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(54) **METHOD AND APPARATUS FOR ENHANCING IMAGE QUALITY OF A TWO-DIMENSIONAL ULTRASOUND IMAGE**

(75) Inventors: **Cheol An Kim**, Yongin-si (KR); **Young Seuk Song**, Seoul (KR); **Eun Ho Yang**, Seoul (KR); **Jong Beom Ra**, Daejeon (KR); **Yong Sun Kim**, Daejeon (KR); **Dong Hoon Yu**, Gwangju (KR)

Correspondence Address:
OBLON, SPIVAK, MCCLELLAND, MAIER & NEUSTADT, P.C.
1940 DUKE STREET
ALEXANDRIA, VA 22314 (US)

(73) Assignee: **Medison Co., Ltd.**, Hongchun-gun (KR)

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(57) **ABSTRACT**

The present invention relates a method and an apparatus for enhancing ultrasound image quality through a post-processing. A method for enhancing an image quality of a two-dimensional (2D) ultrasound image, comprises the steps of: a) decomposing the 2D ultrasound image into a plurality of images having a multi-resolution by N levels, wherein N is a positive integer; b) determining characteristics of each pixel in the decomposed image; c) performing an enhancement process for the decomposed image based on the pixel characteristics; d) performing 1st-level composition for the decomposed image; and e) repeatedly performing steps b) to d) until a size of the composed image is identical to that of the 2D ultrasound image.

