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(54) **CLUSTERING, NOISE REDUCTION AND VISUALIZATION METHOD FOR DOPPLER ULTRASOUND IMAGES**

CLUSTERING-, RAUSCHVERMINDERUNGS- UND VISUALISIERUNGSVERFAHREN FÜR DOPPLER-ULTRASCHALL-BILDER

GROUPAGE, RÉDUCTION DU BRUIT ET PROCÉDÉ DE VISUALISATION D'IMAGES DOPPLER À ULTRASON

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Description**BACKGROUND OF THE INVENTION**5 **Field of the Invention**

[0001] The invention relates to a method of Doppler ultrasound images clustering, noise reduction and visualization. In particular, a method implemented in an image processing system for Doppler ultrasound images.

10 **Descriptions of the Related Art**

[0002] Receiving of ultrasound images may be distinguished as power Doppler ultrasound image and color Doppler ultrasound image. Power Doppler ultrasound image shows complete artery and vein image, but it does not have direction information on blood flow. Nevertheless color Doppler ultrasound image only shows indirect direction information on blood flow. Otherwise, noise in the Doppler ultrasound images caused by the motion artifacts is also a critical problem for explaining the blood flow information. Thus, some patients should keep stationary during the Doppler examination because breathing may produce motion artifacts. Additionally, there are probe motion artifacts which may be arisen by using a hand-held probe (called a transducer) which is placed directly on and moved over the patient. Therefore, it is necessary to provide a suitable noise-reduced Doppler ultrasound image for evaluating the completely pulsatile information on blood flow.

[0003] In the prior art, Taiwan Patent No. 1275,383 in and US patent No. 8,047,993 B2 disclose a non-invasive measurement method of tumor hemodynamic parameters to detect the degree of malignancy in tumors. The method comprises the steps of: using a power Doppler ultrasound unit to scan a tumor and capture sequential color images in a heartbeat cycle, and choosing an area of interest (AREA_ROI) from the images, labeling pixels reflecting signals of blood flow in the images during one heartbeat cycle to contour an area of tumor blood vessels (AREA_vessel); calculating a difference of PDVI between maximal systolic pressure and diastolic pressure during the heartbeat cycle to obtain tumor differential vascularity index (TDVI), in which PDVI is the ratio obtained by dividing pixels of AREA_vessel by total area in the section of AREA_ROI to determine the degree of malignancy by the TDVI. It can be applied to clinical diagnostic.

[0004] Furthermore, US patent No. 8,047,993 B2 discloses a method for evaluation of renal perfusion with power Doppler ultrasonography. Serial renal vascular images at different vascular areas including the whole vascular tree, interlobar, arcuate, and interlobular vessels were captured. Imaging processing software was designed to analyze the changes of power Doppler intensity of colored pixels within regions of interest (ROI). Power Doppler Vascularity index (PDVI) has been defined as the percentage of vascular perfusion within a region of interest (ROI). The renal vascular perfusion index (RVPI) was defined as the maximal power Doppler vascular index which divided by minimal power Doppler vascular index (PDVI max/PDVI min) among the serial images. The mean of weighted power Doppler vascular index (WPDVI mean) was defined as the average of the intensity of colored pixels among the ROI within the serial images. By using the RVPI and WPDVI mean, a more dynamic sense of vascular perfusion and a novel approach for the evaluation of renal vascular function in clinical practice can be provided.

[0005] However, TW 1275383, US 8,047,993 B2 and US 8,777,860 B2 do not disclose clustering methods for evaluation of pulsatile information from blood flow in a sequence of power Doppler ultrasound images and the color Doppler ultrasound images. Document US5279302 discloses an ultrasonic Doppler blood flow measuring apparatus comprises a plurality of frame memories for storing information pieces about a blood flow speed in a unit of frame, circuits for comparing blood flow speed information pieces at corresponding addresses on the plurality of frame, memories and determining a speed difference, a circuit for comparing the speed difference with a predetermined threshold value and determining a blood flow at the corresponding address as an arterial flow when the speed difference exceeds the threshold value but as a venous flow when the speed difference is below the threshold value, and a circuit for displaying the determined arterial and venous flows in different colors. This prior art document fails to disclose the use of a reference sequence, as well as, the classification of the noise signal. In particular, the present invention provides a method and system to quantify and classify the color pixels in the Doppler ultrasound images into three groups, namely the primary pulsatile signal, the secondary pulsatile signal, and noise signal based on the intensity changes of each color pixel over the sequence of Doppler ultrasound images. The classified signals will be visualized with different color values. Therefore, methods and systems in this invention provide the noise-reduced pulsatile signal images for reflecting pulsatile information form blood flow in the images, which is intended for vascular pulsatility analysis.

55 **SUMMARY OF THE INVENTION**

[0006] The present invention provides a system of clustering, noise reduction and visualization for Doppler ultrasound image as defined in claim 1. The dependent claims define further embodiments. The Doppler ultrasound image processing

system comprises a capture device, a processing device, and an output device, wherein the processing device further comprises a data conversion processor, a data analysis processor, and a data record processor.

[0007] The capture device obtains a plurality of Doppler ultrasound images based on a time domain, wherein each Doppler ultrasound image comprises a color value in each pixel.

[0008] The data conversion processor arranges each color value in each pixel of the Doppler ultrasound images based on the time domain to obtain a plurality of color value sequences.

[0009] The data analysis processor calculates the color value sequences through a referencing method to obtain a reference sequence, and compares the reference sequence with each color value sequences through a clustering method to obtain a plurality of correlation coefficient values, then classifies the color value sequences into a primary pulsatile signal, a secondary pulsatile signal, and a noise signal based on the correlation coefficient values through a clustering and noise reduction method.

[0010] The data record processor annotates the color values of the primary pulsatile signal, the secondary pulsatile signal, and the noise signal to obtain a plurality of visualized pulsatile ultrasound images.

[0011] The output device is connected to the processing device for displaying the visualized pulsatile ultrasound images.

[0012] In an embodiment of the invention, a method as defined in claim 16 implemented in an image processing system of clustering, noise reduction and visualization for Doppler ultrasound image, which comprises: obtaining a plurality of Doppler ultrasound images based on time domain, wherein each Doppler ultrasound image comprises a color value in each pixel; and arranging each color value in each pixel of Doppler ultrasound images based on the time domain to obtain a plurality of color value sequences.

[0013] The method further comprises: calculating the color value sequences through a referencing method to obtain a reference sequence; comparing the reference sequence with each color value sequences through a clustering method to obtain a plurality of correlation coefficient values; using a clustering and noise reduction method to classify the color value sequences into a primary pulsatile signal, a secondary pulsatile signal, and a noise signal based on the correlation coefficient values; and annotating the color values of the primary pulsatile signal, the secondary pulsatile signal, and the noise signal to obtain a plurality of visualized pulsatile ultrasound images.

[0014] Other systems, methods, features, and advantages of the present invention will be or become apparent to one with skill in the art upon examination of following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present invention, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] Many aspects of the disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. 1 is a block diagram of this system of clustering, noise reduction and visualization method for Doppler ultrasound image in accordance with various embodiments of the present invention.

FIG. 2A illustrates a sequence of Doppler ultrasound images based on a time domain in accordance with various embodiments.

FIG. 2B illustrates an arrangement of a plurality of color value sequences based on a time domain in accordance with various embodiments.

FIG. 3 illustrates a diagram for clustering and noise reduction method in accordance with various embodiments of the present invention.

FIG. 4 illustrates common carotid artery and internal jugular vein in the original power Doppler ultrasound image and the corresponding visualized pulsatile ultrasound image in accordance with one embodiment of the present invention.

FIG. 5 illustrates common carotid artery and internal jugular vein in the original color Doppler ultrasound image and the corresponding visualized pulsatile ultrasound image in accordance with one embodiment of the present invention.

FIG. 6 illustrates renal artery and renal vein in the original power Doppler ultrasound image and the corresponding visualized pulsatile ultrasound image in accordance with one embodiment of the present invention.

FIG. 7 illustrates brachial artery and brachial vein of arm in the original power Doppler ultrasound image and the corresponding visualized pulsatile ultrasound image in accordance with one embodiment of the present invention.

5 **FIG. 8** illustrates a diagram for reclassifying the color values to obtain the visualized pulsatile ultrasound image in accordance with one embodiment of the present invention.

FIG. 9 illustrates intensity change value trends of the visualized pulsatile ultrasound image in accordance with one embodiment of the present invention.

10 **FIG. 10** is a flowchart for the method of clustering, noise reduction and visualization for Doppler ultrasound images according to various embodiments of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

15 **[0016]** Having summarized various aspects of the present invention, reference will now be made in detail to the description of the disclosure as illustrated in the drawings. However, these embodiments are not intended to limit the present invention to any environment, applications, or implementations described in these embodiments. Therefore, description of these embodiments is only for purpose of illustration rather than to limit the scope of the present invention. It shall be appreciated that elements unrelated to the present invention are omitted from depiction in the following
20 embodiments and the attached drawings.

[0017] The present invention discloses a method of clustering, noise reduction and visualization for Doppler ultrasound image. It should be noted that the method provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the various components of a system, a computer system, a multiprocessor computing device, and so forth. The execution steps of the present invention may include application
25 specific software which may store in any portion or component of the memory including, for example, random access memory (RAM), read-only memory (ROM), hard drive, solid-state drive, magneto optical (MO), IC chip, USB flash drive, memory card, optical disc, or other memory components.

[0018] For some embodiments, the system comprises a capture device, a processing device, and an output device. The capture device is used to provide data such as image, text or control signals to the processing device such as a
30 computer or other information appliance. The processing device performs data calculations, data comparisons, and data copying. Finally, the information from the analyzing system can be provided by the processing device and presented on the output device such as CRT monitors, LCD monitors and displays, gas plasma monitors, and televisions. The output device visually conveys text, graphics, and spectrum. Information shown on the output device is called soft copy because the information exists electronically and is displayed for a temporary period of time.

35 **[0019]** In accordance with some embodiments, the system further comprises of a storage medium and a memory. For example and without limitation, the storage medium can be a hard drive, an optical device or a remote database server coupled to a network, and storage software. The memory typically is the processor in which information is encoded, stored, and retrieved etc. The software can be stored in the memory and executed by the processing device when the computer system executes the method of clustering, noise reduction and visualization for Doppler ultrasound image.

40 **[0020]** **FIG. 1** is a block diagram of a system **100** of clustering, noise reduction and visualization method for Doppler ultrasound image in accordance with various embodiments of the present invention. The Doppler ultrasound image processing system comprises a capture device **110**, a processing device **120**, and an output device **130**. The processing device **120** includes a data conversion processor **122**, a data analysis processor **124**, and a data record processor **126**.

45 **[0021]** Please refer to **FIG. 2A** and **FIG. 2B** together. **FIG. 2A** illustrates a sequence of Doppler ultrasound images in accordance with various embodiments. **FIG. 2B** illustrates an arrangement of a plurality of color value sequences based on a time domain in accordance with various embodiments. The capture device **110** acquires a plurality of Doppler ultrasound images (*I* frames) **210** based on a time domain, wherein each Doppler ultrasound image comprises a color value in each pixel ($B_{j,i}$) **212**.

50 **[0022]** The data conversion processor **122** arranges the color value in each pixel ($j=1\sim J$) **212** of the Doppler ultrasound images based on the time domain ($i=1\sim I$) to obtain a plurality of color value sequences ($C_1, C_2, C_3, \dots, C_j$) **214**. Each of the color value sequence is a sequence showing intensity change of the pixels. For various embodiments, the sequence showing intensity change of the pixels (C_j) is obtained according to the following expression:

55
$$C_j = \{B_{j,i}\}, \quad i = 1, 2, 3, \dots, I \quad (\text{Equation 1})$$

wherein each $B_{j,i}$ of input data represents the intensity value of the j^{th} pixel at the i^{th} frame based on the definition of the intensity color map given by the original Doppler ultrasound image.

[0023] The data analysis processor 124 calculates the color value sequences through a referencing method to obtain a reference sequence (Cref). The referencing method comprises an intensity percentage method, an average standard deviation ratio method, an autocorrelation method, a hierarchical correlation method or any combination thereof.

