unit is then configured to select the tone values that correspond to the pixel values according to the criteria given in Fig. 2. Hence, the image data are in a condition to be printed by the printer 14, to which they are transferred through the means for data transfer 15. The printer comprises

a buffer memory 51 and a print process 52 for marking a support material with marking material, such as toner or ink.

CLAIMS

1. Method for multilevel halftoning, wherein a tone value is being attributed to a pixel of an image, the tone value being taken from a number of tone values and the pixel having a pixel value from a number of pixel values, each tone value being associated with a predetermined amount of marking material to be applied in a print process, and wherein a number of threshold values is being associated with each pixel to select one of the tone values corresponding to the pixel value, the method comprising the steps of
- 5 a) defining a region comprising a number of pixels of the image;
- 10 b) determining a tone value for each pixel in the region using the associated threshold values;
- c) determining a difference between a sum of tone values of the pixels in the region and a sum of pixel values of the pixels in the region;
- d) if an absolute value of the difference determined in step c) is larger than an error
- 15 threshold, adapting the associated threshold values of the pixels in the region and repeating steps b) to d),
- wherein the associated threshold values are lowered if the sum of tone values is lower than the sum of pixel values and wherein the associated threshold values are raised if the sum of tone values is higher than the sum of pixel values.
- 20
2. Method according to claim 1, wherein the region comprises an area of the image having a minimum of 64 pixels.
3. Method according to claim 1, wherein the error threshold is approximately the
- 25 difference between two consecutive pixel values times the number of pixels in the region.
4. Method according to claim 1, wherein the number of pixel values comprises 256 values and the number of tone values comprises two values.
- 30
5. Method according to claim 1, wherein the number of times the steps b) to d) are repeated, is smaller than a predefined number of times.
6. A computer readable medium comprising computer executable instructions for
- 35 performing the method according to claim 1.

7. Printer system comprising a controller for scheduling and interpreting print jobs and a print engine for marking support material, the controller comprising modules for generating print signals for a digital image, characterized in that the controller further
- 5 comprises a module for executing a method according to claim 1.

