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(54) METHOD, COMPUTER PROGRAM PRODUCT AND APPARATUS FOR ENHANCING A COMPUTERIZED TOMOGRAPHY IMAGE

VERFAHREN, COMPUTERPROGRAMMPRODUKT UND VORRICHTUNG ZUR VERBESSERUNG EINES COMPUTERISIERTEN TOMOGRAPHIEBILDES

METHODE, PRODUIT DE PROGRAMME INFORMATIQUE ET APPAREIL POUR AMELIORER UNE IMAGE TOMOGRAPHIQUE INFORMATISEE

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Description

Technical Field

[0001] The present invention relates to a method, an apparatus and a computer program product for improving a digital image, and more specifically a computerized tomography image consisting of reconstructed data, according to the preamble of the respective independent claim.

Technical Background

[0002] It is known that in computerized tomography (CT) images, the intensity level may be used for distinguishing different types of tissue. A CT system may be calibrated such that the intensity values correspond to Hounsfield units (HU) as given in the table below:

Tissue	Intensity value [HU]
Bone	1000
Liver	40-60
White matter in brain	46
Gray matter in brain	43
Blood	40
Muscle	10-40
Kidney	30
Cerebrospinal fluid	15
Water	0
Fat	-50 - 100
Air	-1000

[0003] The Hounsfield units normally range from -1000 to 3000, but in some applications the HU scale is shifted into values between 0 and 4000.

[0004] As is apparent from the table above, examination of different types of tissue requires the inspection of different intensity value ranges, also referred to as intensity windows.

[0005] Due to the limitations of display screens, and also to limitations of the human eye, it is common to display a maximum of 256 (2^8) different gray values or shades on the display screen. Hence, in order to obtain a useful view of a CT image showing tissues having intensity values close to each other, it is necessary to display only a limited portion of the total HU scale.

[0006] In the following, the displayed or processed intensity value range will be referred to as an 'intensity window'. If e.g. bones are examined one typically chooses a very wide window width of 1000-2000 HU, whereas for the examination of soft tissue, more narrow window widths of 400-600 HU are used and for brain examinations very narrow window widths of 50-100 HU are common.

[0007] Due to the different anatomies viewed and the very different intensity ranges, the different cases require different noise reduction and contrast enhancement treatment. However it is still desirable to store the result in one image and be able to switch between intensity windows in case different tissues are to be examined.

[0008] In US 5,594,767, an original CT image is combined with a smoothed version of the original CT image, the combination being based on a classification map. The smoothed image is non-selectively smoothed, i.e. it smoothes the entire image, regardless of the values of the respective image elements.

Summary of the Invention

[0009] It is an object of the present invention, which is defined by the appended claims, to provide an improved method for improving a CT image.

[0010] The objective is achieved by a method, a device, a signal, and a computer program product according to the appended independent claims. Embodiments are set forth in the appended dependent claims and in the following

description.

[0011] in brief, there is provided a method for enhancing a CT image composed of a plurality of elements, each having an intensity value indicative of a tissue type. The method comprises receiving a first CT image, providing a plurality of copies of said first CT image, subjecting said plurality of copies of said first CT image to an enhancement processing, where said enhancement processing enhances said plurality of copies of said first CT image with respect to predetermined intensity value ranges, and combining said processed plurality of copies of said first CT image with said first CT image, whereby an enhanced CT image is provided, said combining being based on a classification with respect to intensity values of regions within said first CT image and said plurality of copies of said first CT image.

[0012] A CT image may be any representation of CT scan data, e.g. a two-, three- or four dimensional data set.

[0013] The plurality of copies of the first CT image constitute enhancement processed full or partial copies of the first CT image, e.g. they may comprise subsets of the elements of the first CT image.

[0014] The enhancement processing may be any processing with a view to improving the quality of the plurality of copies of the first CT image.

[0015] According to yet another aspect, there is provided a method for enhancing a first digital image composed of a plurality of elements, each having an intensity value associated therewith. The method comprises receiving a first digital image, providing, by enhancement processing based on said first digital image, a plurality of copies of said first digital image, and combining said plurality of copies of said first digital image with said first digital image, whereby an enhanced digital image is provided. The combining is based on a classification with respect to intensity values of regions within said first digital image and the plurality of copies of said first digital images. The enhancement processing is performed with respect to predetermined intensity value ranges. The digital image may be any type of medical image, such as a CT image, an x-ray image etc. The digital image may be two-, three-, or four dimensional.

[0016] This approach allows for intrinsically different processing of different intensity windows. Also, the above described method enables the use of different processing settings for different intensity windows and then combines the results into one image.

[0017] The presented approach also allows the use of more advanced processing methods that for instance adapt locally to the image structure in an anisotropic way.

[0018] Hence, in contrast to prior art, the present invention keeps a weight for each considered intensity window, i.e. tissue class. Then different methods are applied to the different regions and finally the results are combined. A plurality of different images are created that are combined into a single result according to the original intensity values.

[0019] According to further aspects, there are provided a computer program product and an apparatus for implementing the above described method.

Brief description of the drawings

[0020] Embodiments will now be described in more detail with reference to the appended drawings.

[0021] Fig. 1 is a schematic flow chart illustrating a *method according to the present disclosure.

[0022] Fig. 2 is a schematic flow chart illustrating a detail of the flow chart of Fig. 1.

[0023] Fig. 3 is a schematic diagram of a device 1 in which the method of Figs 1 and 2 may be implemented.

[0024] Fig. 4 is a section of a simplified CT image.

[0025] Fig. 5 is a first processed version of the CT image in Fig. 4.

[0026] Fig. 6 is a second processed version of the CT image in Fig. 4.

[0027] Fig. 7 is a combined CT image based on the first and second CT images.

[0028] Figs 8-10 illustrates masks used in combining the CT images.

Description of Embodiments

[0029] For a description of the general function of a CT system, reference is made to US 5,594,767. Hence, the description of how a CT image is generated is left out.

[0030] Fig. 1 flow chart illustrating a method for improving CT scan data. In step 101, a CT image is received. It is understood that a CT image, for the purpose of this description, may be received in different manners and formats, e.g. from a storage device, via a computer network, or directly from a computer that performed an image reconstruction based on CT detector data.

[0031] Furthermore, in the following description, the CT images are assumed to be two-dimensionally indexed data sets, composed of a plurality of elements, each of which being associated with an intensity value, which may be presented in Hounsfield units. Hence, the original CT image received in step 101 has been subjected to some known type of preprocessing and/or image reconstruction such as to provide a data set that is processable as an image.

[0032] In step 102, processing parameters are received. Such processing parameters may include an indication of what intensity value range or ranges to study, an indication of what type or types of processing to perform, an indication

of parameters subject to which the respective processing is to be performed. The input or inputs in step 102 may be received in different manners, e.g. in the form of a selection made by a user, in the form of an automatic determination made based on what is to be studied (e.g. what type of tissue), or it may be preprogrammed.

[0033] It is recognized that steps 101 and 102 may be performed in the reverse order.