[0024] In one embodiment, the data analysis processor 124 performs the intensity percentage method to obtain the reference sequence. The intensity percentage method comprises the steps of: arranging the color value sequences (C1, C2, C3, ...Cj) 214 according to the largest color value of each color value sequence to obtain a plurality of percentile ranks; choosing the color value sequences (j=1~J') which the percentile rank is within a predetermined rank range to obtain a reference group (R.G.); and averaging the color value sequences which the percentile rank belongs to the reference group to obtain the reference sequence. For various embodiments, the reference sequence is calculated according to the following expression:

$$C_{ref.} = \left\{ \frac{\sum_{j \in R.G.} B_{j,i}}{J'} \right\}, \quad i = 1, 2, \dots, I \quad (\text{Equation 2})$$

[0025] In another embodiment, the data analysis processor 124 performs the average standard deviation ratio method to obtain the reference sequence. The average standard deviation ratio method comprises the steps of: calculating the color value in each pixel of color value sequences (j=1~J) to obtain a plurality of standard (Std_j) values; and dividing the standard (Std_j) values by an average value of the standard values (Std Avg) to obtain a plurality of average standard deviation ratio (Avg STD ratio) values. The average standard deviation ratio value is calculated according to the following expression:

$$\text{Avg STD ratio} = \frac{\text{Std}_j}{\text{Std Avg}} = \frac{\text{Std of each } C_j}{\sum_{j=1}^J \frac{\text{Std}_j}{J}}, \quad \forall j \quad (\text{Equation 3})$$

[0026] Then, the reference group is obtained by choosing the color value sequences which the averaging standard deviation ratio value is within a predetermined ratio range, and the reference sequence is obtained by averaging the color value sequences from the reference group.

[0027] In another embodiment, the data analysis processor 124 performs the autocorrelation method to obtain the reference sequence. The autocorrelation method comprises the steps of: calculating each color value sequence through an autocorrelation function with a plurality of lag varieties to obtain a plurality of autocorrelation function values; and choosing a color value sequence which has the smallest autocorrelation value to obtain the reference sequence.

[0028] In another embodiment, the data analysis processor 124 performs the hierarchical correlation method to obtain the reference sequence. The hierarchical correlation method comprises the following steps of: (a) gathering the color value sequences into an ⁱth reference sequence set, wherein an initial value of i is 1; (b) obtaining a plurality of correlation coefficient values of the ⁱth reference sequence set by calculating each pair of the color value sequences in the ⁱth reference sequence set through a correlation function; (c) selecting the pair of the color value sequences in the ⁱth reference sequence set, which have a largest correlation coefficient value; (d) averaging the selected pair of the color value sequences in the ⁱth reference sequence set to generate a new color value sequence; (e) gathering the new color value sequence and the color value sequences in the ⁱth reference sequence set except for the selected pair of the color value sequences into a (ⁱ+1)th reference sequence set; (f) obtaining a plurality of correlation coefficient values of the (ⁱ+1)th reference sequence set by calculating each pair of the color value sequences in the (ⁱ+1)th reference sequence set through the correlation function; (g) determining whether all of the correlation coefficient values of the (ⁱ+1)th reference sequence set are less than a predetermined correlation threshold; and (h) when one of the correlation coefficient values of the (ⁱ+1)th reference sequence set is not less than the predetermined correlation threshold, setting i=i+1 and repeating steps (c), (d), (e), (f) and (g), and when the all of the correlation coefficient values of the (ⁱ+1)th reference sequence set are less than the predetermined correlation threshold, outputting the color value sequence in the (ⁱ+1)th reference sequence set which is generated by averaging a most number of the color value sequences in the first reference sequence set as a reference sequence.

[0029] For example, the data analysis processor 124 performs the hierarchical correlation method on the eight color value sequences C₁, C₂, ..., C₈ to obtain the reference sequence. First, the data analysis processor 124 gathers the eight color value sequences C₁, C₂, ..., C₈ into a 1st reference sequence set. Next, the analysis processor 124 obtains the correlation coefficient values of the 1st reference sequence set by calculating each pair of the color value sequences in the 1st reference sequence set through the correlation function. On the assumption the pair of the color value sequences (i.e., C₂ and C₃) has the largest correlation coefficient value, the analysis processor 124 selects the pair of the color

value sequences (i.e., C_2 and C_3) in the 1st reference sequence set, which have the largest correlation coefficient value, and averages the color value sequences C_2 and C_3 to generate a new color value sequence $C'_{2,3}$. Next, the analysis processor **124** gathers $C'_{2,3}$ and the color value sequences C_1 , C_4 , C_5 , C_6 , C_7 , C_8 into a 2nd reference sequence set. Similarly, the analysis processor **124** obtains the correlation coefficient values of the 2nd reference sequence set by calculating each pair of the color value sequences in the 2th reference sequence set through the correlation function.

[0030] Afterwards, the analysis processor **124** determines whether all of the correlation coefficient values of the 2nd reference sequence set are less than a predetermined correlation threshold. Assuming there is at least one of the correlation coefficient values of the 2nd reference sequence set is not less than the predetermined correlation threshold, the analysis processor **124** selects the pair of the color value sequences in the 2nd reference sequence set, which have a largest correlation coefficient value. Then, on the assumption the pair of the color value sequences (C_i and $C'_{2,3}$) has the largest correlation coefficient value, the analysis processor **124** selects the pair of the color value sequences (i.e., C_1 and $C'_{2,3}$) in the 2nd reference sequence set, which have the largest correlation coefficient value, and averages the pair of the color value sequences (i.e., C_1 and $C'_{2,3}$) to generate a new color value sequence $C'_{1,2,3}$.

[0031] Next, the analysis processor **124** gathers the new color value sequence $C'_{1,2,3}$ and the color value sequences C_4 , C_5 , C_6 , C_7 , C_8 into a 3rd reference sequence set. Similarly, the analysis processor **124** obtains the correlation coefficient values of the 3rd reference sequence set by calculating each pair of the color value sequences in the 3rd reference sequence set through the correlation function, and determines whether all of the correlation coefficient values of the 3rd reference sequence set are less than a predetermined correlation threshold. Assuming there is at least one of the correlation coefficient values of the 3rd reference sequence set is not less than the predetermined correlation threshold, the analysis processor **124** selects the pair of the color value sequences in the 3rd reference sequence set, which have a largest correlation coefficient value. Then, on the assumption the pair of the color value sequences (i.e., C_5 and C_6) has the largest correlation coefficient value, the analysis processor **124** selects the pair of the color value sequences (i.e., C_5 and C_6) in the 3rd reference sequence set, which have the largest correlation coefficient value, and averages the pair of the color value sequences (i.e., C_5 and C_6) to generate a new color value sequence $C'_{5,6}$.

[0032] Next, the analysis processor **124** gathers the new color value sequence $C'_{5,6}$ and the color value sequences $C'_{1,2,3}$, C_4 , C_7 , C_8 into a 4th reference sequence set. Similarly, the analysis processor **124** obtains the correlation coefficient values of the 4th reference sequence set by calculating each pair of the color value sequences in the 4th reference sequence set through the correlation function, and determines whether all of the correlation coefficient values of the 4th reference sequence set are less than the predetermined correlation threshold.

[0033] On the assumption that all of the correlation coefficient values of the 4th reference sequence set are less than the predetermined correlation threshold, the analysis processor **124** outputs the color value sequence $C'_{1,2,3}$ in the 4th reference sequence set which is generated by averaging the most number (i.e., 3) of the color value sequences (i.e., C_1 , C_2 and C_3) in the first reference sequence set as a reference sequence.

[0034] The data analysis processor **124** compares the reference sequence with each color value sequences through a clustering method to obtain the correlation coefficient values. The clustering method comprises a correlation grouping method, a grouping with lag-correlation method or a two-centers correlation clustering method or any combination thereof.

[0035] In an embodiment, the data analysis processor **124** performs the correlation grouping method to obtain the correlation coefficient values. The correlation grouping method comprises the step of: calculating each color value sequence with the reference sequence through a correlation function to obtain the correlation coefficient values of the color value sequences.

[0036] In another embodiment, the data analysis processor **124** performs the grouping with lag-correlation method to obtain the correlation coefficient values and the lag varieties. The grouping with lag-correlation method comprises the steps of: calculating each color value sequences with the reference sequence through a correlation function with a plurality of lag varieties to obtain a plurality of correlation coefficient values; and choosing the largest correlation coefficient value and the corresponding lag variety to obtain the correlation coefficient value and the lag variety of each color value sequence.

[0037] In another embodiment, the data analysis processor **124** performs the two-centers correlation clustering method to obtain a plurality of correlation coefficient values. The two-centers correlation clustering method comprises the following steps of: (a) gathering the color value sequences into an operation set; (b) calculating each of the color value sequences in the operation set with the reference sequence through a correlation function to obtain a plurality of temporary correlation coefficient values of the color value sequences; (c) removing the color value sequence with the smallest temporary correlation coefficient value from the operation set and assigning the smallest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence with the smallest temporary correlation coefficient value; (d) removing the color value sequence with the largest temporary correlation coefficient value and assigning the largest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence with the largest temporary correlation coefficient value; (e) updating the reference sequence by averaging the color value sequence with the largest temporary correlation coefficient value and the reference sequence; and (f) repeating steps (b), (c), (d), and (e) until all of the color value sequences are assigned with the correlation coefficient values.

[0038] For example, the data analysis processor **124** performs the two-centers correlation clustering method on the eight color value sequences C_1, C_2, \dots, C_8 to obtain the plurality of correlation coefficient values. First, the data analysis processor **124** gathers the eight color value sequences C_1, C_2, \dots, C_8 into an operation set. Next, the analysis processor **124** obtains a plurality of temporary correlation coefficient values of the color value sequences by calculating each of the color value sequences C_1, C_2, \dots, C_8 in the operation set with the reference sequence through a correlation function. On the assumption the color value sequence C_8 has the smallest temporary correlation coefficient value and the color value sequence C_2 has the largest temporary correlation coefficient value. Thereafter, the analysis processor **124** removes the color value sequence C_8 from the operation set and assigns the smallest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence C_8 . Similarly, the analysis processor **124** removes the color value sequence C_2 from the operation set and assigns the largest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence C_2 . Afterwards, the analysis processor **124** update the reference sequence by averaging the color value sequence C_2 (which has the largest temporary correlation coefficient value) and the current reference sequence.

[0039] Next, the analysis processor **124** obtains a plurality of temporary correlation coefficient values of the color value sequences by calculating each of the color value sequences $C_1, C_3, C_4, C_5, C_6, C_7$ in the operation set with the updated reference sequence through the correlation function. On the assumption the color value sequences C_3 has the smallest temporary correlation coefficient value and the color value sequence C_1 has the largest temporary correlation coefficient value. Thereafter, the analysis processor **124** removes the color value sequence C_3 from the operation set and assigns the smallest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence C_3 . Similarly, the analysis processor **124** removes the color value sequence C_1 from the operation set and assigns the largest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence C_1 . Afterwards, the analysis processor **124** updates the reference sequence again by averaging the color value sequence C_1 (which has the largest temporary correlation coefficient value) and the current reference sequence.

[0040] Next, the analysis processor **124** obtains a plurality of temporary correlation coefficient values of the color value sequences by calculating each of the color value sequences (C_4, C_5, C_6, C_7) in the operation set with the updated reference sequence through the correlation function. On the assumption the color value sequence C_4 has the smallest temporary correlation coefficient value and the color value sequence C_7 has the largest temporary correlation coefficient value. Thereafter, the analysis processor **124** removes the color value sequences C_4 from the operation set and assigns the smallest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence C_4 . Similarly, the analysis processor **124** removes the color value sequence C_7 with the largest temporary correlation coefficient value from the operation set and assigns the largest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence C_7 .

[0041] Once again, the analysis processor **124** updates the reference sequence again by averaging the color value sequence C_7 (which has the largest temporary correlation coefficient value) and the current reference sequence. Afterwards, the analysis processor **124** obtains a plurality of temporary correlation coefficient values of the color value sequence by calculating the color value sequence (C_5, C_6) in the operation set with the updated reference sequence through the correlation function.

[0042] On the assumption the color value sequence C_6 has the smallest temporary correlation coefficient value and the color value sequence C_5 has the largest temporary correlation coefficient value. Thereafter, the analysis processor **124** removes the color value sequences C_6 from the operation set and assigns the smallest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence C_6 . Similarly, the analysis processor **124** removes the color value sequence C_5 from the operation set and assigns the largest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence C_5 . By the aforesaid operations all of the color value sequences (C_1, C_2, \dots, C_8) are assigned with their correlation coefficient values.

[0043] The data analysis processor **124** classifies the color value sequences into a primary pulsatile signal, a secondary pulsatile signal, and a noise signal based on the correlation coefficient values through a clustering and noise reduction method.