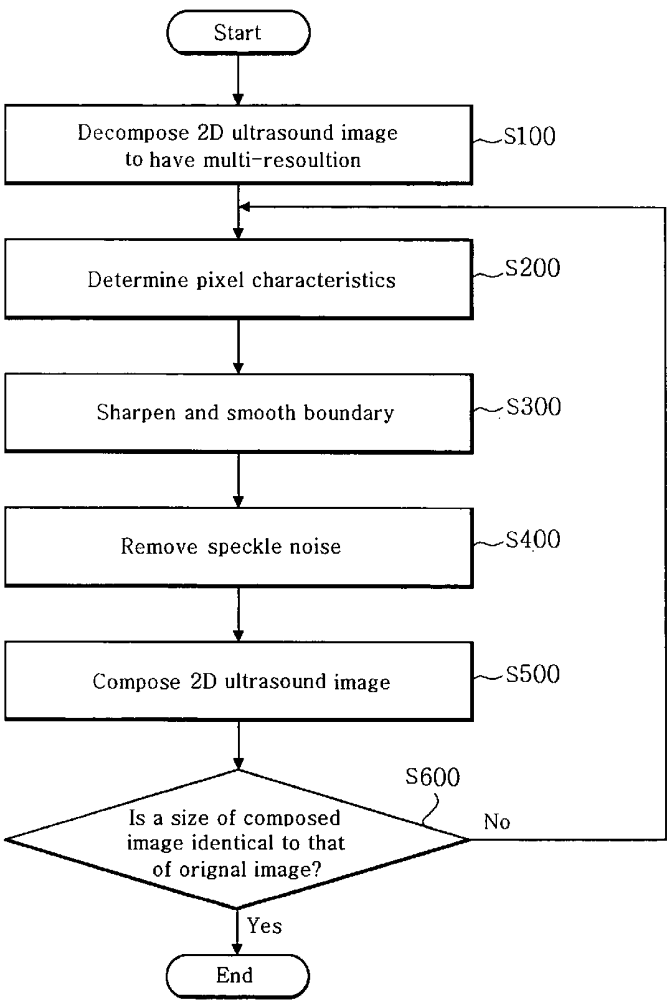


Fig. 1

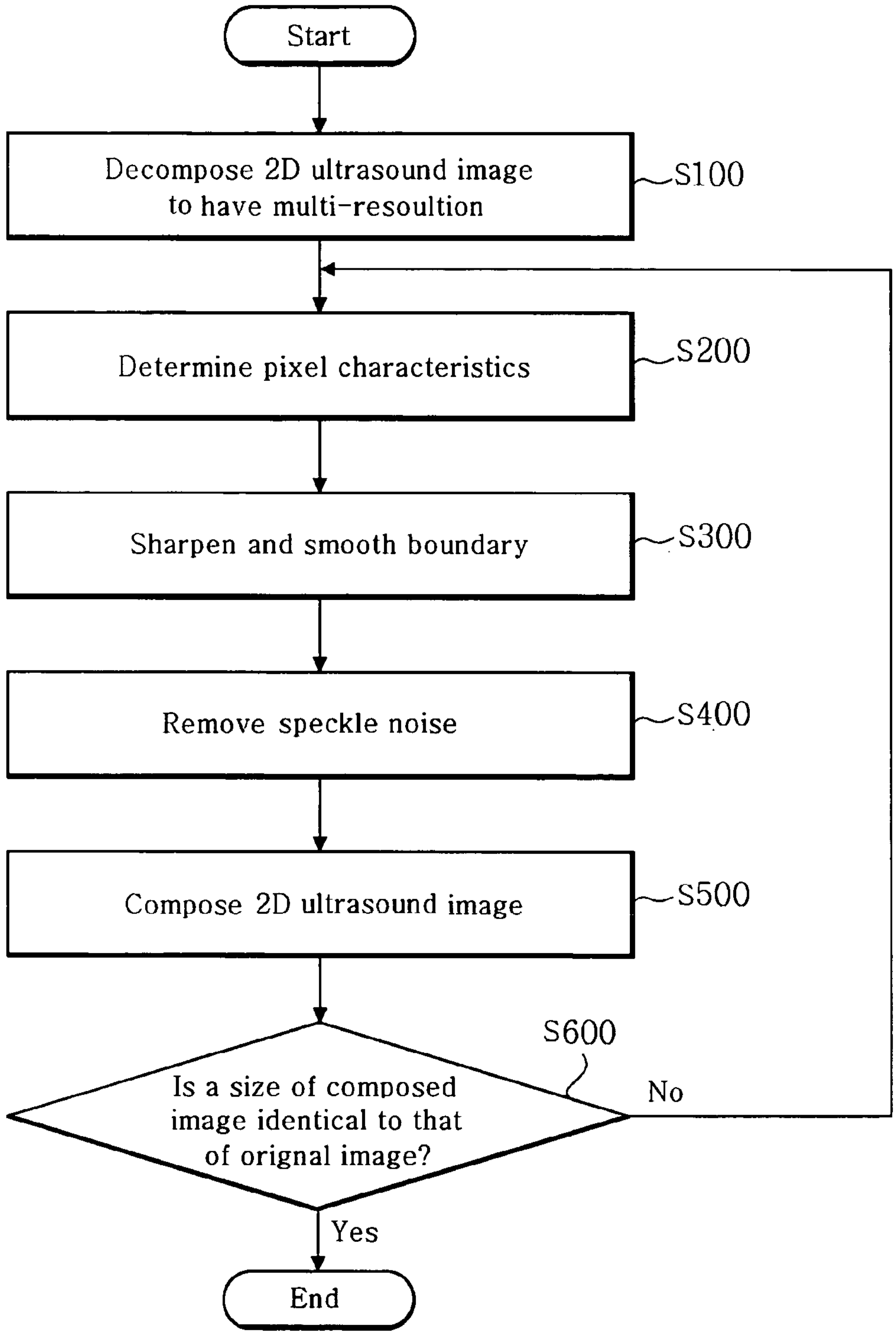

Start
Decompose 2D ultrasound image to have multi-resoultion
S100
Determine pixel characteristics
S200
Sharpen and smooth boundary
S300
Remove speckle noise
S400
Compose 2D ultrasound image
S500
S600
Is a size of composed image identical to that of orignal image?
No
Yes
End