[0034] In a first embodiment, the original CT image may be used as input to the processing step 103, whereby an enhanced image is provided as an output, and whereby the original CT image, or a copy thereof, is maintained.

[0035] One or more CT image copies may be provided based on the original CT image. The CT image copy may be used as input to the processing step 103, so as to maintain the CT image intact. The CT image copies may be complete or partial copies of the original CT image. For example, a CT image copy may be a copy of only a region of the original CT image, such that the CT image copy becomes smaller than the original CT image. As another example, a CT image copy may be a copy of only those elements of the original CT image, which have intensity values within a certain, predetermined intensity value range. The CT image copies may be stored in a working memory or in a non-volatile memory.

[0036] Step 102 and the step of providing the CT image copy may be performed in reverse order.

[0037] In step 103, the CT image copies are subjected to enhancement processing, whereby an enhancement processed CT image is obtained.

[0038] Each one of the images may be processed in a predetermined manner. In one embodiment, the different images are subjected to processing within certain intensity windows. In another embodiment, the different images are subjected to different types of processing, i.e. to different algorithms. In yet another embodiment, the different images are subjected to the same type of processing but with different processing parameters. In yet another embodiment, one of the images is not subjected to processing at all, whereas the other images are.

[0039] In one embodiment, the CT image is maintained and then combined with the enhancement processed CT image. In yet another embodiment, also the original CT image is subjected to enhancement processing and then combined with another enhancement processed CT image. Hence, two, three or more enhancement processed CT images may be provided and combined.

[0040] There are many different types of processing of the original CT image and/or the CT image copies: low-pass filters, contrast enhancement using unsharp masking as described in US 5,038,387, rank filters such as the median and its variants and more advanced processing methods such as adaptive filtering, such as described in Westin,C.-F., Richolt, J., Moharir, V. & Kikinis, R.: Affine Adaptive Filtering of CT Data, Medical Image Analysis 4, 161-177. 2000 and in US 6,556,720. Such adaptive filtering may for example be based on local structure analysis, as described in US 4,747,150, US 4,747,151, US 4,747,152 and Carmona, R.A. & Zhong, S.: Adaptive smoothing respecting feature directions, IEEE Transactions on Image Processing 7(3), 353-358. 1998. Other types of processing includes mean-shift filtering as described in Dominguez, G.F., Bischof, H. & Beichel, R.: Fast 3D Mean Shift Filter for CT Images, SCIA, 438-445, 2003, Göteborg, Sweden, Springer, LNCS 2749; variational methods as described in Niessen, W., Ter Haar Romeny, B. & Viergever, M.A.: Geodesic Deformable Models for Medical Image Analysis, IEEE Transaction on Medical Imaging 17 (4), 634-641, 1998 and Gilboa, G., Sochen, N. & Zeevi, Y.Y.: Forward and Backward Diffusion Processes for Adaptive Image Enhancement and Denoising, IEEE Transaction on Image Processing 11(7), 689-703, 2002; multiband techniques such as those described in Dippel, S., Stahl, M., Wiemker, R. & Blaffert, T.: Multiscale Contrast Enhancement Radiographies: Laplacian Pyramid Versus Fast Wavelet Transform, IEEE Transactions on Medical Imaging 21(4), 343-353, 2002, Vuylsteke, P.P. & Schoeters, E.P.: Multiscale Image Contrast Amplification (MUSICA), SPIE Vol. 2167 Medical Imaging: Image Processing, 551-560. 1994 and in US 5,644,662; or wavelet techniques as described in.Yang, G.Z., Rubens, M.B. & Hansell, D.M.: The use of hybrid structural filtering for the detection of obliterative bronchiolitis from computed tomographic images, IPA, IEE Conference Publication No. 443, 631-635, 1997.

[0041] In one embodiment, it is determined beforehand which data subsets of the original CT image or CT image copy need to be processed, whereby all other data elements are excluded from the processing, in order to increase the overall execution speed. However, in a simple implementation the entire data set can be processed in parallel, or sequentially.

[0042] There is no explicit need to segment the various intensity windows beforehand and it suffices to apply the various enhancement schemes adapted to each window in parallel. However, in order to speed up the overall calculation, it is possible to compute masks (weights) for each window as described below and only apply the computation where the associated weight differs from zero.

[0043] In step 104, the enhancement processed images and possibly also the original CT image (or a copy thereof) are combined or merged such that a combined CT image is obtained. Merging of the results obtained by the different processing methods or parameter settings is based, on the associated intensity window or intensity value range. As changes are more visible for smaller window widths, the results may be ranked according to the window width, such that smaller windows are given priority over larger windows.

[0044] In the following, a description of an algorithm for merging the images will be given with reference to Fig. 2, wherein the windows are assumed to be specified by their respective center c and width w.

[0045] The algorithm may consist of the following steps, which are performed for all data elements:

[0046] In step 1041, the CT images are prioritized according to window width (intensity value range), such that the window having the smallest width is placed first: w1 < w2 < ... < wN. By prioritizing the intensity windows, it is possible to control which window is to be used in case of overlapping areas.

[0047] In step 1042, region masks are determined by thresholding the original image, according to the following exemplifying pseudo code, wherein masks is the thus far segmented data, orgIm is the original CT image, maskX is a mask for the respective CT image copy and maskB is a mask for the non-segmented parts of the original image.

```
maskS = 0
for X = 1 ... N
      {
      maskX = 1 if (cX - wX/2 ≤ orgIm ≤ cX + wX/2) and (maskS =
      0)
      maskS = maskS + maskX
      }
maskB = non-segmented parts
```

[0048] Step 1042 may also be expressed according to the following:

1. initialize: $M_s(m,n)=0 \; \forall n,m$
x=1

2.

$$M_x(m,n) = \begin{cases} 1 & if \quad (c_x - {}^{w_x}\!/_2) \le I(m,n) \le (c_x + {}^{w_x}\!/_2) \quad AND \quad M_s(m,n) = 0 \\ 0 & else \end{cases}$$

3.

$$M_s(m,n) = M_s(m,n) + M_x(m,n)$$

4. ifx<N then x = x+1 goto step 2

5.

$$M_b(m,n) = \left\| M_s(m,n) - 1 \right\|$$

where M_i indicates mask number i and i=x, s, b, I represents the original image data and m,n indexes the data elements.

[0049] It is recognized that steps 1041 and 1042 may be performed in the reverse order.

[0050] In step 1044, which is optional, the masks are smoothened by convolving with a low-pass kernel designated G:

$$\texttt{maskX = G * maskX for X = 1 … N, B}$$

[0051] Step 1044 may also be expressed according to the following:

$$M_x = G * M_x$$

which is to be understood as convolution of the entire mask array.