[0044] FIG. 3 illustrates a diagram for clustering and noise reduction method in accordance with various embodiments of the present invention. The data analysis processor **124** performs the clustering and noise reduction method comprising the steps of: classifying the color value sequences into the primary pulsatile signal if the correlation coefficient value within a main correlation coefficient threshold **300** and the lag variety within a main lag-coefficient threshold **302, 304**; and classifying the color value sequences into the secondary pulsatile signal if the correlation coefficient values within a secondary correlation coefficient threshold **306, 308** and the lag variety within a secondary lag-coefficient threshold **310**. The data analysis processor **124** further classifies the remaining color value sequences into the noise signal.

[0045] FIG. 4 illustrates common carotid artery **402** and internal jugular vein **404** in the original power Doppler ultrasound image **400** and the visualized pulsatile ultrasound images **410** in accordance with various embodiments of the present invention. The data analysis processor **124** performs the referencing method based on the combination of the intensity percentage and the average standard methods. The data analysis processor **124** further performs the clustering method

based on the correlation grouping method, and then performs the clustering and noise reduction method.

[0046] The data analysis processor 124 chooses the color value sequences which the percentile rank is within a predetermined rank range, and chooses the color value sequences which the averaging standard ratio value is within a predetermined ratio range to obtain the reference group, wherein the predetermined rank range is less than 5% and predetermined ratio range is less than 0.1. The data analysis processor 124 averages the color value sequences in the reference group to obtain the reference sequence.

[0047] The data analysis processor 124 classifies the color value sequences into the primary pulsatile signal 412 if the correlation coefficient value within a main correlation coefficient range, which is between 0.6 and 1.0, and classifies the color value sequences into the secondary pulsatile signal 414 if the correlation coefficient values within a secondary correlation coefficient threshold, which is between -1.0 and 0.4. The data analysis processor 124 further classifies the remaining color value sequences into the noise signal 416.

[0048] The data record processor 126 obtains a sequence of pulsatile ultrasound images 410 by classifying the color value sequences into three groups: the primary pulsatile signal, the secondary pulsatile signal, and the noise signal. The pixels of the primary pulsatile signal 412 in the visualized pulsatile ultrasound images 410 are displayed in first color values (e.g., warm colors from yellowish to dark red). The pixels of the secondary pulsatile signal 414 in the visualized pulsatile ultrasound images 410 are display in second color values (e.g., cold colors from light cyan to dark blue). The pixels of the noise signal are display in a third color value (e.g., a white color).

[0049] FIG. 5 illustrates common carotid artery 502 and internal jugular vein 504 in the original color Doppler ultrasound image 500 and the visualized pulsatile ultrasound image 510 in accordance with various embodiments of the present invention. The data analysis processor 124 performs the referencing method based on the combination of the intensity percentage method and the autocorrelation method. The data analysis processor 124 further performs the clustering method based on the two-centers correlation clustering method, and then performs the clustering and noise reduction method.

[0050] The data analysis processor 124 selects the plurality of color value sequences which the percentile rank is within a predetermined rank range, wherein the predetermined rank range is less than 10%. The plurality of color value sequences are calculated by the autocorrelation function calculation with lag varieties from 5 to 8. The data analysis processor 124 chooses the color value sequence which has the smallest autocorrelation function value to obtain the reference sequence.

[0051] Then, the data analysis processor 124 obtains a plurality of correlation coefficient values by calculating each color value sequence with the reference sequence through a correlation function. The data analysis processor 124 chooses the color value sequence with the smallest correlation coefficient value to obtain a minimum correlation coefficient value, and chooses the color value sequence with the largest correlation coefficient value to obtain a maximum correlation coefficient value.

[0052] The data analysis processor 124 averages the color value sequences which belong to the maximum correlation coefficient value and the reference sequence to obtain an updated reference sequence. Afterwards, the data analysis processor 124 obtains the correlation coefficient values of all color value sequence by calculate each remaining color value sequence with the updated reference sequence through the correlation function in sequence.

[0053] Furthermore, the data analysis processor 124 classifies the color value sequences into the primary pulsatile signal 512 if the correlation coefficient value within a main correlation coefficient threshold, wherein the main correlation coefficient threshold is between 0.6 and 1.0. The pixels of the primary pulsatile signal 512 in the visualized pulsatile ultrasound image are annotated by first color values (e.g., warm color values from light yellow to dark red).

[0054] The data analysis processor 124 classifies the color value sequences into the secondary pulsatile signal 514 if the correlation coefficient values within a secondary correlation coefficient threshold, wherein the secondary correlation coefficient threshold is between -1.0 and 0.4. The pixels of the secondary pulsatile signal 514 in the visualized pulsatile ultrasound image are annotated by second color values (e.g., cold color values from light cyan to dark blue).

[0055] The data analysis processor 124 classifies the remaining color value sequences into the noise signal 516 in a third color value (e.g., a white color). The data record processor 126 displays the visualized pulsatile ultrasound images 510 for visualization of the primary pulsatile signal 512, the secondary pulsatile signal 514 and the noise signal 516 based on clustering and noise reduction methods.

[0056] FIG. 6 illustrates renal artery 602 and renal vein 604 in the original power Doppler ultrasound image 600 and the visualized pulsatile ultrasound images 610 in accordance with various embodiments of the present invention. The data analysis processor 124 performs the referencing method based on hierarchical correlation method to obtain the reference sequence, as aforementioned. Then, the data analysis processor 124 further performs the clustering method based on correlation grouping method to obtain the correlation coefficient values of the color value sequences by calculating each color value sequence with the reference sequence through a correlation function to obtain the correlation coefficient values.

[0057] Next, the data analysis processor 124 performs the clustering and noise reduction method as follows. The data analysis processor 124 classifies the color value sequences into the primary pulsatile signal 612 if the correlation coef-

ficient value within a main correlation coefficient threshold, e.g., the main correlation coefficient threshold is between 0.6 and 1.0. The pixels of the primary pulsatile signal **612** in the visualized pulsatile ultrasound image are annotated by first color values (e.g. warm color values from yellowish to dark red) for showing the intensity changes of pixels.

[0058] The data analysis processor **124** classifies the color value sequences into the secondary pulsatile signal **614** if the correlation coefficient values within a secondary correlation coefficient threshold, e.g., the secondary coefficient threshold is between -1.0 to 0.2. The pixels of the secondary pulsatile signal **612** in the visualized pulsatile ultrasound image are annotated by second color values (e.g., cold color values from light cyan to dark blue) for showing the intensity changes of pixels.

[0059] The data analysis processor **124** classifies remaining color value sequences into the noise signal **616**. The data record processor **126** displays the visualized pulsatile ultrasound images **610** for visualization of the primary pulsatile signal, the secondary pulsatile signal, and the noise signal based on clustering and noise reduction methods.

[0060] **FIG. 7** illustrates brachial artery **702** and brachial vein **704** of arm in the original power Doppler ultrasound image **700** and the visualized pulsatile ultrasound image **710** in accordance with various embodiments of the present invention. The data analysis processor **124** performs the referencing method based on the combination of the intensity percentage method and the average standard deviation ratio method. The data analysis processor **124** further performs the clustering method based on the grouping with lag-correlation method, and then performs the clustering and noise reduction method.

[0061] The data analysis processor **124** arranges the color value sequences according to the largest color value of each of the color value sequences to obtain a plurality of percentile ranks. The data analysis processor **124** chooses the color value sequences which the percentile rank is within a predetermined rank range, and chooses the color value sequences which the averaging standard ration value is within a predetermined ration range to obtain the reference group, wherein the predetermined rank range is less than 5% and predetermined ration range is less than 0.1. The data analysis processor **124** averages the color value sequences in the reference group to obtain the reference sequence.

[0062] Then, the data analysis processor **124** performs the grouping with lag-correlation method to obtain the correlation coefficient values, and calculates each color value sequences with the reference sequence through a correlation function with a plurality of lag varieties to obtain a plurality of correlation coefficient values, wherein the range of the lag varieties are 0 to 8.

[0063] Furthermore, the data analysis processor **124** chooses the largest correlation coefficient value and the corresponding lag variety to obtain the correlation coefficient value and the lag variety of each color value sequence. The data analysis processor **124** classifies the color value sequences into the primary pulsatile signal **712** if the correlation coefficient value within a main correlation coefficient threshold and the lag variety within a main lag-coefficient threshold, e.g., the main correlation coefficient threshold is between -0.2 and 1.0 and the main lag-coefficient threshold is between 0 and 1. The pixels of the primary pulsatile signal **712** in the visualized pulsatile ultrasound image are annotated by first color values (e.g., warm color values from light yellow to dark red).

[0064] The data analysis processor **124** classifies the color value sequences into the secondary pulsatile signal **714** if the correlation coefficient values within a secondary correlation coefficient threshold and the lag variety within a secondary lag-coefficient threshold, e.g., the secondary correlation coefficient threshold is between -0.2 and 1.0 and the secondary lag-coefficient threshold is between 2 and 8. The pixels of the secondary pulsatile signal **714** in the visualized pulsatile ultrasound image are annotated by second color values (e.g. cold color values from light cyan to dark blue).

[0065] The data analysis processor **124** classifies remaining color value sequences into the noise signal **716**. The data record processor **126** displays the visualized pulsatile ultrasound images **710** for visualization of the primary pulsatile signal **712**, the secondary pulsatile signal **714** and the noise signal **716** based on clustering and noise reductions.

[0066] **FIG. 8** illustrates a diagram for reclassifying the color values in the primary pulsatile signal and secondary pulsatile signal to obtain the visualized pulsatile ultrasound images (e.g., the visualized pulsatile ultrasound images **410** in **FIG. 4**) in accordance with various embodiments of the present invention. For each of the visualized pulsatile ultrasound images, the data record processor **126** selects a pixel of the noise signal **806** as a center pixel of a mask region, and starts at the center pixel and follows direction of arrow to search and calculate the number of pixels in the mask region of the visualized pulsatile ultrasound image.

[0067] Then, the data record processor **126** reclassifies the noise signal (i.e. center pixel) into the primary pulsatile signals **802** if the number of primary pulsatile signals is more than that of the secondary pulsatile signals in the mask region, and reclassifies the noise signal (i.e. center pixel) into the secondary pulsatile **804** if the number of secondary pulsatile signals is more than that of the primary pulsatile signals in the mask region.

[0068] The present invention provides a method and system to classify all pixels. In theory, the pixels from actual artifact interference are more likely to have a lower intensity and a random fluctuation. Therefore, the data record processor **126** will keep these pixels in the noise group, while, the remaining pixels (i.e. the pixels with a higher intensity and a periodical fluctuation) are to be reclassified to avoid misjudgment with a higher correlation coefficient threshold.

[0069] **FIG. 9** illustrates intensity value change trends of the visualized pulsatile ultrasound image in accordance with

various embodiments of the present invention. As shown in Equation 4, the intensity value in each frame is expressed in percent.

$$\text{Intensity value} = \frac{\text{Sum of the normalized color values of the pixels}}{\text{the total number of the pixels}} \times 100 (\%) \quad (\text{Equation 4})$$

[0070] The data record processor **126** normalizes the color values of each pixel of the primary pulsatile signal, the secondary pulsatile signal, and the noise signal in the region of interest of the visualized pulsatile ultrasound image. Then, for color values of each pixel of the primary pulsatile signal in each frame (i.e., at each capture time), the data record processor **126** calculates the average of the normalized color values to obtain the intensity value in each frame. And, for color values of each pixel of the secondary pulsatile signal in each frame, the data record processor **126** calculates the average of the normalized color values to obtain the intensity value in each frame. Similarly, for color values of each pixel of the noise signal on each frame, the data record processor **126** calculates the average of the normalized color values to obtain the intensity value in each frame. Therefore, the intensity value change trends **900** of the primary pulsatile signal, the secondary pulsatile signal, and the noise signal are obtained.

[0071] In an embodiment, the data record processor **126** calculates a plurality of the first similarity indices (SI_{ps}) between the intensity value change trend of the primary signal and the intensity value change trend of the secondary pulsatile signal, the second similarity indices (SI_{pn}) between the intensity value change trend of the primary signal and the intensity value change trend of the noise signal, and the third similarity indices (SI_{sn}) between the intensity value change trend of the secondary signal and the intensity value change trend of the noise signal through a correlation function with a plurality of lag varieties, chooses the largest value from the first similarity indices (SI_{ps}) to be the pulsatile similarity index (PSI), chooses the largest value from the second similarity indices (SI_{pn}) and the similarity indices (SI_{sn}) to be the noise similarity index (NSI), and obtains a ratio coefficient (RC) by Equation 5 to assist evaluating the efficiency of visualization through outputting the ratio coefficient (RC) by the output device **130**.

$$RC = \frac{NSI}{PSI} = \frac{\text{Max}(SI_{pn}, SI_{sn})}{\text{Max}(SI_{ps})} \quad (\text{Equation 5})$$

[0072] FIG. 10 is a flowchart for the method of clustering, noise reduction and visualization for Doppler ultrasound images according to various embodiments of the present invention. It should be noted that the flowchart of FIG. 10 provides merely an example of the many different types of functional arrangements that may be employed to implement the operation of the various components of the image processing system **100** (FIG. 1). As an alternative, the flowchart of FIG. 10 may be viewed as depicting an example of steps of a method implemented in the image processing system **100** according to one or more embodiments.