Fig. 2A

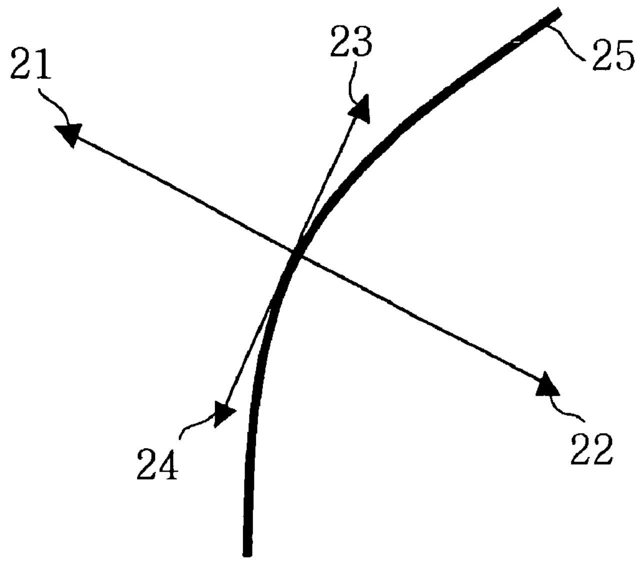
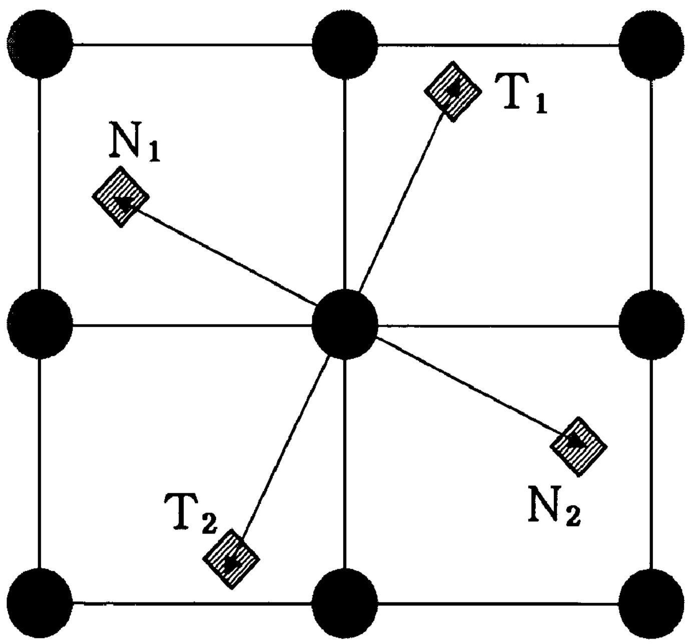


Fig. 2B



METHOD AND APPARATUS FOR ENHANCING IMAGE QUALITY OF A TWO-DIMENSIONAL ULTRASOUND IMAGE

FIELD OF THE INVENTION

[0001] The present invention generally relates to an ultrasound diagnostic device, and more particularly to a method and an apparatus for enhancing the image quality of an ultrasound image in an ultrasound diagnostic device.

BACKGROUND OF THE INVENTION

[0002] An ultrasound diagnostic device is used in various medical fields. The ultrasound diagnostic device is adapted to transmit ultrasound signals to organs and acquire an ultrasound image by detecting the ultrasound signals that reflect from the organs. When the ultrasound signals are transmitted to the organs, the reflection and scattering of the ultrasound signals occur at the same time, thus generating a speckle noise. The speckle noise degrades not only the ultrasound image quality but also the accuracy of displaying important parts such as the boundary between a target object and a background. Also, the speckle noise makes it difficult to analyze the ultrasound image and to distinguish different types of organs from the ultrasound image.

[0003] In order to resolve the above-identified problems, a method for removing the speckle noise has been sought and researched in the art. Currently, the most widely used method for removing the speckle noise is to apply a heat equation. According to this method, the pixels of an ultrasound image are segmented into a plurality of areas wherein an appropriate Gaussian filtering for each area is carried out, thereby removing the speckle noise. Also, the speckle noise can be removed by applying a non-linear threshold to each frequency in the ultrasound image on the basis of wavelet. However, since the ultrasound image removing the speckle noise according to the conventional methods produces uncomfortable and unnatural feelings, it is not useful for application in a clinical setting. Also, when the ultrasound image removing the speckle noise according to the conventional methods is displayed on a display unit, a problem typically arises in which the boundaries of organs are not clearly displayed.

SUMMARY OF THE INVENTION

[0004] It is an object of the present invention to provide a method and an apparatus for enhancing the image quality of a two-dimensional (2D) ultrasound image by efficiently removing the speckle noise and conspicuously displaying the boundaries of organs.

[0005] In accordance with an aspect of the present invention, there is provided a method for enhancing the image quality of a two-dimensional (2D) ultrasound image. The method comprises the following steps: a) decomposing the 2D ultrasound image into a plurality of images having multi-resolution by N levels, wherein N is a positive integer; b) determining characteristics of each pixel in the decomposed image; c) performing an enhancement process for the decomposed image based on the pixel characteristics; d) performing 1-level composition for the decomposed image; and e) repeatedly performing steps b) to d) until a size of the composed image is identical to that of the 2D ultrasound image.