[0052] In step 1045, the region masks are normalized according to the following exemplifying pseudo code:

```
maskX = maskX / (mask1 + mask2 + … + maskN + maskB)  for X = 1
… N, B
```

[0053] Step 1045 may also be expressed as:

$$M_x(m,n) = \frac{M_x(m,n)}{M_1(m,n) + M_2(m,n) + \ldots + M_N(m,n) + M_B(m,n)}$$

[0054] In step 1046, the results are combined according to the following exemplifying pseudo code, wherein enhIm designates the enhanced combined CT image and wherein resultX etc indicates the output of the processing step 104a-c for CT image copy number X:

```
enhIm = maskB · orgIm + mask1 · result1 + … + maskN · resultN
```

[0055] Step 1046 may also be expressed as:

$$E(m,n) = M_B(m,n) \cdot I(m,n) + M_1(m,n) \cdot R_1(m,n) + \ldots + M_N(m,n) \cdot R_N(m,n)$$

where E denotes the final enhanced image and R_i, i=1..N, the previously obtained results from the processing according to the individual intensity windows.

[0056] It should be noted that in order to avoid artifacts near the boundaries of the respective regions, it is possible to apply a low-pass filter to the segmented masks in step 1044 above. In one embodiment, a small Binomial or Gaussian filter may be chosen, however any other low-pass kernel will do.

[0057] The method segments the original data and then applies a spatial transition (smoothing) between areas to smooth the transition.

[0058] The combining as described above, and in particular the normalizing, may be useful as the proposed method recombines intensity values and it is essential that the local mean of these Hounsfield units is not altered by the processing.

[0059] In step 105, the combined CT image is output, e.g. by being displayed on a screen, stored in a memory or sent via a network.

[0060] Optionally, a step 1047 comprising a morphological closing and/or opening may be included with respect to the masks, thereby removing or filling small gaps in the respective masks. The morphological closing and/or opening step 1047 may be arranged to take place at anytime between the determination of the region masks 1042 and the combining 1046 of the CT images.

[0061] Fig. 3 is a schematic diagram of a device 1 in which the above described method may be implemented. The device 1 comprises receiving means 2 for receiving a CT image from e.g. a network, a storage medium or from a preprocessing device. The device 1 further comprises a processing unit 3, which is adapted for performing the above described method or methods. The device 1 also comprises output means 4 for outputting an enhanced CT image. The processing unit may consist of a programmable processor, which by means of software is programmed to perform the described method. In another embodiment, the preprocessing device may take the shape of a digital signal processor that is adapted to perform the described method. Such a preprocessing device may be provided in the form of e.g. an ASIC or any structure having similar functionality.

[0062] It is also possible to implement the method in the form of a propagated signal comprising components for performing the steps of the above described method when said components are executed in a computer.

[0063] Below, the processing of a section of a simplified 2D CT image will be described with reference to Figs 4-10. In Figs 4-7, the horizontal axis illustrates image elements in e.g. a vertical line of the respective CT image. The vertical axis illustrates the HU value of the respective image element in the section.

[0064] Fig. 4 is a section of an original CT image, e.g. as received in step 101 (Fig. 1). In the described example, two

intensity windows will be considered: a wide window ranging from about 1250 HU to about 3650 HU, which is illustrated by the dotted lines in Fig. 4; and a narrow window ranging from about 2150 to about 2600 HU, which is illustrated by the dashed lines in Fig. 4. The respective window may be determined as described above. In one particular embodiment, the limits of the intensity window may be determined by a graphical user interface, wherein the lines illustrating the limits of the intensity window are presented in relation to a section of the image that is to be processed, whereby the user, by means of a pointing device, drags the lines to desired positions.

[0065] Fig. 5 is a first processed version of the original CT image in Fig. 4, as provided by step 103 (Fig. 1). In the illustrated embodiment, the original CT image of Fig. 4 has been subjected to a low-pass filter, with respect to the wide window. Such low-pass filtering suppresses noise.

[0066] Fig. 6 is a second processed version of the original CT image in Fig. 4. In the illustrated embodiment, the original CT image has been subjected to a structure-adaptive processing with respect to the narrow window. Such structure-adaptive processing preserves small details in the CT image, but does not suppress noise to the same extent.

[0067] Fig. 7 is a combined CT image based on the first and second processed CT images, as provided by step 104 (Fig. 1). The combination has been made with respect to the intensity windows associated with the first and second processed CT images.

[0068] Figs 8-10 illustrates masks used in combining the CT images. Fig. 8 illustrates the mask associated with the narrow window, i.e. with all image elements having values within that window. Fig. 9 illustrates the mask associated with the wide window, i.e. with all image elements falling within that window, but outside the narrow window. Fig. 10 illustrates the background mask, i.e. with all image elements falling outside both the narrow and the wide window. It should be noted that the masks have a slightly smooth transition, due to the low-pass filtering of the original binary masks.

[0069] It should also be noted that in case a morphological closing and/or opening step 1047 (Fig. 2) would be performed with respect to the masks illustrated in Figs 8 and 9, then the unevenness shown in the regions between 50-90 and 170-210 on the horizontal scale would be removed.

[0070] Referring back to Fig. 7, it is noted that for those elements whose HU values fall outside both windows, the data from the original CT image (Fig. 4) is used. For those elements whose HU values fall within the narrow window, the data from the second CT image (Fig. 6) is used. For those elements whose HU values fall within the wide window, but outside the narrow window, the data from the first CT image (Fig. 5) is used.

[0071] Even though the above description focuses on 2D image slices, the method is analogously applicable to the processing of higher dimensional data such as direct 3D or 4D enhancement of CT data.

[0072] It should also be noted that although the description focuses on CT images, the described method is analogously applicable to any type of image, and in particular to medical images, such as x-ray, MRI, etc.

[0073] Additional areas of application for the method described above include, but is not limited to, nondestructive testing, e.g. for use in quality assurance in the manufacturing industry; analysis of logs in saw mills and in connection with airport luggage security checks.

Claims

1. A method of enhancing a first digital image composed of a plurality of elements, each having an intensity value, said image depicting objects, the method comprising:

receiving (101) said first digital image,
providing at least one copy of said first digital image,
subjecting said at least one copy to enhancement processing (103) such that each said at least one copy is enhanced with respect to a respective predetermined intensity value range corresponding to one object class, and
combining (104) said at least one copy with said first digital image, whereby an enhanced digital image is provided, said combining comprising:

determining (1042) a first region mask for said first image, said first region mask defining an area within the first image, whose elements have intensity values within a first intensity value range,
determining (1042) a respective additional region mask for said at least one copy, said respective additional region mask defining an area within a respective copy, whose elements have intensity values within said predetermined intensity value range, and
combining (1046) said first image and said at least one copy, weighted by their respective region masks, whereby said enhanced image is provided, wherein the method is **characterized by** further comprising:

prioritizing (1041) said first digital image and said at least one copy of said first digital image, whereby

an element of an image having a higher priority is included in the enhanced image and a correspondingly located element of an image having a lower priority is excluded from the enhanced image.

2. The method of claim 1, further comprising receiving an indication of said predetermined value range and associating said predetermined intensity value range with said at least one copy of said first digital image.