[0073] Although the flowchart of FIG. 10 shows a specific order of execution, it should be noted that the order of execution may differ from that which is depicted. For example, the order of execution of two or more blocks may be scrambled relative to the order shown. Also, two or more blocks shown in succession in FIG. 10 may be executed concurrently or with partial concurrence. It should be noted that all such variations are within the scope of the present invention.

[0074] Beginning with step **S1010**, a sequence of Doppler ultrasound images (I frames) **210** based on a time domain are obtained, wherein each Doppler ultrasound image comprises a color value in each pixel ($B_{j,i}$).

[0075] In step **S1020**, each color value in each pixel of the Doppler ultrasound images are arranged based on the time domain to obtain a plurality of color value sequences.

[0076] In step **S1030**, a reference sequence (C_{ref}) is obtained through a referencing method. The referencing method comprises an intensity percentage method, an average standard deviation ratio method, an autocorrelation method, a hierarchical correlation method or any combination thereof.

[0077] In step **S1040**, the data analysis processor **124** compares the reference sequence with each color value sequence through a clustering method to obtain a plurality of correlation coefficient values. The clustering method comprises a correlation grouping method, a grouping with lag-correlation method, a two-centers correlation clustering method or any combination thereof.

[0078] In step **S1050**, the data analysis processor **124** further performs a clustering and noise reduction method to classify the color value sequences into a primary pulsatile signal, a secondary pulsatile signal, and a noise signal based on the correlation coefficient values.

[0079] Finally, in step **S1060**, the data record processor **126** annotates the color value in each pixel which belong to the primary pulsatile signal, the secondary pulsatile signal, and the noise signal with different color values to obtain a

plurality of visualized pulsatile ultrasound images.

[0080] In addition to the aforesaid steps, the method of clustering, noise reduction and visualization for Doppler ultrasound images of the present invention can also execute all the operations and have all the corresponding functions set forth in all the aforesaid embodiments. How this embodiment executes these operations and has these functions will be readily appreciated by those of ordinary skill in the art based on the explanation of all the aforesaid embodiments, and thus will not be further described herein.

[0081] According to the above descriptions, the system and the method of clustering, noise reduction and visualization for Doppler ultrasound images of the present invention provide the Doppler ultrasound images with different colors to visually segment the primary pulsatile signal, the secondary pulsatile signal, and the noise signal in consideration that signal intensities of Doppler ultrasound images would be affected by pulsatile flow intensities of the artery and the vein. Therefore, the method and system in this invention can apply different appropriate analysis methods on different specific organs, respectively, to visualize information of the artery and the vein and reduce the noise caused by the motion artifacts to clearly present the artery and the vein, thereby improving diagnostic accuracy and efficiency.

[0082] It shall be appreciated that the method and system do not limit to blood signal of the specific organ and utilizes one of the clustering methods, for example, the correlation grouping method, the two-center correlation clustering method, and hierarchical correlation clustering method to obtain the Doppler ultrasound images for different organs. It should be emphasized that the above-described embodiments of the present invention are merely possible examples of implementations set forth for a clear understanding of the principles of the disclosure. Modifications and variations are intended to be included herein as far as they are protected by the following claims.

Claims

1. A system of clustering, noise reduction and visualization for Doppler ultrasound image, comprising:

a capture device (110), being configured to obtain a plurality of Doppler ultrasound images based on a time domain, wherein each of the Doppler ultrasound image comprises a color value in each pixel;
a processing device (120), being connected to the capture device, and comprising:

a data conversion processor (122), being configured to arrange the color value in each pixel of the Doppler ultrasound images based on the time domain to obtain a plurality of color value sequences (214); a data analysis processor (124), being configured to calculate the color value sequences through a referencing method to obtain a reference sequence, compare the reference sequence with each of the color value sequences through a clustering method to obtain a plurality of correlation coefficient values, and classify the color value sequences into a primary pulsatile signal, a secondary pulsatile signal, and a noise signal based on the correlation coefficient values through a clustering and noise reduction method; and
a data record processor (120), being configured to annotate the color values of the primary pulsatile signal, the secondary pulsatile signal, and the noise signal to obtain a plurality of visualized pulsatile ultrasound images;
an output device (130), being connected to the processing device and configured to display the visualized pulsatile ultrasound images.

2. The system of claim 1, wherein the output device is adapted to provide selection of a region of interest in the visualized pulsatile ultrasound images, the data record processor is adapted to obtain a plurality of intensity value change trends of the primary pulsatile signal, the secondary pulsatile signal, and the noise signal in the region of interest of the visualized pulsatile ultrasound images by following steps:

normalizing the color values of each pixel of the primary pulsatile signal, the secondary pulsatile signal, and the noise signal in the region of interest of the visualized pulsatile ultrasound image;
calculating an average of the normalized color values of the primary pulsatile signal at each capture time to obtain a plurality of intensity value of the primary signal;
calculating an average of the normalized color values of the secondary pulsatile signal at each capture time to obtain a plurality of intensity values of the secondary pulsatile signal; and
calculating an average of the normalized color values of the noise signal at each capture time to obtain a plurality of intensity values of the noise signal;
wherein the output device further displays a plurality of intensity value change trends in a chart according to the intensity values of the primary signal, the secondary pulsatile signal, and the noise signal.

3. The system of claim 2, wherein the output device is adapted to calculate a plurality of first similarity indices between the intensity value change trend of the primary pulsatile signal and the intensity value change trend of the secondary pulsatile signal, a plurality of second similarity indices between the intensity value change trend of the primary signal and the intensity value change trend of the noise signal, and a plurality of third similarity indices similarity indices
 5 between the intensity value change trend of the secondary signal and the intensity value change trend of the noise signal through a correlation function with a plurality of lag varieties, and the output device is adapted to choose a largest value from the first similarity indices to be a pulsatile similarity index, to choose the largest value from the second and third similarity indices to be the noise similarity index, and to obtain a ratio coefficient by dividing the noise similarity index by the pulsatile similarity index .
- 10
4. The system of any one of claims 1-3, wherein the referencing method comprises an intensity percentage method, an average standard deviation ratio method, an autocorrelation method, a hierarchical correlation method or any combination thereof.
- 15
5. The system of claim 4, wherein the data analysis processor is adapted to perform the intensity percentage method to obtain the reference sequence, and the intensity percentage method comprises the following steps of:
- arranging the color value sequences according to the largest color value of each of the color value sequences to obtain a plurality of percentile ranks;
 20 choosing the color value sequences which the percentile rank is within a predetermined rank range to obtain a reference group; and
 averaging the color value sequences in the reference group to obtain the reference sequence.
- 25
6. The system of claim 4, wherein the data analysis processor is adapted to perform the average standard deviation ratio method to obtain the reference sequence, and the average standard deviation ratio method comprises the following steps of:
- calculating the color value in each color value sequences to obtain a plurality of standard deviation values, and then dividing by an average value of the standard deviation values to obtain a plurality of average standard
 30 deviation ratio values;
 choosing the color value sequences which the averaging standard deviation ratio value is within a predetermined ratio range to obtain a reference group; and
 averaging the color value sequences in the reference group to obtain the reference sequence.
- 35
7. The system of claim 4, wherein the data analysis processor is adapted to perform the autocorrelation method to obtain the reference sequence, and the autocorrelation method comprises the following steps of:
- calculating each color value sequence through an autocorrelation function with a plurality of lag varieties to obtain a plurality of autocorrelation coefficient values; and
 40 choosing a color value sequence which has the smallest autocorrelation coefficient value to obtain the reference sequence.
- 45
8. The system of claim 4, wherein the data analysis processor is adapted to perform the hierarchical correlation method to obtain the reference sequence, and the hierarchical correlation method comprises the following steps of:
- (a) gathering the color value sequences into an i^{th} reference sequence set, wherein an initial value of i is 1;
 (b) obtaining a plurality of correlation coefficient values of the i^{th} reference sequence set by calculating each pair of the color value sequences in the i^{th} reference sequence set through a correlation function;
 (c) selecting the pair of the color value sequences in the i^{th} reference sequence set, which have a largest
 50 correlation coefficient value;
 (d) averaging the selected pair of the color value sequences in the i^{th} reference sequence set to generate a new color value sequence;
 (e) gathering the new color value sequence and the color value sequences in the i^{th} reference sequence set except for the selected pair of the color value sequences into a $(i+1)^{\text{th}}$ reference sequence set;
 55 (f) obtaining a plurality of correlation coefficient values of the $(i+1)^{\text{th}}$ reference sequence set by calculating each pair of the color value sequences in the $(i+1)^{\text{th}}$ reference sequence set through the correlation function;
 (g) determining whether all of the correlation coefficient values of the $(i+1)^{\text{th}}$ reference sequence set are less than a predetermined correlation threshold; and

(h) when one of the correlation coefficient values of the $(i+1)^{\text{th}}$ reference sequence set is not less than the predetermined correlation threshold, setting $i=i+1$ and repeating steps (c), (d), (e), (f) and (g), and when the all of the correlation coefficient values of the $(i+1)^{\text{th}}$ reference sequence set are less than the predetermined correlation threshold, outputting the color value sequence in the $(i+1)^{\text{th}}$ reference sequence set which is generated by averaging a most number of the color value sequences in the first reference sequence set as a reference sequence.

9. The system of any one of claims 1-8, wherein the clustering method comprises a correlation grouping method, a grouping with lag-correlation method, a two-centers correlation clustering method or any combination thereof.

10. The system of claim 9, wherein the data analysis processor is adapted to perform the correlation grouping method to obtain the correlation coefficient values, and the correlation grouping method comprises the following step of: calculating each of the color value sequences with the reference sequence through a correlation function to obtain the correlation coefficient values of the color value sequences.

11. The system of claim 9, wherein the data analysis processor is adapted to perform the two-centers correlation clustering method to obtain the correlation coefficient values, and the two-centers correlation clustering method comprises the following steps of:

- (a) gathering the color value sequences into an operation set;
- (b) calculating each of the color value sequences in the operation set with the reference sequence through a correlation function to obtain a plurality of temporary correlation coefficient values of the color value sequences;
- (c) removing the color value sequence with the smallest temporary correlation coefficient value from the operation set and assigning the smallest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence with the smallest temporary correlation coefficient value;
- (d) removing the color value sequence with the largest temporary correlation coefficient value and assigning the largest temporary correlation coefficient value to be the correlation coefficient value of the color value sequence with the largest temporary correlation coefficient value;
- (e) updating the reference sequence by averaging the color value sequence with the largest temporary correlation coefficient value and the reference sequence; and
- (f) repeating steps (b), (c), (d), and (e) until all of the color value sequences are assigned with the correlation coefficient values.

12. The system of claim 9, wherein the data analysis processor is adapted to perform the grouping with lag-correlation method to obtain the correlation coefficient values, and the grouping with lag-correlation method comprises the following steps of:

- calculating each color value sequences with the reference sequence through a correlation function with a plurality of lag varieties to obtain a plurality of correlation coefficient values;
- choosing the largest correlation coefficient value and the corresponding lag variety to obtain the correlation coefficient value and the lag variety of each color value sequence.

13. The system of any one of claims 1-12, wherein the data analysis processor is further adapted to compare the reference sequence with each of the color value sequences through the clustering method to obtain the correlation coefficient values and a plurality of lag varieties corresponding to the correlation coefficient values of the color value sequences and performs the clustering and noise reduction method comprising the following steps of:

- classifying the color value sequences, the correlation coefficient values of which are within a main correlation coefficient threshold (300) and the lag varieties of which are within a main lag-coefficient threshold (302,304), into the primary pulsatile signal;
- classifying the color value sequences, the correlation coefficient values of which are within a secondary correlation coefficient threshold (306,308) and the lag varieties of which are within a secondary lag-coefficient threshold (310), into the secondary pulsatile signal; and
- classifying the color value sequences, the correlation coefficient values of which are not within the main correlation coefficient threshold and the secondary correlation coefficient threshold and the lag variety of which are not within the main lag-coefficient threshold and the secondary lag-coefficient threshold, into the noise signal.