[0006] In accordance with another aspect of the present invention, there is provided an apparatus for enhancing the image quality of a two-dimensional (2D) ultrasound image. The apparatus comprises the following elements: a decomposition unit for decomposing the 2D ultrasound image into a plurality of images having multi-resolution by N levels, wherein N is a positive integer; a determination unit for determining characteristics of each pixel in the decomposed image; an enhancement unit for enhancing the decomposed image according to the pixel characteristics; and a composition unit for performing an N-level composition for the decomposed image.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The above and other objects and features of the present invention will become apparent from the following description of preferred embodiments given in conjunction with the accompanying drawings, in which:

[0008] **FIG. 1** is a flow chart showing a process for enhancing an image quality of a 2-dimensional (2D) ultrasound image through a post-processing in accordance with the present invention;

[0009] **FIG. 2A** is a diagram illustrating an eigenvector at a boundary; and

[0010] **FIG. 2B** is a schematic diagram illustrating an enhancement process in accordance with the present invention.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

[0011] **FIG. 1** is a flow chart showing a process for enhancing an image quality of a 2-dimensional (2D) ultrasound image through a post-processing in accordance with the present invention.

[0012] Referring to **FIG. 1**, an ultrasound image is decomposed to obtain a multi-resolution at step **S100**. The ultrasound image may be an image before or after performing a scan conversion process. The multi-resolution analysis is carried out by decomposing an arbitrary image into a plurality of images having a multi-resolution and analyzing the decomposed images. A high frequency component and a low frequency component in the ultrasound image can be obtained through the multi-resolution analysis. In order to obtain the image having the multi-resolution, the wavelet transform and Laplacian pyramid code may preferably be used. In accordance with the present invention, any image decomposition method can be applied to obtain the image having the multi-resolution. Further, the decomposition process can be carried out by N levels, wherein N is a positive integer.

[0013] Hereinafter, the decomposition method using N-level wavelet transform for the ultrasound image will be described in detail as an example in accordance with the present invention. After the 1^{st}-level wavelet transform is performed, the images of the low frequency component and the high frequency component, wherein each image corresponds to a 2^{-1} size of an original image, can be obtained. Also, the images of the low frequency component and the high frequency component, wherein each image corresponds to a 2^{-2} size of the original image, can be obtained through the 2^{nd}-level wavelet transform. By repeating the wavelet transform by N, the images of the low frequency component and the high frequency component, wherein each image corresponds to a 2^{-N} size of the original image, can be obtained.

[0014] Pixels of the image of the low frequency component, among the images decomposed through the N-level wavelet transform, are segmented according to pixel characteristics at step **S200**. In order to segment the pixels of the image of the low frequency component, it must be determined whether each pixel of the image corresponds to a boundary of organs, a speckle, or a plate area according to the pixel characteristics.

[0015] First, after computing an eigenvalue and an eigenvector of a predetermined range of pixels (e.g., 5×5 or 10×10) with linear algebra used in the pertinent art, a tangential direction vector and a normal direction vector of each pixel are computed by using the eigenvalue and the eigenvector. Thereafter, a magnitude difference between the tangential direction vector and the normal direction vector is compared with a threshold value. Then, the pixel characteristics are determined according to the comparison result.

[0016] That is, if the magnitude difference between the tangential direction vector and the normal direction vector is greater than the threshold value, then this means that a magnitude component of one of the vectors is dominant in one direction such that it is determined that the pixel corresponds to the boundary of the organs. On the other hand, if the magnitude difference between the tangential direction vector and the normal direction vector is smaller than the threshold value, then this means that there are no dominant magnitude components in any direction. If a certain pixel is a speckle, since magnitudes of the two vectors are largely represented in every direction, a magnitude difference between the tangential direction vector and the normal direction vector becomes smaller than the threshold value. Also, if a certain pixel is a plate area, since the two vectors are represented as a small vector in every direction, a magnitude difference between the tangential direction vector and the normal direction vector becomes smaller than the threshold value.

[0017] Through the above process, the tangential direction vector and the normal direction vector in each pixel are extracted so that it can be determined whether the pixel corresponds to the boundary of the organs, the speckle or the plate area.

[0018] An enhancement process for a portion determined to be the boundary of the organs at step **S200** is carried out at step **S300**. A smoothing process is carried out in a tangential vector direction so as to enhance the continuity of the boundary. Then, a sharpening process is carried out to make the boundary clear in the normal vector direction. The sharpening process can be implemented through a low-pass filtering process performed only in a tangential direction of the boundary.