3. The method of claim 1, wherein said enhancement processing (103) is adaptive to a local structure defined by at least some of said plurality of elements.

4. The method of claim 3, wherein said local structure is defined by a group of elements whose intensity values are within said predetermined intensity value range.

5. The method of claim 1, wherein said enhancement processing (103) comprises applying a non-linear filter to said at least one copy of said first digital image.

6. The method of claim 1, wherein said enhancement processing (103) is selected from a group consisting of a noise reduction using a low pass filter, a contrast enhancement using unsharp masking, a rank filtering, an adaptive filtering, a mean-shift filtering, a variational method, a multiband technique and a wavelet technique.

7. The method of any one of claims 1 or 6, further comprising smoothing (1044) said region masks.

8. The method of any one of claims 1-7 further comprising normalizing (1045) said region masks.

9. The method of any one of claims 1-8, further comprising subjecting at least one of said region masks to a morphological closing and/or opening algorithm.

10. The method of any one of claims 1-9, wherein said first digital image is selected from a group consisting of a two-dimensional array, a three-dimensional array and a four-dimensional array.

11. The method as claimed in any one of claims 1-10, wherein said first digital image is subjected to a second enhancement processing prior to said combining (104).

12. The method as claimed in claim 11, wherein said second enhancement processing is performed with respect to a second predetermined intensity value range.

13. The method as claimed in any one of claims 1 to 12, wherein said first digital image is a CT image and wherein said object class is a tissue type.

14. A computer program product comprising software code portions for performing the steps of any one of claims 1-13, when said product is run on a computer.

15. A storage medium having stored thereon a computer program product according to claim 14.

16. A propagated signal comprising software code for performing the steps of the method according to any one of claims 1-13, when said software code is run on a computer.

17. A device for enhancing a first digital image composed of a plurality of elements, each having an intensity valuer, said image depicting objects, the device comprising:

means (2) for receiving said first digital image,
means (3) for providing at least one copy said first digital image,
means for subjecting said at least one copy to enhancement processing (103) such that each said at least one copy is enhanced with respect to a respective predetermined intensity value range corresponding to one object class, and
means for combining (104) said at least one copy with said first digital image, whereby an enhanced digital image is provided, said device further comprising:

means for determining (1042) a first region mask for said first image, said first region mask defining an area

within the first image, whose elements have intensity values within a first intensity value range,
means for determining (1042) a respective additional region mask for said at least one copy, said respective additional region mask defining an area within a respective copy, whose elements have intensity values within said predetermined intensity value range, and
means for combining (1046) said first image and said at least one copy, weighted by their respective region masks, whereby said enhanced image is provided, wherein the device is **characterized in that** it further comprises:

means for prioritizing (1041) said first digital image and said at least one copy of said first digital image, whereby an element of an image having a higher priority is included in the enhanced image and a correspondingly located element of an image having a lower priority is excluded from the enhanced image.

Patentansprüche

1. Verfahren zum Verbessern eines ersten Digitalbildes, zusammengesetzt aus einer Mehrzahl von Elementen mit jeweils einem Intensitätswert, wobei das Bild Gegenstände wiedergibt, mit den folgenden Verfahrensschritten:

- Aufnehmen (101) des ersten digitalen Bildes,
- Bereitstellen wenigstens einer Kopie des ersten digitalen Bildes,
- Unterwerfen wenigstens einer Kopie einem Verbesserungsprozess (103), wobei jede der wenigstens einen Kopie in Bezug auf einen jeweiligen vorgegebenen Intensitätswertbereich, entsprechend einer Objektklasse verbessert wird,
- Kombinieren (104) die wenigstens eine Kopie mit dem ersten digitalen Bild, wobei ein verbessertes digitales Bild erzeugt wird, und wobei das Kombinieren umfasst:

Bestimmen (1042) einer ersten Bereichsmaske für das erste Bild, wobei die erste Bereichsmaske ein Feld innerhalb des ersten Bildes definiert, dessen Elemente Intensitätswerte innerhalb des ersten Intensitätswertbereiches aufweisen;
Bestimmen (1042) einer entsprechenden zusätzlichen Bereichsmaske für die wenigstens eine Kopie, wobei die entsprechende zusätzliche Bereichsmaske ein Feld innerhalb einer entsprechenden Kopie definiert, dessen Elemente Intensitätswerte innerhalb des genannten vorbestimmten Intensitätwertbereiches aufweisen, und
Kombinieren (1046) des ersten Bildes mit der wenigstens einen Kopie, gewichtet durch deren entsprechende Bereichsmasken, wobei das genannte verbesserte Bild geschaffen wird, wobei das Verfahren durch den weiteren Verfahrensschritt **gekennzeichnet**:

Priorisieren (1041) des ersten digitalen Bildes und der wenigstens einen Kopie des ersten digitalen Bildes, wobei ein Element eines Bildes mit höherer Priorität im verbesserten Bild eingeschlossen ist, und ein entsprechend angeordnetes Element eines Bildes mit einer niederen Priorität vom verbesserten Bild ausgeschlossen ist.

2. Verfahren nach Anspruch 1, umfassend das Aufnehmen einer Anzeige des genannten vorgegebenen Wertbereiches sowie dessen Zuordnen zu der genannten wenigstens einen Kopie des genannten ersten digitalen Bildes.

3. Verfahren nach Anspruch 1, wobei der Verbesserungsprozess (103) an eine lokale Struktur anpassbar ist, definiert durch wenigstens einige der Mehrzahl von Bildelementen.

4. Verfahren nach Anspruch 3, wobei die genannte lokale Struktur definiert ist durch eine Gruppe von Elementen, deren Intensitätswerte innerhalb des genannten vorgegebenen Intensitätswertbereiches liegen.

5. Verfahren nach Anspruch 1, wobei der genannte Verbesserungsprozess (103) das Anwenden eines nicht-linearen Filters auf die genannte wenigstens eine Kopie des ersten digitalen Bildes umfasst.

6. Verfahren nach Anspruch 1, wobei der genannte Verbesserungsprozess (103) ausgewählt ist aus einer Gruppe, bestehend aus einem Rauschunterdrücken unter Verwendung eines low-path Filters, einer Kontrastverbesserung unter Verwenden einer unscharfen Maske, einem Bereich filtern, einem adaptiven Filtern, einem Mittelverschiebe-

filtern (mean-shift filtering), einem Variationenverfahren, einer Multibandtechnik und einer Wellenlängentechnik.

7. Verfahren nach einem der Ansprüche 1 bis 6, weiterhin umfassend das Glätten (1044) der genannten Bereichsmasken.

8. Verfahren nach einem der Ansprüche 1 bis 7, weiterhin umfassend das Normalisieren (1045) der genannten Bereichsmasken.

9. Verfahren nach einem der Ansprüche 1 bis 8, weiterhin umfassend das Unterwerfen wenigstens einer der genannten Bereichsmasken einem morphologischen Schließ- und/oder Öffnungs-Algorithmus.