14. The system of any one of claims 1-13, wherein the step of obtaining the visualized pulsatile ultrasound images

executed by the data record processor comprises the following steps of:
for each of the visualized pulsatile ultrasound images:

5 selecting a pixel of the noise signal as a center pixel of a mask region;
calculating a number of pixels in the mask region;
reclassifying the noise signal into the primary pulsatile signal if the number of primary pulsatile signals is more
than that of the secondary pulsatile signals in the mask region; and
reclassifying the noise signal into the secondary pulsatile signal if the number of secondary pulsatile signals is
10 more than that of the primary pulsatile signals in the mask region.

15. The system of any one of claims 1-14, wherein the step of obtaining the visualized pulsatile ultrasound images
executed by the data record processor, further comprises the following steps of:

15 annotating the pixels which belong to the primary pulsatile signal with first color values;
annotating the pixels which belong to the secondary pulsatile signal with second color values;
annotating the pixels which belong to the noise signal with a third color value; and
obtaining the visualized pulsatile ultrasound images.

20 16. A method of clustering, noise reduction and visualization for Doppler ultrasound image, comprising:

20 obtaining a plurality of Doppler ultrasound images based on time domain, wherein each of Doppler ultrasound
images comprises a color value in each pixel (S1010); arranging each color value in each pixel of Doppler
ultrasound images based on the time domain to obtain a plurality of color value sequences (S1020); calculating
the color value sequences through a referencing method to obtain a reference sequence (S1030); comparing
25 the reference sequence with each color value sequences through a clustering method to obtain a plurality of
correlation coefficient values (S1040); classifying the color value sequences into a primary pulsatile signal, a
secondary pulsatile signal, and a noise signal based on the correlation coefficient values through a clustering
and noise reduction method (S1050); and
30 annotating the color values of the primary pulsatile signal, the secondary pulsatile signal, and the noise signal
with first color values, second color values, and a third color value, respectively, to obtain a plurality of visualized
pulsatile ultrasound images (S1060).

35 Patentansprüche

1. System zum Clustering, zur Rauschreduzierung und zum Visualisieren für ein Doppler-Ultraschallbild, umfassend:

40 eine Erfassungsvorrichtung (110), die eingerichtet ist, um eine Vielzahl von Doppler-Ultraschallbildern basierend
auf einer Zeitdomäne zu erhalten, wobei jedes der Doppler-Ultraschallbilder einen Farbwert in jedem Pixel
umfasst;
eine Verarbeitungsvorrichtung (120), die mit der Erfassungsvorrichtung verbunden ist und umfasst:

45 einen Datenumwandlungsprozessor (122), der eingerichtet ist, um den Farbwert in jedem Pixel der Doppler-
Ultraschallbilder basierend auf der Zeitdomäne anzuordnen, um eine Vielzahl von Farbwertsequenzen
(214) zu erhalten;
einen Datenanalyseprozessor (124), der eingerichtet ist, um die Farbwertsequenzen durch ein Referen-
zierungsverfahren zu berechnen, um eine Referenzsequenz zu erhalten, die Referenzsequenz mit jeder
der Farbwertsequenzen durch ein Clustering-Verfahren zu vergleichen, um eine Vielzahl von Korrelations-
koeffizientenwerten zu erhalten, und die Farbwertsequenzen in ein primäres pulsartiges Signal, ein sekun-
50 däres pulsartiges Signal und ein Rauschsignal basierend auf der Grundlage der Korrelationskoeffizienten-
werte durch ein Clustering- und Rauschreduzierungsverfahren zu klassifizieren; und
einen Datensatzprozessor (120), der eingerichtet ist, die Farbwerte des primären pulsartigen Signals, des
sekundären pulsartigen Signals und des Rauschsignals zu annotieren, um eine Vielzahl von visualisierten
pulsartigen Ultraschallbildern zu erhalten;

55 eine Ausgabevorrichtung (130), die mit der Verarbeitungsvorrichtung verbunden und eingerichtet ist, die visu-
alisierten pulsartigen Ultraschallbilder anzuzeigen.

2. System nach Anspruch 1, wobei die Ausgabevorrichtung angepasst ist, um eine Auswahl eines interessierenden Bereichs in den visualisierten pulsartigen Ultraschallbildern bereitzustellen, wobei der Datensatzprozessor angepasst ist, um eine Vielzahl von Intensitätswertänderungstrends des primären pulsartigen Signals, des sekundären pulsartigen Signals und des Rauschsignals in dem interessierenden Bereich der visualisierten pulsartigen Ultraschallbilder durch folgende Schritte zu erhalten:

Normieren der Farbwerte jedes Pixels des primären pulsartigen Signals, des sekundären pulsartigen Signals und des Rauschsignals im interessierenden Bereich des visualisierten pulsartigen Ultraschallbildes;
 Berechnen eines Mittelwertes der normierten Farbwerte des primären pulsartigen Signals bei jeder Aufnahmezeit, um eine Vielzahl von Intensitätswerten des primären Signals zu erhalten;
 Berechnen eines Mittelwertes der normierten Farbwerte des sekundären pulsartigen Signals bei jeder Aufnahmezeit, um eine Vielzahl von Intensitätswerten des sekundären pulsartigen Signals zu erhalten; und
 Berechnen eines Mittelwertes der normierten Farbwerte des Rauschsignals bei jeder Aufnahmezeit, um eine Vielzahl von Intensitätswerten des Rauschsignals zu erhalten;
 wobei die Ausgabevorrichtung weiterhin eine Vielzahl von Intensitätswertänderungstrends in einem Diagramm entsprechend der Intensitätswerte des Primärsignals, des sekundären pulsartigen Signals und des Rauschsignals anzeigt.

3. System nach Anspruch 2, wobei die Ausgabevorrichtung angepasst ist, eine Vielzahl von ersten Ähnlichkeitsindizes zwischen dem Intensitätswertänderungstrend des primären pulsartigen Signals und dem Intensitätswertänderungstrend des sekundären pulsartigen Signals, eine Vielzahl von zweiten Ähnlichkeitsindizes zwischen dem Intensitätswertänderungstrend des primären Signals und dem Intensitätswertänderungstrend des Rauschsignals, und einer Vielzahl von dritten Ähnlichkeitsindizes zwischen dem Intensitätswertänderungstrend des sekundären Signals und dem Intensitätswertänderungstrend des Rauschsignals durch eine Korrelationsfunktion mit einer Vielzahl von Verzögerungsvarianten zu berechnen, und wobei die Ausgabevorrichtung angepasst ist, um einen größten Wert aus den ersten Ähnlichkeitsindizes als einen pulsartigen Ähnlichkeitsindex auszuwählen, um den größten Wert aus den zweiten und dritten Ähnlichkeitsindizes als den Rauschähnlichkeitsindex zu wählen, und um einen Verhältniskoeffizienten zu erhalten, indem der Rauschähnlichkeitsindex durch den pulsartigen Ähnlichkeitsindex geteilt wird.

4. System nach einem der Ansprüche 1-3, wobei das Referenzierungsverfahren ein Intensitätsprozentverfahren, ein Mittelungsstandardabweichungsverhältnisverfahren, ein Autokorrelationsverfahren, ein hierarchisches Korrelationsverfahren oder eine beliebige Kombination davon umfasst.

5. System nach Anspruch 4, wobei der Datenanalyseprozessor angepasst ist, um das Intensitätsprozentverfahren durchzuführen, um die Referenzsequenz zu erhalten, und wobei das Intensitätsprozentverfahren die folgenden Schritte umfasst:

Anordnen der Farbwertsequenzen nach dem größten Farbwert jeder der Farbwertsequenzen, um eine Vielzahl von Prozenträngen zu erhalten;
 Auswählen der Farbwertsequenzen, deren Prozentrang innerhalb eines vorgegebenen Rangbereichs liegt, um eine Referenzgruppe zu erhalten; und
 Mitteln der Farbwertsequenzen in der Referenzgruppe, um die Referenzsequenz zu erhalten.

6. System nach Anspruch 4, wobei der Datenanalyseprozessor angepasst ist, um das Mittelungsstandardabweichungsverhältnisverfahren durchzuführen, um die Referenzsequenz zu erhalten, und wobei das Mittelungsstandardabweichungsverhältnisverfahren die folgenden Schritte umfasst:

Berechnen des Farbwertes in jeder Farbwertsequenz, um eine Vielzahl von Standardabweichungswerten zu erhalten, und dann Dividieren durch einen Mittelwert der Standardabweichungswerte, um eine Vielzahl von mittleren Standardabweichungsverhältnissen zu erhalten;
 Auswählen der Farbwertsequenzen, deren Mittelwert des Standardabweichungsverhältnisses innerhalb eines vorbestimmten Verhältnissbereichs liegt, um eine Referenzgruppe zu erhalten; und
 Mitteln der Farbwertsequenzen in der Referenzgruppe, um die Referenzsequenz zu erhalten.

7. System nach Anspruch 4, wobei der Datenanalyseprozessor angepasst ist, das Autokorrelationsverfahren durchzuführen, um die Referenzsequenz zu erhalten, und wobei das Autokorrelationsverfahren die folgenden Schritte umfasst:

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Berechnen jeder Farbwertsequenz durch eine Autokorrelationsfunktion mit einer Vielzahl von Verzögerungsvarianten, um eine Vielzahl von Autokorrelationskoeffizientenwerten zu erhalten; und
Auswählen einer Farbwertsequenz, die den kleinsten Autokorrelationskoeffizientenwert hat, um die Referenzsequenz zu erhalten.

5

8. System nach Anspruch 4, wobei der Datenanalyseprozessor angepasst ist, das hierarchische Korrelationsverfahren auszuführen, um die Referenzsequenz zu erhalten, und wobei das hierarchische Korrelationsverfahren die folgenden Schritte umfasst:

10 (a) Sammeln der Farbwertsequenzen zu einem i-ten Referenzsequenz-Satz, wobei ein Anfangswert von i gleich 1 ist;

(b) Erhalten einer Vielzahl von Korrelationskoeffizientenwerten des i-ten Referenzsequenz-Satzes durch Berechnen jedes Paares der Farbwertsequenzen in dem i-ten Referenzsequenz-Satz durch eine Korrelationsfunktion;

15 (c) Auswählen des Paares der Farbwertsequenzen, die einen größten Korrelationskoeffizientenwert haben, in dem i-ten Referenzsequenz-Satz;

(d) Mitteln des ausgewählten Paares der Farbwertsequenzen in dem i-ten Referenzsequenz-Satz, um eine neue Farbwertsequenz zu erzeugen;

20 (e) Sammeln der neuen Farbwertsequenz und der Farbwertsequenzen in dem i-ten Referenzsequenz-Satz mit Ausnahme des ausgewählten Paares der Farbwertsequenzen in einem $(i+1)$ -ten Referenzsequenz-Satz;

(f) Erhalten einer Vielzahl von Korrelationskoeffizientenwerten des $(i+1)$ -ten Referenzsequenz-Satzes durch Berechnen jedes Paares der Farbwertsequenzen in dem $(i+1)$ ten Referenzsequenz-Satz durch die Korrelationsfunktion;

25 (g) Bestimmen, ob alle Korrelationskoeffizientenwerte des $(i+1)$ -ten Referenzsequenz-Satzes kleiner als eine vorbestimmte Korrelationsschwelle sind; und

(h) wenn einer der Korrelationskoeffizientenwerte des $(i+1)$ -ten Referenzsequenz-Satzes nicht kleiner als die vorbestimmte Korrelationsschwelle ist, Setzen von $i=i+1$ und Wiederholen der Schritte (c), (d), (e), (f) und (g), und wenn alle Korrelationskoeffizientenwerte des $(i+1)$ -ten Referenzsequenz-Satzes kleiner als die vorbestimmte Korrelationsschwelle sind, Ausgeben der Farbwertsequenz in dem $(i+1)$ -ten Referenzsequenz-Satz, der durch Mitteln einer größten Zahl der Farbwertsequenzen in dem ersten Referenzsequenz-Satz erzeugt wird, als eine Referenzsequenz.

30

9. System nach einem der Ansprüche 1-8, wobei das Clustering-Verfahren ein Korrelationsgruppierungsverfahren, ein Gruppierungsverfahren mit Verzögerungs-Korrelationsverfahren, ein Zwei-Zentren-Korrelations-Clustering-Verfahren oder eine beliebige Kombination davon umfasst.