[0019] **FIGS. 2A and 2B** are diagrams illustrating the enhancement process in accordance with the present invention. After decomposing the ultrasound image to obtain the multi-resolution through the wavelet transform, the eigenvector and the eigenvalue are computed for each pixel. Then, the tangential direction vectors **23** and **24** and the normal direction vectors **21** and **22** are represented at an arbitrary pixel, as shown in **FIG. 2A**.

[0020] Next, the scalar values T**1** and T**2** in a tangential direction of a boundary **25**, which are magnitudes of the vectors **23** and **24** in a tangential direction, are computed through linear interpolation. Also, the scalar values N**1** and N**2** in a normal direction of boundary **25**, which are magnitudes of the vectors **21** and **22**, are computed in the same manner.

[0021] Thereafter, the directional smoothing process is carried out in the tangential direction of the boundary by using the scalar values T**1** and T**2** so as to enhance the continuity of the boundary. Then, the directional sharpening process is carried out in the normal direction of the boundary by using the scalar values N**1** and N**2** so as to render the boundary clear. The enhancement process can be represented by the following equation:

$$I'(x,y)=(1-2t+2n)\cdot I(x,y)+t\cdot(T1+T2)-n\cdot(N1+N2) \quad \text{Eq. 1}$$

[0022] Wherein, I'(x,y) represents the pixel values after performing the filtering process; I(x,y) represents the pixel values before performing the filtering process; T**1** and T**2** represent the magnitudes of tangential direction vectors at the pixel; N**1** and N**2** represent the magnitudes of normal direction vectors at the pixel; t represents the degree of directional smoothing; and n represents the degree of directional sharpening.

[0023] The speckle is removed or reduced at step **S400**. Step **S400** is applied to pixels determined as a speckle or a plate area at step **S200**. The speckle can be reduced by applying low pass filtering to the pixels. Also, when using the wavelet transform, the speckle can be reduced by decreasing the coefficients of the high frequency components at the pixels.

[0024] A low-resolution image enhancing the boundary and reducing the speckle is obtained through steps **100** to **S400**. The 1st-level composition process for the low-resolution image is carried out at step **S500**. When the wavelet transform is carried out by N levels for the original image, the image has a 2^{-N} size of the original image. If an inverse wavelet transform of 1st-level is carried out for the decomposed image after carrying out steps **S200** to **S400**, a filtered image having a $2^{-(N-1)}$ size of the original image is obtained.

[0025] Thereafter, it is determined whether a size of the image composed at step **S500** is identical to that of the original image at step **S600**. If the size of the composed image is not identical to that of the original image, then steps **S200** to **S500** are repeated until the size of the composed image is identical to that of the original image. That is, if the decomposition process is carried out by N times, then steps **S200** to **S500** are repeatedly performed by N times. Therefore, an ultrasound image, the boundary of which becomes clearer and in which the speckle noise is removed, can be obtained.

[0026] As described above, after the process for sharpening a portion determined as the boundary is carried out at step **S300**, the process for removing the speckle noise is carried out at step **S400**. Also, the process for removing the speckle noise can be performed prior to the process for sharpening a portion determined as the boundary.

[0027] The present invention can be applied to a 2-dimensional ultrasound image such as a 2-dimensional B mode image representing an arbitrary slice in a 3-dimensional image or the like.

[0028] While the present invention has been described and illustrated with respect to a preferred embodiment of the invention, it will be apparent to those skilled in the art that variations and modifications are possible without deviating from the broad principles and teachings of the present invention which should be limited solely by the scope of the claims appended hereto.

What is claimed is:

1. A method for enhancing an image quality of a two-dimensional (2D) ultrasound image, comprising the steps of:

a) decomposing the 2D ultrasound image into a plurality of images having a multi-resolution by N levels, wherein N is a positive integer;

b) determining characteristics of each pixel in the decomposed image;

c) performing an enhancement process for the decomposed image based on the pixel characteristics;

d) performing 1^{st}-level composition for the decomposed image; and

e) repeatedly performing steps b) to d) until a size of the composed image is identical to that of the 2D ultrasound image.

2. The method as recited in claim 1, wherein the step a) is carried out by using a wavelet transform or a Laplacian pyramid code.