10. Verfahren nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet, dass** das erste genannte digitale Bild ausgewählt ist aus einer Gruppe, umfassend ein zweidimensionales Feld, ein dreidimensionales Feld und ein vierdimensionales Feld.

11. Verfahren nach einem der Ansprüche 1 bis 10, **dadurch gekennzeichnet, dass** das genannte erste digitale Bild einem zweiten Verbesserungsprozess vor dem genannten Kombinieren (104) unterworfen wird.

12. Verfahren nach Anspruch 11, **dadurch gekennzeichnet, dass** der zweite Verbesserungsprozess in Bezug auf einen vorgegebenen Intensitätswertbereich ausgeführt wird.

13. Verfahren nach einem der Ansprüche 1 bis 12, **dadurch gekennzeichnet, dass** das genannte erste digitale Bild ein CT-Bild ist, und dass die Objektklasse eine Gewebeart ist.

14. Computerprogrammprodukt, umfassend Softwarecodebereiche zum Durchführen der Schritte gemäß einem der Ansprüche 1 bis 13, wenn das genannte Produkt auf einem Computer läuft.

15. Speichermedium, auf dem ein Computerprogrammprodukt gemäß Anspruch 14 gespeichert ist.

16. Ein fortschreitendes Signal, umfassend einen Softwarecode zum Durchführen der Schritte gemäß dem Verfahren nach einem der Ansprüche 1 bis 13, wenn der Softwarecode (TS) auf einem Computer läuft.

17. Vorrichtung zum Verbessern eines ersten Digitalbildes, zusammengesetzt aus einer Mehrzahl von Elementen, deren jedes einen Intensitätswert aufweist, wobei das Bild ein Objekt wiedergibt, umfassend:

- Mittel (2) zum Aufnehmen des ersten digitalen Bildes
- Mittel (3) zum Bereitstellen wenigstens einer Kopie des genannten ersten digitalen Bildes
- Mittel zum Unterwerfen der wenigstens einen Kopie einem Verbesserungsprozess (103), derart, dass jede der genannten wenigstens einen Kopie in Bezug auf einen entsprechenden vorgegebenen Intensitätswertbereich entsprechend einer Objektklasse unterworfen wird, und
- Mittel zum Kombinieren (104) der wenigstens einen Kopie mit dem genannten ersten digitalen Bild, wobei das verbesserte digitale Bild erzeugt wird, wobei die Vorrichtung weiterhin umfasst:

  - Mittel zum Bestimmen (1042) einer ersten Bereichsmaske für das genannte erste Bild, wobei die erste Bereichsmaske ein Feld innerhalb des ersten Bildes definiert, dessen Elemente Intensitätswerte innerhalb eines ersten Intensitätswertbereiches aufweist
  - Mittel zum Bestimmen (1042) einer entsprechenden zusätzlichen Bereichsmaske für die genannte wenigstens eine Kopie, wobei die entsprechende zusätzliche Bereichsmaske ein Feld innerhalb einer entsprechenden Kopie definiert, dessen Elemente Intensitätswerte innerhalb des genannten vorgegebenen Intensitätswertbereiches aufweisen, und
  - Mittel zum Kombinieren (1046) des ersten Bildes und der ersten genannten Kopie, gewichtet durch ihre entsprechenden Bereichsmasken, wobei das genannte verbesserte Bild erzeugt wird, **dadurch gekennzeichnet, dass** weiterhin vorgesehen sind:

    - Mittel zum Priorisieren (1041) des genannten ersten digitalen Bildes und der genannten wenigstens einen Kopie des ersten digitalen Bildes, wobei ein Element eines Bildes einer höheren Priorität im verbesserten Bild eingeschlossen ist, und ein entsprechend angeordnetes Element eines Bildes mit einer niedrigeren Priorität vom verbesserten Bild ausgeschlossen ist.

Revendications

1. Procédé d'amélioration d'une première image numérique constituée d'une pluralité d'éléments, chacun ayant une valeur d'intensité, ladite image représentant des objets, le procédé comprenant :

   la réception (101) de ladite première image numérique,
   la fourniture d'au moins un exemplaire de ladite première image numérique,
   la soumission d'au moins ledit exemplaire à un traitement d'amélioration (103) de sorte qu'au moins ledit exemplaire soit amélioré par rapport à une gamme de valeurs d'intensité prédéterminée respective correspondant à une classe d'objet, et
   la combinaison (104) d'au moins ledit exemplaire avec une première image numérique, moyennant quoi une image numérique améliorée est obtenue, ladite combinaison comprenant :

      la détermination (1042) d'un masque d'une première région pour ladite première image, ledit masque de la première région définissant une zone dans la première image dont les éléments ont des valeurs d'intensité dans une première gamme de valeurs d'intensité,
      la détermination(1042) d'un masque respectif d'une région supplémentaire pour au moins ledit exemplaire, ledit masque respectif de région supplémentaire définissant une zone dans un exemplaire respectif dont les éléments ont des valeurs d'intensité dans ladite gamme de valeurs d'intensité prédéterminée, et
      la combinaison (1046) de ladite première image et dudit exemplaire, pondérée par leurs masques de région respectifs, moyennant quoi, une image améliorée est obtenue, le procédé étant **caractérisé par le fait qu'**il comprend en outre :

         le classement par ordre de priorité (1041) de ladite première image numérique et dudit exemplaire de ladite première image numérique, moyennant quoi un élément d'une image ayant une priorité supérieure est intégré dans l'image améliorée et un élément situé de façon correspondante d'une image ayant une priorité inférieure est exclu de l'image améliorée.

2. Procédé selon la revendication 1, comprenant en outre la réception d'une indication de ladite gamme de valeurs prédéterminée et l'association de ladite gamme de valeurs d'intensité prédéterminée avec au moins ledit exemplaire de ladite première image numérique.

3. Procédé selon la revendication 1, dans lequel ledit traitement d'amélioration (103) s'adapte à une structure locale définie par au moins certains des multiples éléments.

4. Procédé selon la revendication 3, dans lequel ladite structure locale est définie par un groupe d'éléments dont les valeurs d'intensité entrent dans ladite gamme d'intensité prédéterminée.

5. Procédé selon la revendication 1, dans lequel ledit traitement d'amélioration (103) comprend l'application d'un filtre non linéaire au moins audit exemplaire de ladite première image.

6. Procédé selon la revendication 1, dans lequel ledit traitement d'amélioration (103) est choisi dans un groupe comprenant une réduction du bruit en utilisant un filtre passe-bas, un renforcement du contraste en utilisant un masquage flou, un filtrage de rang, un filtrage adaptatif, un filtrage à décalage moyen, un procédé à variations, une technique multibande et une technique par ondelettes.

7. Procédé selon l'une quelconque des revendications 1 à 6, comprenant en outre le lissage (1044) desdits masques de région.

8. Procédé selon l'une quelconque des revendications 1 à 7, comprenant en outre la normalisation (1045) desdits masques de région.

9. Procédé selon l'une quelconque des revendications 1 à 8, comprenant en outre la soumission d'au moins l'un desdits masques de région à un algorithme morphologique de fermeture et/ou d'ouverture.