35

10. System nach Anspruch 9, wobei der Datenanalyseprozessor angepasst ist, das Korrelationsgruppierungsverfahren durchzuführen, um die Korrelationskoeffizientenwerte zu erhalten, und das Korrelationsgruppierungsverfahren den folgenden Schritt umfasst:

40 Berechnen jeder der Farbwertsequenzen mit der Referenzsequenz durch eine Korrelationsfunktion, um die Korrelationskoeffizientenwerte der Farbwertsequenzen zu erhalten.

11. System nach Anspruch 9, wobei der Datenanalyseprozessor angepasst ist, das Zwei-Zentren-Korrelations-Clustering-Verfahren durchzuführen, um die Korrelationskoeffizientenwerte zu erhalten, und das Zwei-Zentren-Korrelations-Clustering-Verfahren die folgenden Schritte umfasst:

45

(a) Sammeln der Farbwertsequenzen in einen Operationssatz;

(b) Berechnen jeder der Farbwertsequenzen in dem Operationssatz mit der Referenzsequenz durch eine Korrelationsfunktion, um eine Vielzahl von temporären Korrelationskoeffizientenwerten der Farbwertsequenzen zu erhalten;

50

(c) Entfernen der Farbwertsequenz mit dem kleinsten temporären Korrelationskoeffizientenwert aus dem Operationssatz und Zuweisen des kleinsten temporären Korrelationskoeffizientenwerts zum Korrelationskoeffizientenwert der Farbwertsequenz mit dem kleinsten temporären Korrelationskoeffizientenwert;

(d) Entfernen der Farbwertsequenz mit dem größten temporären Korrelationskoeffizientenwert und Zuweisen des größten temporären Korrelationskoeffizientenwerts als Korrelationskoeffizientenwert der Farbwertsequenz mit dem größten temporären Korrelationskoeffizientenwert;

55

(e) Aktualisieren der Referenzsequenz durch Mitteln der Farbwertsequenz mit dem größten temporären Korrelationskoeffizientenwert und der Referenzsequenz; und

(f) Wiederholen der Schritte (b), (c), (d) und (e), bis alle Farbwertsequenzen mit den Korrelationskoeffizientenwerten zugeordnet sind.

- 5 12. System nach Anspruch 9, wobei der Datenanalyseprozessor angepasst ist, um die Gruppierung mit dem Verzögerungs-Korrelationsverfahren durchzuführen, um die Korrelationskoeffizientenwerte zu erhalten, und wobei die Gruppierung mit dem Verzögerungs-Korrelationsverfahren die folgenden Schritte umfasst:

10 Berechnen jeder Farbwertsequenz mit der Referenzsequenz durch eine Korrelationsfunktion mit einer Vielzahl von Verzögerungsvarianten, um eine Vielzahl von Korrelationskoeffizientenwerten zu erhalten;
Auswählen des größten Korrelationskoeffizientenwertes und der entsprechenden Verzögerungsvariante, um den Korrelationskoeffizientenwert und die Verzögerungsvariante jeder Farbwertsequenz zu erhalten.

- 15 13. System nach einem der Ansprüche 1-12, wobei der Datenanalyseprozessor ferner angepasst ist, die Referenzsequenz mit jeder der Farbwertsequenzen durch das Clustering-Verfahren zu vergleichen, um die Korrelationskoeffizientenwerte und eine Vielzahl von Verzögerungsvarianten zu erhalten, die den Korrelationskoeffizientenwerten der Farbwertsequenzen entsprechen, und das Clustering- und Rauschreduzierungsverfahren durchführt, welches die folgenden Schritte umfasst:

20 Klassifizieren der Farbwertsequenzen, deren Korrelationskoeffizientenwerte innerhalb einer Hauptkorrelationskoeffizientenschwelle (300) liegen und deren Verzögerungsvarianten innerhalb einer Hauptverzögerungskoeffizientenschwelle (302, 304) liegen, in das primäre pulsartige Signal;
Klassifizieren der Farbwertsequenzen, deren Korrelationskoeffizientenwerte innerhalb einer sekundären Korrelationskoeffizientenschwelle (306, 308) liegen und deren Verzögerungsvarianten innerhalb einer sekundären Verzögerungskoeffizientenschwelle (310) liegen, in das sekundäre pulsartige Signal; und
25 Klassifizieren der Farbwertsequenzen, deren Korrelationskoeffizientenwerte nicht innerhalb der Hauptkorrelationskoeffizientenschwelle und der sekundären Korrelationskoeffizientenschwelle liegen und deren Verzögerungsvarianten nicht innerhalb der Hauptverzögerungskoeffizientenschwelle und der sekundären Verzögerungskoeffizientenschwelle liegen, in das Rauschsignal.

- 30 14. System nach einem der Ansprüche 1-13, wobei der Schritt des Erhaltens der visualisierten pulsartigen Ultraschallbilder, der von dem Datensatzprozessor ausgeführt wird, die folgenden Schritte umfasst:
für jedes der visualisierten pulsartigen Ultraschallbilder:

35 Auswählen eines Pixels des Rauschsignals als ein Mittelpixel eines Maskenbereichs;
Berechnen einer Anzahl von Pixeln im Maskenbereich;
Reklassifizieren des Rauschsignals in das primäre pulsartige Signal, wenn die Anzahl der primären pulsartigen Signale größer ist als die der sekundären pulsartigen Signale im Maskenbereich; und
Reklassifizieren des Rauschsignals in das sekundäre pulsartige Signal, wenn die Anzahl der sekundären pulsartigen Signale größer ist als die der primären pulsartigen Signale im Maskenbereich.

- 40 15. System nach einem der Ansprüche 1-14, wobei der Schritt des Erhaltens der visualisierten pulsartigen Ultraschallbilder, die von dem Datensatzprozessor ausgeführt wird, weiterhin die folgenden Schritte umfasst:

45 Annotieren der Pixel, die zum primären pulsartigen Signal gehören, mit ersten Farbwerten;
Annotieren der Pixel, die zum sekundären pulsartigen Signal gehören, mit zweiten Farbwerten;
Annotieren der Pixel, die zum Rauschsignal gehören, mit einem dritten Farbwert; und
Erhalten der visualisierten pulsartigen Ultraschallbilder.

- 50 16. Verfahren zum Clustering, zur Rauschreduzierung und zum Visualisieren für ein Doppler-Ultraschallbild, umfassend:

Erhalten einer Vielzahl von Doppler-Ultraschallbildern basierend auf einer Zeitdomäne, wobei jedes der Doppler-Ultraschallbilder einen Farbwert in jedem Pixel (S1010) umfasst;
Anordnen jedes Farbwertes in jedem Pixel von Doppler-Ultraschallbildern basierend auf der Zeitdomäne, um eine Vielzahl von Farbwertsequenzen (S1020) zu erhalten;
55 Berechnen der Farbwertsequenzen durch ein Referenzierungsverfahren, um eine Referenzsequenz (S1030) zu erhalten;
Vergleichen der Referenzsequenz mit jeder Farbwertsequenz durch ein Clustering-Verfahren, um eine Vielzahl von Korrelationskoeffizientenwerten (S1040) zu erhalten;

Klassifizieren der Farbwertsequenzen in ein primäres pulsartiges Signal, ein sekundäres pulsartiges Signal und ein Rauschsignal basierend auf den Korrelationskoeffizientenwerten durch ein Clustering- und Rauschreduzierungsverfahren (S1050); und

5 Annotieren der Farbwerte des primären pulsartigen Signals, des sekundären pulsartigen Signals und des Rauschsignals mit ersten Farbwerten, zweiten Farbwerten und einem dritten Farbwert, um eine Vielzahl von visualisierten pulsartigen Ultraschallbildern (S1060) zu erhalten.

10 Revendications

1. Système de groupage, réduction du bruit et visualisation pour une image Doppler à ultrasons, comprenant :

15 un dispositif de capture (110), conçu pour obtenir une pluralité d'images Doppler à ultrasons sur la base d'un domaine temporel, chacune de l'image Doppler à ultrasons comprenant une valeur de couleur dans chaque pixel ;

un dispositif de traitement (120), connecté au dispositif de capture, et comprenant :

20 un processeur de conversion de données (122), conçu pour agencer la valeur de couleur dans chaque pixel des images Doppler à ultrasons sur la base du domaine temporel afin d'obtenir une pluralité de séquences (214) de valeurs de couleur ;

25 un processeur d'analyse de données (124), conçu pour calculer les séquences de valeurs de couleur par l'intermédiaire d'un procédé de référencement afin d'obtenir une séquence de référence, comparer la séquence de référence avec chacune des séquences de valeurs de couleur par l'intermédiaire d'un procédé de groupage afin d'obtenir une pluralité de valeurs de coefficients de corrélation, et classer les séquences de valeurs de couleur en un signal pulsatile primaire, un signal pulsatile secondaire et un signal de bruit sur la base des valeurs de coefficients de corrélation par l'intermédiaire d'un procédé de groupage et réduction du bruit ; et

30 un processeur d'enregistrement de données (120), conçu pour annoter les valeurs de couleur du signal pulsatile primaire, du signal pulsatile secondaire et du signal de bruit afin d'obtenir une pluralité d'images à ultrasons pulsatiles visualisées ;

un dispositif de sortie (130), connecté au dispositif de traitement et conçu pour afficher les images à ultrasons pulsatiles visualisées.

35 2. Système selon la revendication 1, dans lequel le dispositif de sortie est conçu pour fournir une sélection d'une région d'intérêt dans les images à ultrasons pulsatiles visualisées, le processeur d'enregistrement de données est conçu pour obtenir une pluralité de tendances de changement de valeur d'intensité du signal pulsatile primaire, du signal pulsatile secondaire et du signal de bruit dans la région d'intérêt des images à ultrasons pulsatiles visualisées par les étapes suivantes :

40 normaliser les valeurs de couleur de chaque pixel du signal pulsatile primaire, du signal pulsatile secondaire et du signal de bruit dans la région d'intérêt de l'image à ultrasons pulsatile visualisée ;

calculer une moyenne des valeurs de couleur normalisées du signal pulsatile primaire à chaque temps de capture pour obtenir une pluralité de valeur d'intensité du signal primaire ;

45 calculer une moyenne des valeurs de couleur normalisées du signal pulsatile secondaire à chaque temps de capture pour obtenir une pluralité de valeurs d'intensité du signal pulsatile secondaire ; et

calculer une moyenne des valeurs de couleur normalisées du signal de bruit à chaque temps de capture pour obtenir une pluralité de valeurs d'intensité du signal de bruit ;

50 le dispositif de sortie affichant en outre une pluralité de tendances de changement de valeur d'intensité dans un graphique en fonction des valeurs d'intensité du signal primaire, du signal pulsatile secondaire et du signal de bruit.

55 3. Système selon la revendication 2, dans lequel le dispositif de sortie est conçu pour calculer une pluralité de premiers indices de similarité entre la tendance de changement de valeur d'intensité du signal pulsatile primaire et la tendance de changement de valeur d'intensité du signal pulsatile secondaire, une pluralité de deuxièmes indices de similarité entre la tendance de changement de valeur d'intensité du signal primaire et la tendance de changement de valeur d'intensité du signal de bruit, et une pluralité de troisièmes indices de similarité indices de similarité entre la tendance de changement de valeur d'intensité du signal secondaire et la tendance de changement de valeur d'intensité du

signal de bruit par l'intermédiaire d'une fonction de corrélation avec une pluralité de variétés de décalages, et le dispositif de sortie est conçu pour choisir une valeur la plus grande parmi les premiers indices de similarité pour être l'indice de similarité pulsatile, pour choisir la valeur la plus grande parmi les deuxième et troisième indices de similarité pour être l'indice de similarité de bruit, et pour obtenir un coefficient de rapport en divisant l'indice de similarité de bruit par l'indice de similarité pulsatile.

4. Système selon l'une quelconque des revendications 1 à 3, dans lequel le procédé de référencement comprend un procédé de pourcentage d'intensité, un procédé de rapport d'écart-type moyen, un procédé d'autocorrélation, un procédé de corrélation hiérarchique ou une quelconque combinaison de ceux-ci.

5. Système selon la revendication 4, dans lequel le processeur d'analyse de données est conçu pour réaliser le procédé de pourcentage d'intensité afin d'obtenir la séquence de référence, et le procédé de pourcentage d'intensité comprend les étapes suivantes consistant à :

agencer les séquences de valeurs de couleur en fonction de la plus grande valeur de couleur de chacune des séquences de valeurs de couleur afin d'obtenir une pluralité de rangs centiles ;
choisir les séquences de valeurs de couleur pour lesquelles le rang centile est dans une plage de rangs prédéfinie afin d'obtenir un groupe de référence ; et
calculer la moyenne des séquences de valeurs de couleur dans le groupe de référence afin d'obtenir la séquence de référence.