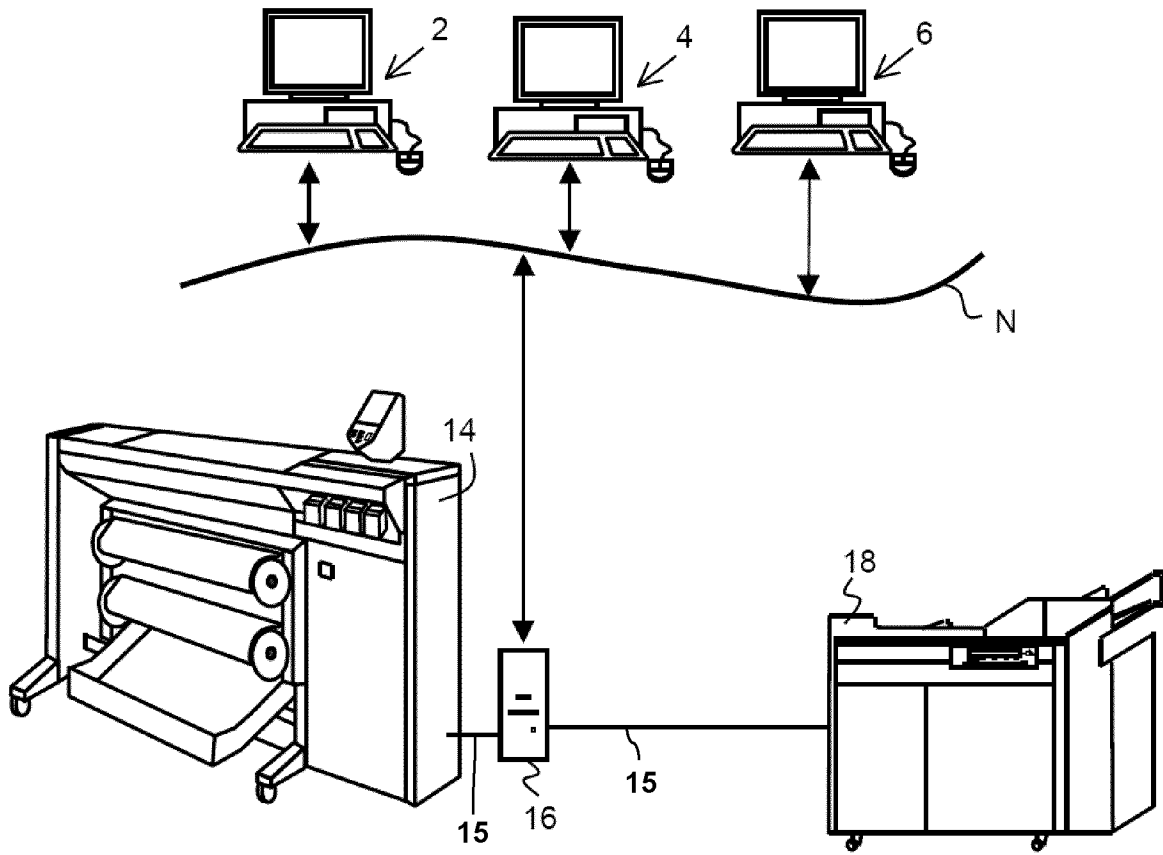


Fig. 1

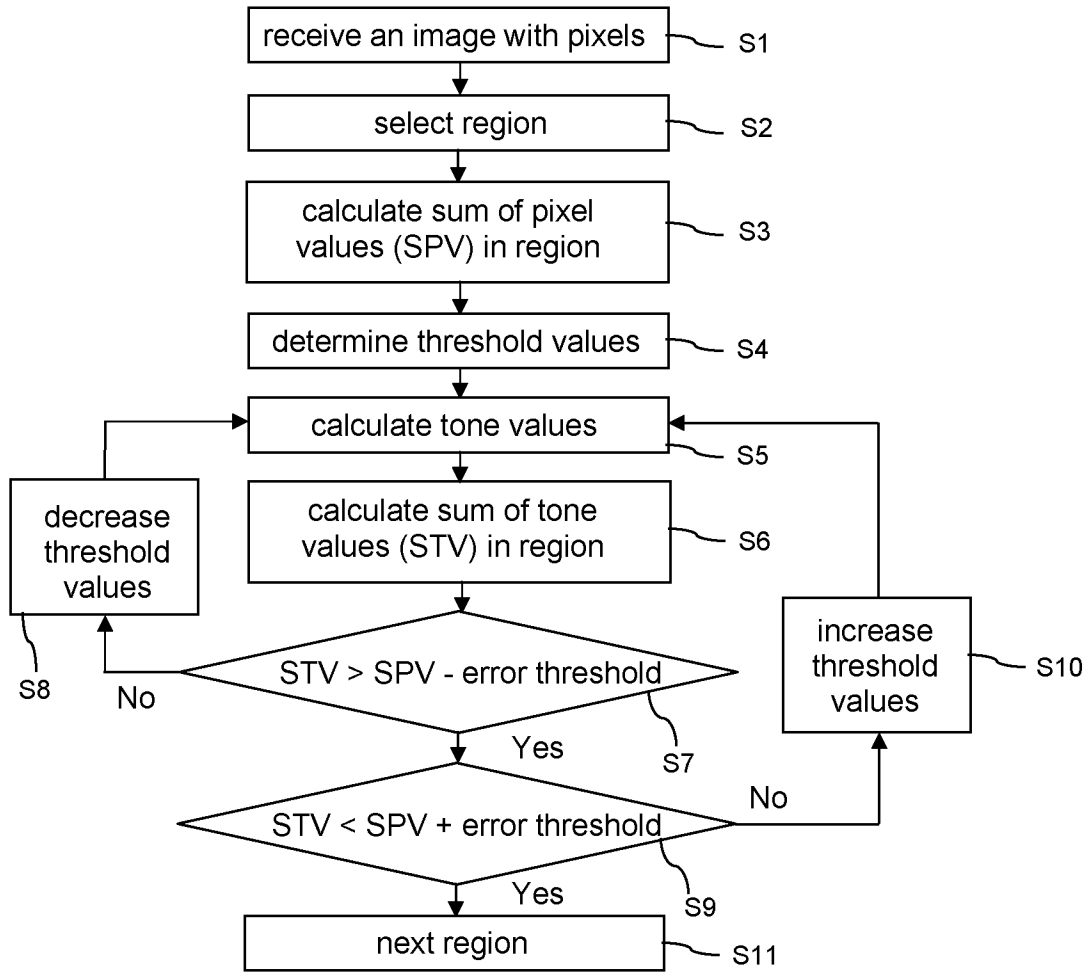


Fig. 2

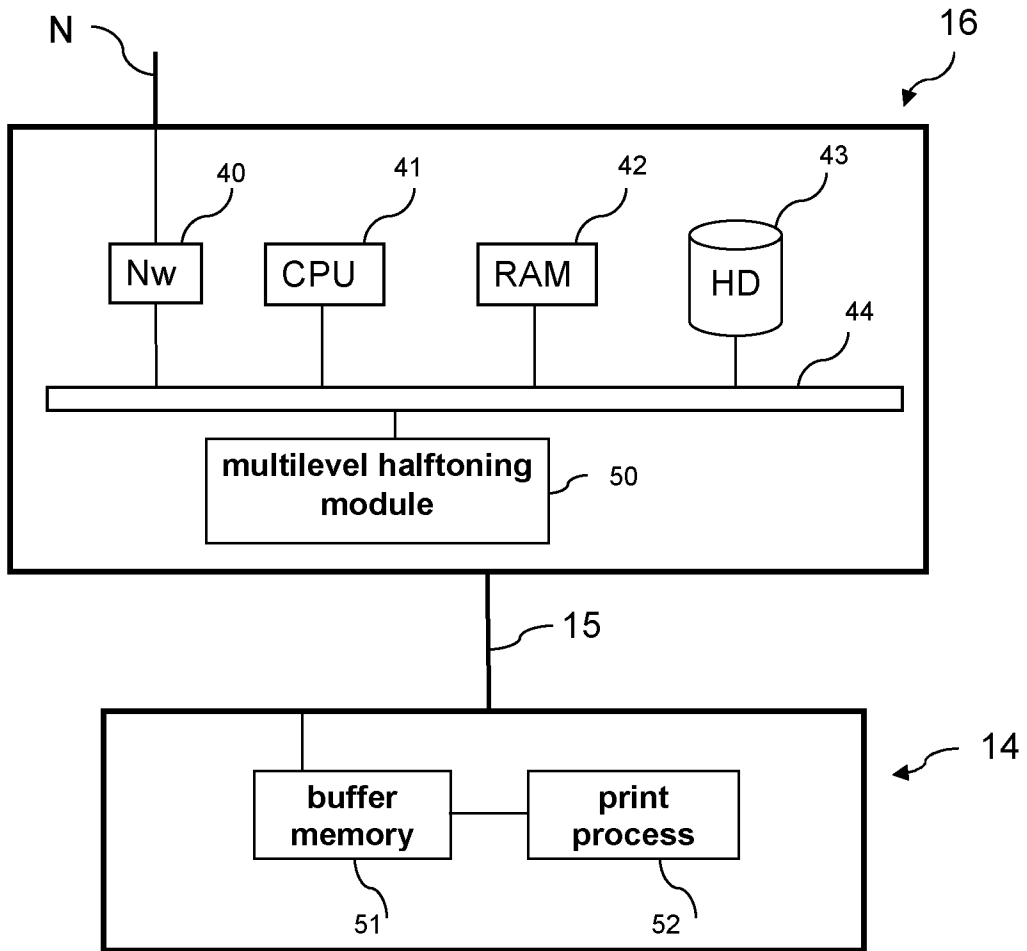


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/050890

A. CLASSIFICATION OF SUBJECT MATTER INV. H04N1/405 H04N1/40 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols) H04N		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2002/196484 A1 (CHANG CHING-WEI [US]) 26 December 2002 (2002-12-26) paragraph [0021] - paragraph [0032] -----	1-7
Y	US 2006/077466 A1 (ISHII HIROSHI [JP] ET AL) 13 April 2006 (2006-04-13) paragraph [0091] - paragraph [0094] paragraph [0125] - paragraph [0141] -----	1-7
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A	US 2002/186417 A1 (INOUE YOSHIAKI [JP]) 12 December 2002 (2002-12-12) paragraph [0114] - paragraph [0180] -----	1-7
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.		
* Special categories of cited documents :		
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed		"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family
Date of the actual completion of the international search 11 April 2012		Date of mailing of the international search report 18/04/2012
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Wunderlich, Doreen

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/EP2012/050890

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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