10. Procédé selon l'une quelconque des revendications 1 à 9, dans lequel ladite première image numérique est choisie dans le groupe comprenant une série bidimensionnelle, une série tridimensionnelle et une série quadridimensionnelle.

11. Procédé selon l'une quelconque des revendications 1 à 10, dans lequel ladite première image numérique est soumise à un deuxième traitement d'amélioration avant ladite combinaison (104).

12. Procédé selon la revendication 11, dans lequel ledit second traitement d'amélioration est réalisé par rapport à une deuxième gamme de valeurs d'intensité prédéterminée.

13. Procédé selon l'une quelconque des revendications 1 à 12, dans lequel ladite première image numérique est une image TD et dans lequel ladite classe d'objets est de type tissu.

14. Produit de programme informatique comprenant des parties de codec logiciel pour réaliser les étapes selon l'une quelconque des revendications 1 à 13, ledit produit étant lu sur un ordinateur.

15. Support de stockage comportant, stocké sur celui-ci, un produit de programme informatique selon la revendication 14.

16. Signal propagé comprenant un codec logiciel pour réaliser les étapes du procédé selon l'une quelconque des revendications 1 à 13, ledit codec logiciel étant lu sur un ordinateur.

17. Dispositif pour améliorer une première image numérique constituée d'une pluralité d'éléments, chacun ayant une valeur d'intensité, ladite image représentant des objets, le dispositif comprenant :

des moyens (2) de réception de ladite première image numérique,
des moyens (3) de fourniture d'au moins un exemplaire de ladite première image numérique,
des moyens de soumission d'au moins ledit exemplaire à un traitement d'amélioration (103) de sorte qu'au moins ledit exemplaire soit amélioré par rapport à une gamme de valeurs d'intensité prédéterminée respective correspondant à une classe 'd'objet, et
la combinaison (104) d'au moins ledit exemplaire avec une première image numérique, moyennant quoi une image numérique améliorée est obtenue, ledit dispositif comprenant en outre :

des moyens de détermination (1042) d'un masque d'une première région pour ladite première image, ledit masque de la première région définissant une zone dans la première image dont les éléments ont des valeurs d'intensité dans une première gamme de valeurs d'intensité,
des moyens de détermination (1042) d'un masque respectif d'une région supplémentaire pour au moins ledit exemplaire, ledit masque respectif de région supplémentaire définissant une zone dans un exemplaire respectif dont les éléments ont des valeurs d'intensité dans ladite gamme de valeurs d'intensité prédéterminée, et
des moyens de combinaison (1046) de ladite première image et dudit exemplaire, pondérée par leurs masques de région respectifs, moyennant quoi, une image améliorée est obtenue, le procédé étant **caractérisé par le fait qu'**il comprend en outre :

des moyens de classement par ordre de priorité (1041) de ladite première image numérique et dudit exemplaire de ladite première image numérique, moyennant quoi un élément d'une image ayant une priorité supérieure est intégré dans l'image améliorée et un élément situé de façon correspondante d'une image ayant une priorité inférieure est exclu de l'image améliorée.

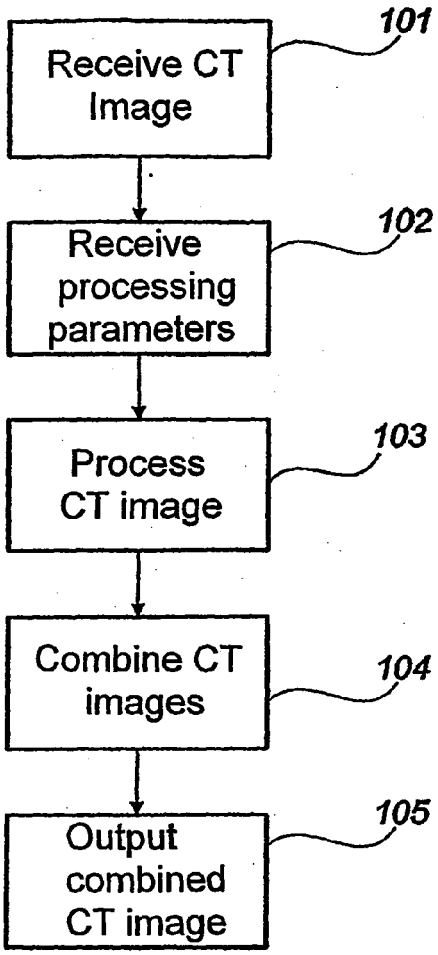

Receive CT Image
101
Receive processing parameters
102
Process CT image
103
Combine CT images
104
Output combined CT image
105