6. Système selon la revendication 4, dans lequel le processeur d'analyse de données est conçu pour exécuter le procédé de rapport d'écart-type moyen afin d'obtenir la séquence de référence, et le procédé de rapport d'écart-type moyen comprend les étapes suivantes consistant à :

calculer la valeur de couleur dans chaque séquence de valeurs de couleur afin d'obtenir une pluralité de valeurs d'écart-type, puis diviser par une valeur moyenne des valeurs d'écart-type afin d'obtenir une pluralité de valeurs de rapport d'écart-type moyennes ;
choisir les séquences de valeurs de couleur pour lesquelles la valeur de rapport d'écart-type moyen est dans une plage de rapports prédéfinie afin d'obtenir un groupe de référence ; et
calculer la moyenne des séquences de valeurs de couleur dans le groupe de référence afin d'obtenir la séquence de référence.

7. Système selon la revendication 4, dans lequel le processeur d'analyse de données est conçu pour réaliser le procédé d'autocorrélation afin d'obtenir la séquence de référence, et le procédé d'autocorrélation comprend les étapes suivantes consistant à :

calculer chaque séquence de valeurs de couleur par le biais d'une fonction d'autocorrélation avec une pluralité de variétés de décalages afin d'obtenir une pluralité de valeurs de coefficients d'autocorrélation ; et
choisir une séquence de valeurs de couleur qui a la valeur de coefficient d'autocorrélation la plus petite afin d'obtenir la séquence de référence.

8. Système selon la revendication 4, dans lequel le processeur d'analyse de données est conçu pour réaliser le procédé de corrélation hiérarchique afin d'obtenir la séquence de référence, et le procédé de corrélation hiérarchique comprend les étapes suivantes consistant à :

(a) rassembler les séquences de valeurs de couleur dans un $i^{\text{ème}}$ ensemble de séquences de référence, une valeur initiale de i étant 1 ;
(b) obtenir une pluralité de valeurs de coefficients de corrélation du $i^{\text{ème}}$ ensemble de séquences de référence en calculant chaque paire des séquences de valeurs de couleur dans le $i^{\text{ème}}$ ensemble de séquences de référence par l'intermédiaire d'une fonction de corrélation ;
(c) sélectionner la paire de séquences de valeurs de couleur dans le $i^{\text{ème}}$ ensemble de séquences de référence, qui a la plus grande valeur de coefficient de corrélation ;
(d) calculer la moyenne de la paire sélectionnée de séquences de valeurs de couleur dans le $i^{\text{ème}}$ ensemble de séquences de référence afin de générer une nouvelle séquence de valeurs de couleur ;
(e) rassembler la nouvelle séquence de valeurs de couleur et les séquences de valeurs de couleur dans le $i^{\text{ème}}$ ensemble de séquences de référence à l'exception de la paire sélectionnée de séquences de valeurs de couleur dans une $(i+1)^{\text{ème}}$ ensemble de séquences de référence ;

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(f) obtenir une pluralité de valeurs de coefficients de corrélation du $(i+1)^{\text{ème}}$ ensemble de séquences de référence en calculant chaque paire de séquences de valeurs de couleur dans le $(i+1)^{\text{ème}}$ ensemble de séquences de référence par l'intermédiaire de la fonction de corrélation ;

(g) déterminer si toutes les valeurs de coefficients de corrélation du $(i+1)^{\text{ème}}$ ensemble de séquences de référence sont inférieures à un seuil de corrélation prédéfini ; et

(h) lorsque l'une des valeurs de coefficients de corrélation du $(i+1)^{\text{ème}}$ ensemble de séquences de référence n'est pas inférieure au seuil de corrélation prédéfini, définir $i=i+1$ et répéter les étapes (c), (d), (e), (f) et (g), et lorsque toutes les valeurs de coefficients de corrélation du $(i+1)^{\text{ème}}$ ensemble de séquences de référence sont inférieures au seuil de corrélation prédéfini, sortir la séquence de valeurs de couleur dans le $(i+1)^{\text{ème}}$ ensemble de séquences de référence qui est généré par le calcul de la moyenne d'un nombre le plus des séquences de valeurs de couleur dans le premier ensemble de séquences de référence en tant que séquence de référence.

9. Système selon l'une quelconque des revendications 1 à 8, dans lequel le procédé de groupage comprend un procédé de groupage avec corrélation, un procédé de groupage avec corrélation de décalages, un procédé de groupage avec corrélation à deux centres ou une quelconque combinaison de ceux-ci.

10. Système selon la revendication 9, dans lequel le processeur d'analyse de données est conçu pour réaliser le procédé de groupage avec corrélation afin d'obtenir les valeurs de coefficients de corrélation, et le procédé de groupage avec corrélation comprend les étapes suivantes consistant à :

calculer chacune des séquences de valeurs de couleur avec la séquence de référence par l'intermédiaire d'une fonction de corrélation afin d'obtenir les valeurs de coefficients de corrélation des séquences de valeurs de couleur.

11. Système selon la revendication 9, dans lequel le processeur d'analyse de données est conçu pour réaliser le procédé de groupage avec corrélation à deux centres afin d'obtenir les valeurs de coefficients de corrélation, et le procédé de groupage avec corrélation à deux centres comprend les étapes suivantes consistant à :

(a) rassembler les séquences de valeurs de couleur en un ensemble d'opérations ;

(b) calculer chacune des séquences de valeurs de couleur de l'ensemble d'opérations avec la séquence de référence par l'intermédiaire d'une fonction de corrélation afin d'obtenir une pluralité de valeurs de coefficients de corrélation temporaires des séquences de valeurs de couleur ;

(c) retirer la séquence de valeurs de couleurs ayant la plus petite valeur de coefficient de corrélation temporaire de l'ensemble d'opérations et attribuer la plus petite valeur de coefficient de corrélation temporaire devant être la valeur de coefficient de corrélation de la séquence de valeurs de couleurs ayant la plus petite valeur de coefficient de corrélation temporaire ;

(d) retirer la séquence de valeurs de couleurs ayant la plus grande valeur de coefficient de corrélation temporaire de l'ensemble d'opérations et attribuer la plus grande valeur de coefficient de corrélation temporaire devant être la valeur de coefficient de corrélation de la séquence de valeurs de couleurs ayant la plus grande valeur de coefficient de corrélation temporaire ;

(e) mettre à jour la séquence de référence en calculant la moyenne de la séquence de valeurs de couleur avec la plus grande valeur de coefficient de corrélation temporaire et la séquence de référence ; et

(f) répéter les étapes (b), (c), (d) et (e) jusqu'à ce que toutes les séquences de valeurs de couleur aient reçu les valeurs de coefficient de corrélation.

12. Système selon la revendication 9, dans lequel le processeur d'analyse de données est conçu pour réaliser le procédé de groupage avec corrélation de décalages afin d'obtenir les valeurs de coefficients de corrélation, et le procédé de groupage avec corrélation de décalages comprend les étapes suivantes consistant à :

calculer chaque séquence de valeurs de couleur avec la séquence de référence par le biais d'une fonction de corrélation avec une pluralité de variétés de décalages afin d'obtenir une pluralité de valeurs de coefficients de corrélation ;

choisir la plus grande valeur de coefficient de corrélation et la variété de décalage correspondante afin d'obtenir la valeur de coefficient de corrélation et la variété de décalage de chaque séquence de valeurs de couleur.

13. Système selon l'une quelconque des revendications 1 à 12, dans lequel le processeur d'analyse de données est en outre conçu pour comparer la séquence de référence avec chacune des séquences de valeurs de couleur par l'intermédiaire du procédé de groupage afin d'obtenir les valeurs de coefficients de corrélation et une pluralité de variétés de décalages correspondant aux valeurs de coefficients de corrélation des séquences de valeurs de couleur et exécute le procédé de groupage et réduction du bruit comprenant les étapes suivantes consistant à :

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classer les séquences de valeurs de couleurs, dont les valeurs de coefficients de corrélation sont dans les limites d'un seuil de coefficient de corrélation principal (300) et dont les variétés de décalages sont dans les limites d'un seuil de coefficient de décalage principal (302, 304), en signal pulsatile primaire ;
classer les séquences de valeurs de couleurs, dont les valeurs de coefficients de corrélation sont dans les limites d'un seuil de coefficient de corrélation secondaire (306, 308) et dont les variétés de décalages sont dans les limites d'un seuil de coefficient de décalage secondaire (310), en signal pulsatile secondaire ; et
classer les séquences de valeurs de couleur, dont les valeurs de coefficients de corrélation ne sont pas dans les limites du seuil de coefficient de corrélation principal et du seuil de coefficient de corrélation secondaire et dont la variété de décalages ne sont pas dans les limites du seuil de coefficient de décalage principal et du seuil de coefficient de décalage secondaire, en signal de bruit.

14. Système selon l'une quelconque des revendications 1 à 13, dans lequel l'étape consistant à obtenir les images à ultrasons pulsatiles visualisées exécutées par le processeur d'enregistrement de données comprend les étapes suivantes consistant à :

pour chacune des images à ultrasons pulsatiles visualisées :

sélectionner un pixel du signal de bruit en tant que pixel central d'une région de masque ;
calculer un nombre de pixels dans la région de masque ;
reclasser le signal de bruit en signal pulsatile primaire si le nombre de signaux pulsatiles primaires est supérieur à celui de signaux pulsatiles secondaires dans la région de masque ; et
reclasser le signal de bruit en signal pulsatile secondaire si le nombre de signaux pulsatiles secondaires est supérieur à celui de signaux pulsatiles primaires dans la région de masque.

15. Système selon l'une quelconque des revendications 1 à 14, dans lequel l'étape consistant à obtenir les images à ultrasons pulsatiles visualisées exécutées par le processeur d'enregistrement de données, comprend en outre les étapes suivantes consistant à :

annoter les pixels qui appartiennent au signal pulsatile primaire avec des premières valeurs de couleur ;
annoter les pixels qui appartiennent au signal pulsatile secondaire avec des deuxièmes valeurs de couleur ;
annoter les pixels qui appartiennent au signal de bruit avec une troisième valeur de couleur ; et
obtenir les images à ultrasons pulsatiles visualisées.

16. Procédé de groupage, réduction du bruit et visualisation pour une image Doppler à ultrasons, consistant à :

obtenir une pluralité d'images Doppler à ultrasons sur la base d'un domaine temporel, chacune des images Doppler à ultrasons comprenant une valeur de couleur dans chaque pixel (S1010) ;
agencer chaque valeur de couleur dans chaque pixel des images Doppler à ultrasons sur la base du domaine temporel afin d'obtenir une pluralité de séquences de valeurs de couleur (S1020) ;
calculer les séquences de valeurs de couleur par l'intermédiaire d'un procédé de référencement afin d'obtenir une séquence de référence (S1030) ;
comparer la séquence de référence avec chaque séquence de valeurs de couleur par l'intermédiaire d'un procédé de groupage afin d'obtenir une pluralité de valeurs de coefficients de corrélation (S1040) ;
classer les séquences de valeurs de couleur en un signal pulsatile primaire, un signal pulsatile secondaire et un signal de bruit sur la base des valeurs de coefficients de corrélation par l'intermédiaire d'un procédé de groupage et réduction du bruit (S1050) ; et
annoter les valeurs de couleurs du signal pulsatile primaire, du signal pulsatile secondaire et du signal de bruit avec des premières valeurs de couleur, des deuxièmes valeurs de couleur et une troisième valeur de couleur, respectivement, afin d'obtenir une pluralité d'images à ultrasons pulsatiles visualisées (S1060).