3. The method as recited in claim 1, wherein the step b) includes the steps of:

b1) computing an eigenvector and an eigenvalue of a predetermined range of pixels in the decomposed image;

b2) computing a tangential direction vector and a normal direction vector of each pixel by using the eigenvector and the eigenvalue;

b3) comparing a magnitude difference between the tangential direction vector and the normal direction vector with a threshold value; and

b4) determining the pixel characteristics according to the comparison result.

4. The method as recited in claim 3, wherein the step c) includes the steps of:

c1) performing a directional smoothing process for pixels determined as a boundary at step b4); and

c2) performing a directional sharpening process for the boundary pixels.

5. The method as recited in claim 4, wherein the step c) further includes the steps of reducing speckles for pixels determined as a speckle at step b4).

6. The method as recited in claim 4, wherein the step c) is carried out with a following equation:

$$I'(x,y)=(1-2t+2n)\cdot I(x,y)+t\cdot(T1+T2)-n\cdot(N1+N2)$$

wherein, I'(x,y) represents pixel values after performing the filtering process; I(x,y) represents pixel values before performing the filtering process; T**1** and T**2** represent magnitudes of tangential direction vectors at the pixel; N**1** and N**2** represent magnitudes of normal direction vectors at the pixel; t represents a degree of directional smoothing; and n represents a degree of directional sharpening.

7. An apparatus for enhancing an image quality of a two-dimensional (2D) ultrasound image, comprising:

a decomposition means for decomposing the 2D ultrasound image into a plurality of images having a multi-resolution by N levels, wherein N is a positive integer;

a determination means for determining characteristics of each pixel in the decomposed image;

an enhancement means for enhancing the decomposed image according to the pixel characteristics; and

a composition means for performing an N-level composition for the decomposed image.

8. The apparatus as recited in claim 7, wherein the decomposition means uses a wavelet transform or a Laplacian pyramid code.

9. The apparatus as recited in claim 7, wherein the determination means includes:

a first computing unit for computing an eigenvector and an eigenvalue of a predetermined range of pixels in the decomposed image;

a second computing unit for computing a tangential direction vector and a normal direction vector of each pixel by using the eigenvector and the eigenvalue;

a comparing unit for comparing a magnitude difference between the tangential direction vector and the normal direction vector with a threshold value; and

a determining unit for determining the pixel characteristics according to the comparison result.

10. The apparatus as recited in claim 9, wherein the enhancement means includes:

a directional smoothing unit for performing a directional smoothing process for pixels determined as a boundary at the determining unit; and

a directional sharpening unit for performing a directional sharpening process for the boundary pixels.

11. The apparatus as recited in claim 10, wherein the enhancement means further includes a speckle reducing unit for reducing speckles for pixels determined as a speckle at the determining unit.

12. The apparatus as recited in claim 10, wherein the enhancement means is carried out with the following equation:

$$I'(x,y)=(1-2t+2n)\cdot I(x,y)+t\cdot(T1+T2)-n\cdot(N1+N2)$$

wherein, I'(x,y) represents pixel values after performing the filtering process; I(x,y) represents pixel values before performing the filtering process; T**1** and T**2** represent magnitudes of tangential direction vectors at the pixel; N**1** and N**2** represent magnitudes of normal direction vectors at the pixel; t represents a degree of directional smoothing; and n represents a degree of directional sharpening.

* * * * *

专利名称(译)	用于增强二维超声图像的图像质量的方法和设备		
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申请(专利权)人(译)	MEDISON CO. , LTD.		
当前申请(专利权)人(译)	韩国高等学院科技		
[标]发明人	KIM CHEOL AN SONG YOUNG SEUK YANG EUN HO RA JONG BEOM KIM YONG SUN YU DONG HOON		
发明人	KIM, CHEOL AN SONG, YOUNG SEUK YANG, EUN HO RA, JONG BEOM KIM, YONG SUN YU, DONG HOON		
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优先权	1020040083120 2004-10-18 KR		
其他公开文献	US7664301		
外部链接	Espacenet USPTO		

摘要(译)

本发明涉及通过后处理增强超声图像质量的方法和装置。一种用于增强二维（2D）超声图像的图像质量的方法，包括步骤：a）将2D超声图像分解为具有N个级别的多分辨率的多个图像，其中N是正整数; b）确定分解图像中每个像素的特征; c）基于像素特性对分解图像执行增强处理; d）对分解图像进行第一级组合; e）重复执行步骤b）至d），直到合成图像的尺寸与2D超声图像的尺寸相同。