Fig. 1

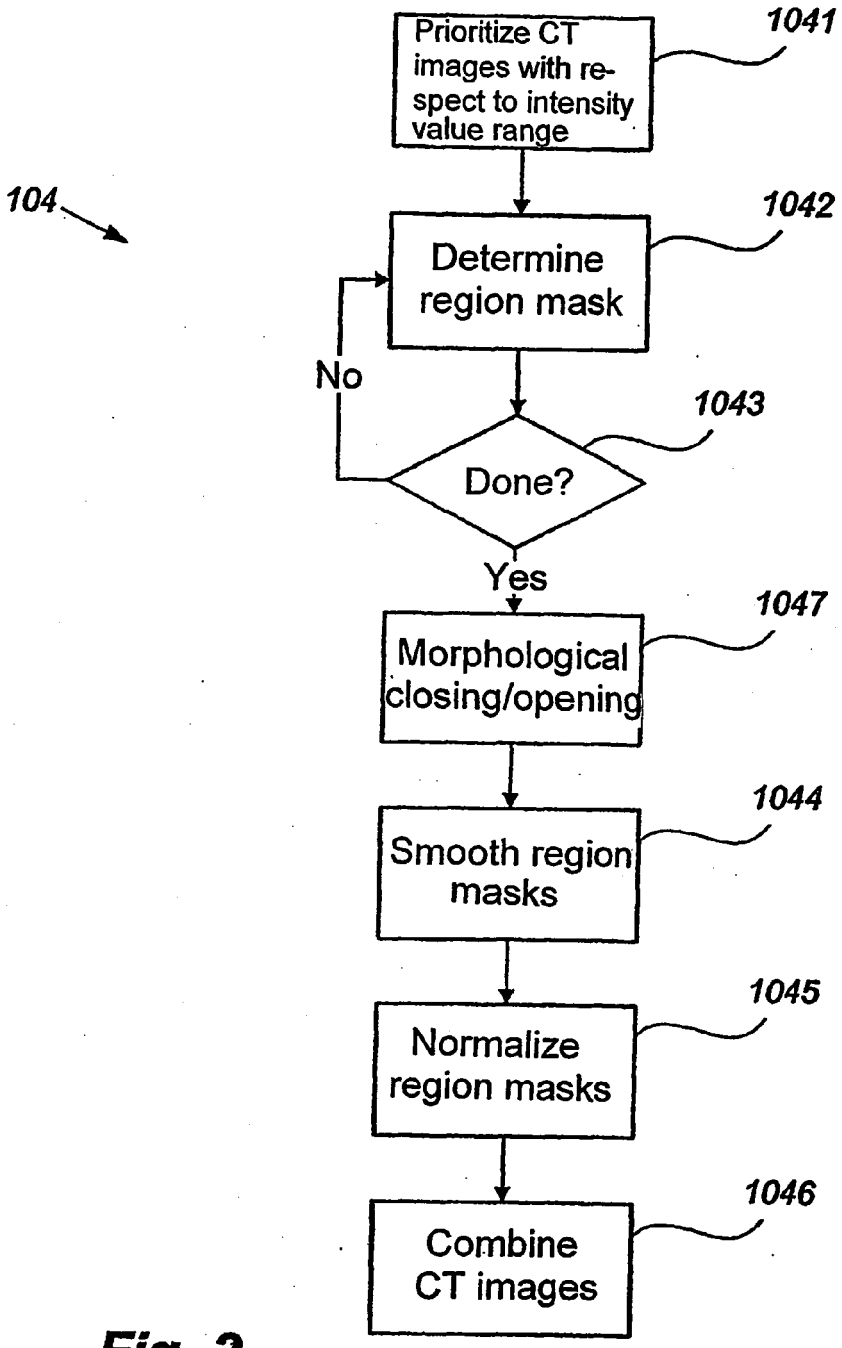

104
Prioritize CT images with respect to intensity value range
1041
Determine region mask
1042
No
Done?
1043
Yes
Morphological closing/opening
1047
Smooth region masks
1044
Normalize region masks
1045
Combine CT images
1046

Fig. 2

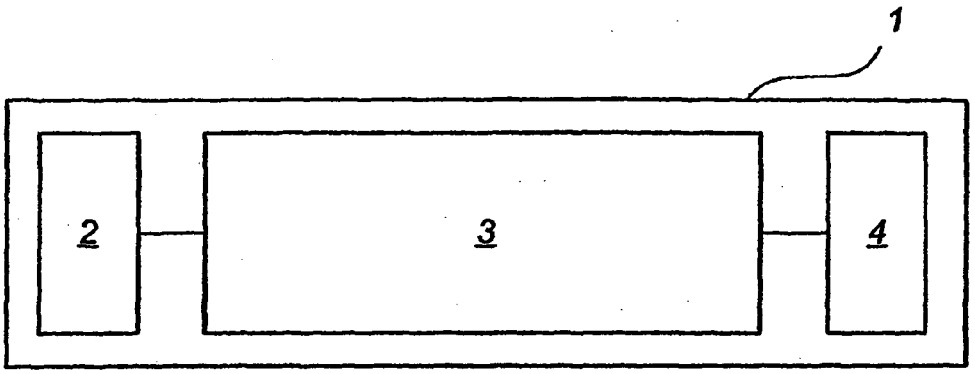
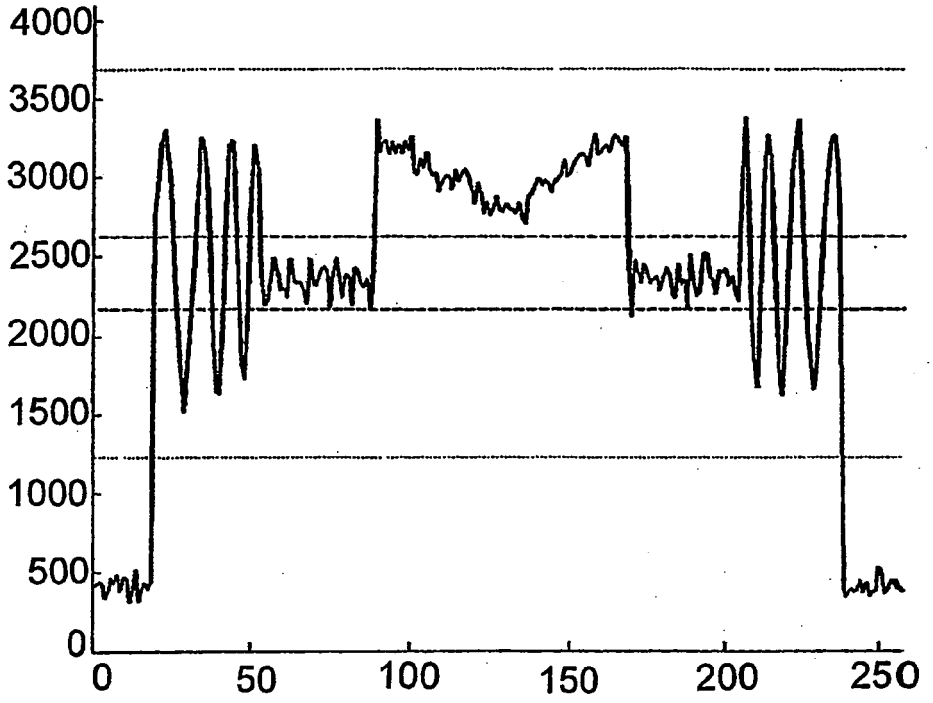


Fig. 3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3000
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2000
1500
1000
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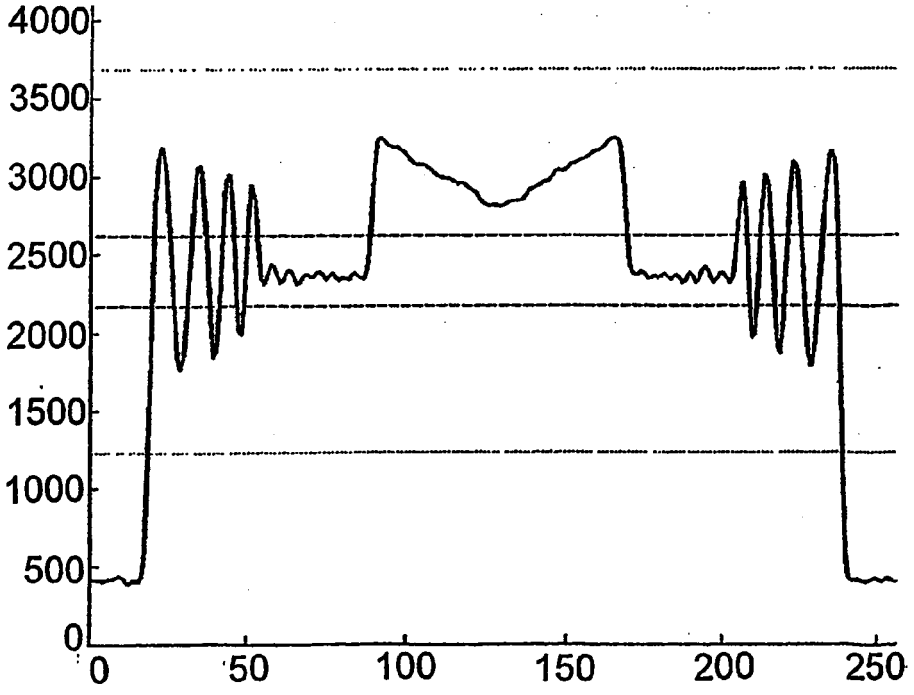
0
0
50
100
150
200
250

Fig. 4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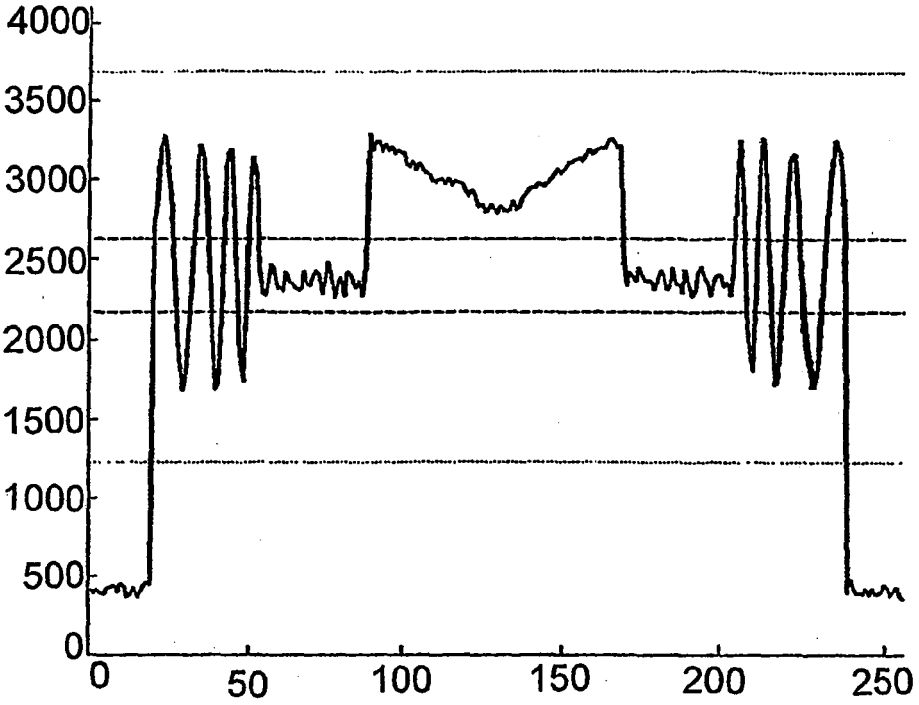
150
200
250

Fig. 5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50
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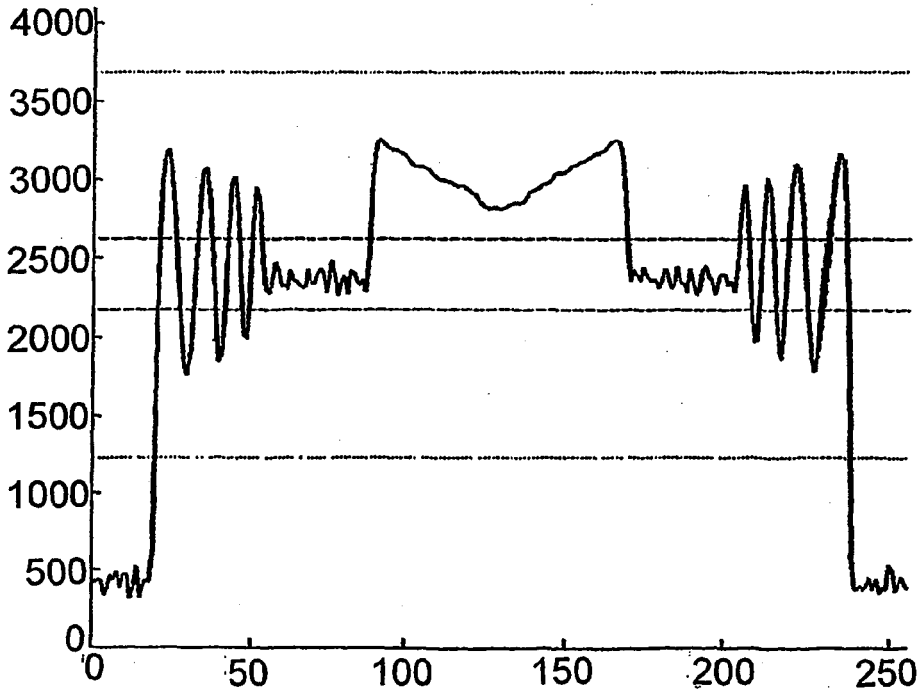
200
250

Fig. 6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0
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100
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200
250

Fig. 7

Fig. 8

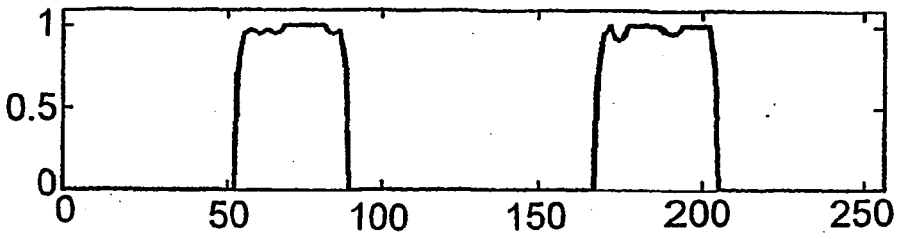


Fig. 9

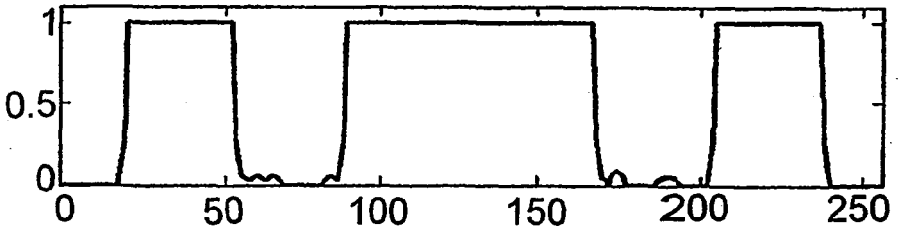
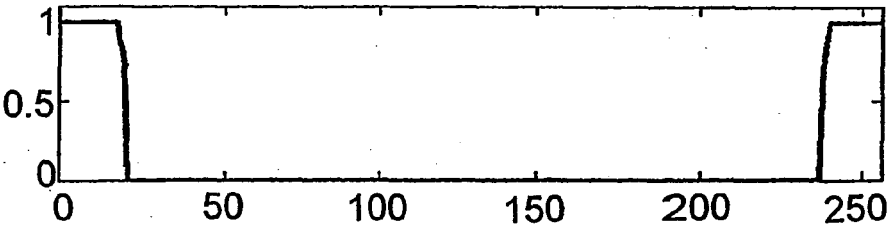


Fig. 10



REFERENCES CITED IN THE DESCRIPTION

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