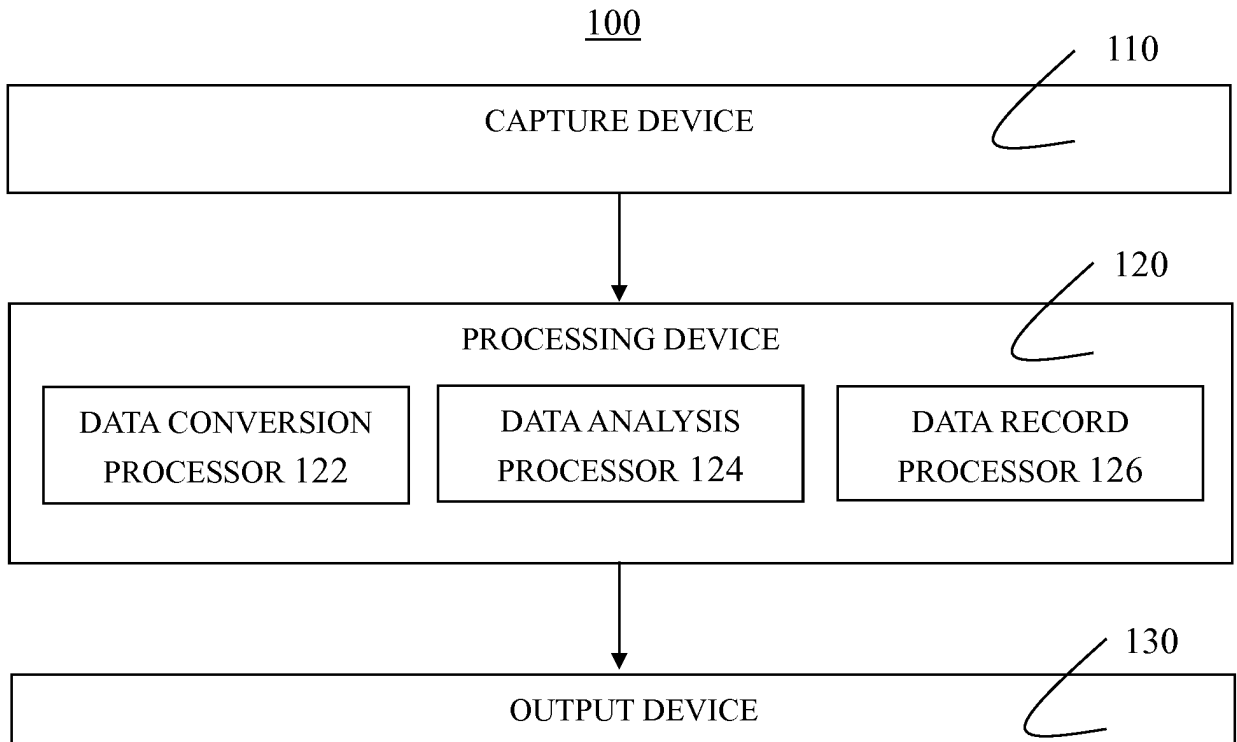


FIG. 1

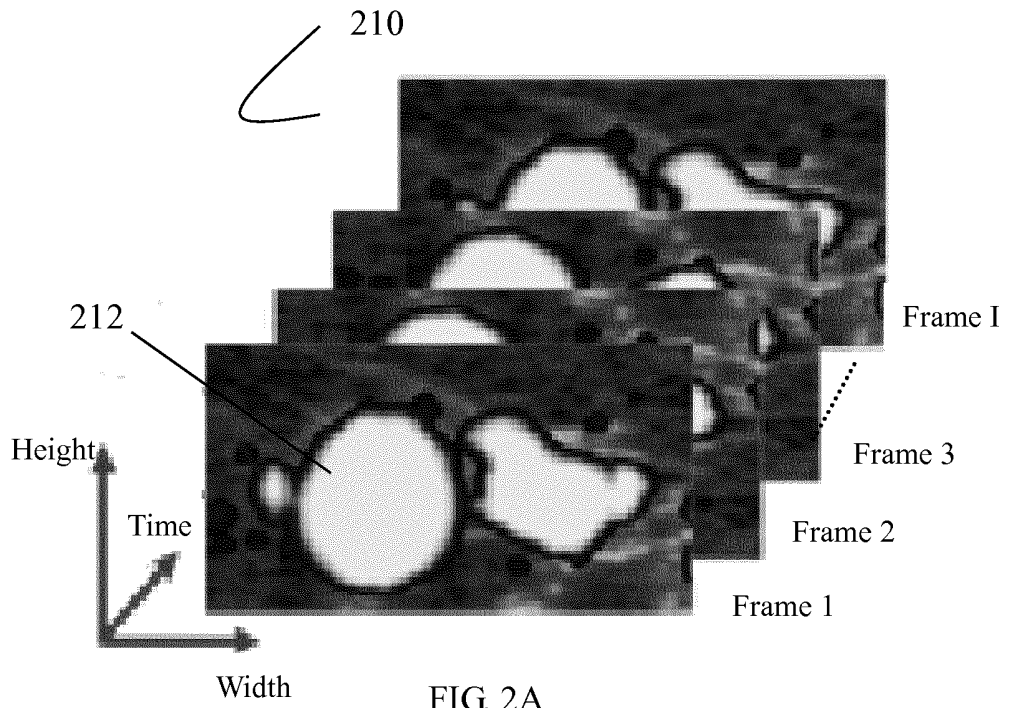


FIG. 2A

	Frame 1	Frame 2	Frame 3	Frame 4	Frame i	Frame I	
Pixel 1	$B_{1,1}$	$B_{1,2}$	$B_{1,3}$	$B_{1,4}$	$B_{1,i}$	$B_{1,I}$	C_1
Pixel 2	$B_{2,1}$	$B_{2,2}$	$B_{2,3}$	$B_{2,4}$	$B_{2,i}$	$B_{2,I}$	C_2
.....
.....
Pixel j	$B_{j,1}$	$B_{j,2}$	$B_{j,3}$	$B_{j,4}$	$B_{j,i}$	$B_{j,I}$	C_j

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FIG. 2B

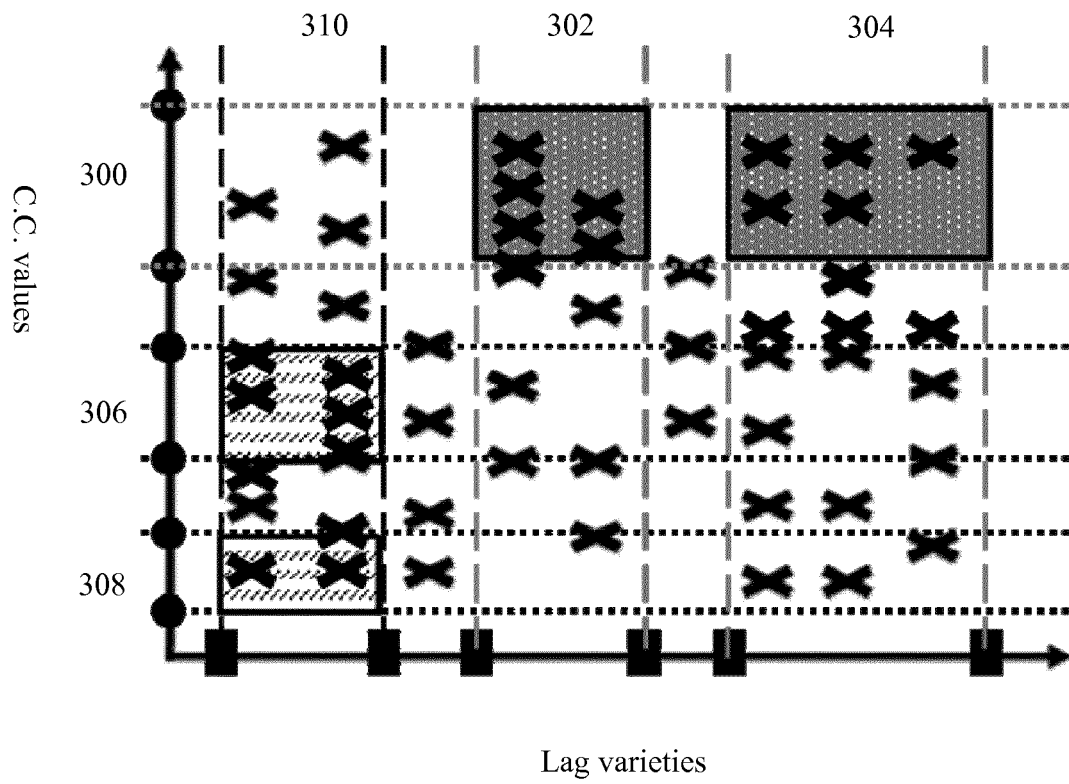


FIG. 3

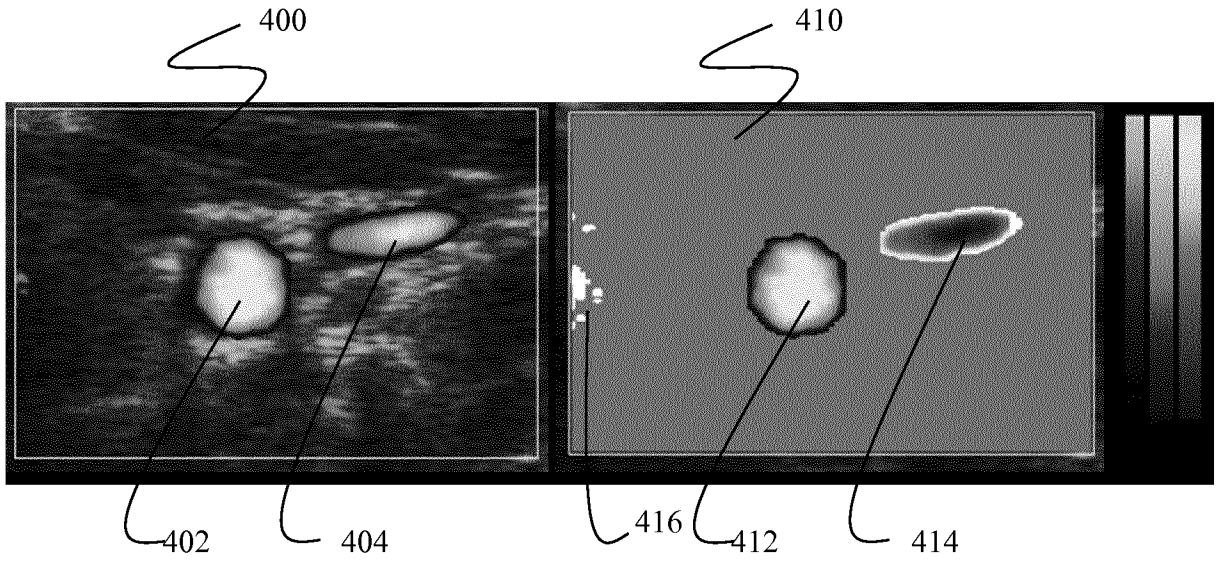


FIG. 4

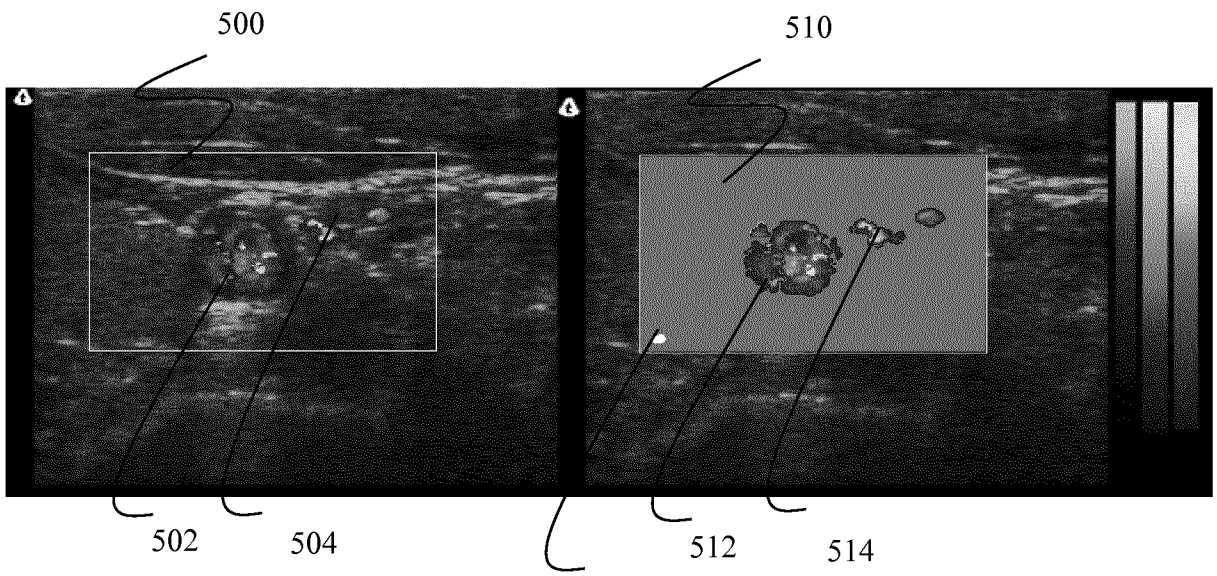


FIG. 5

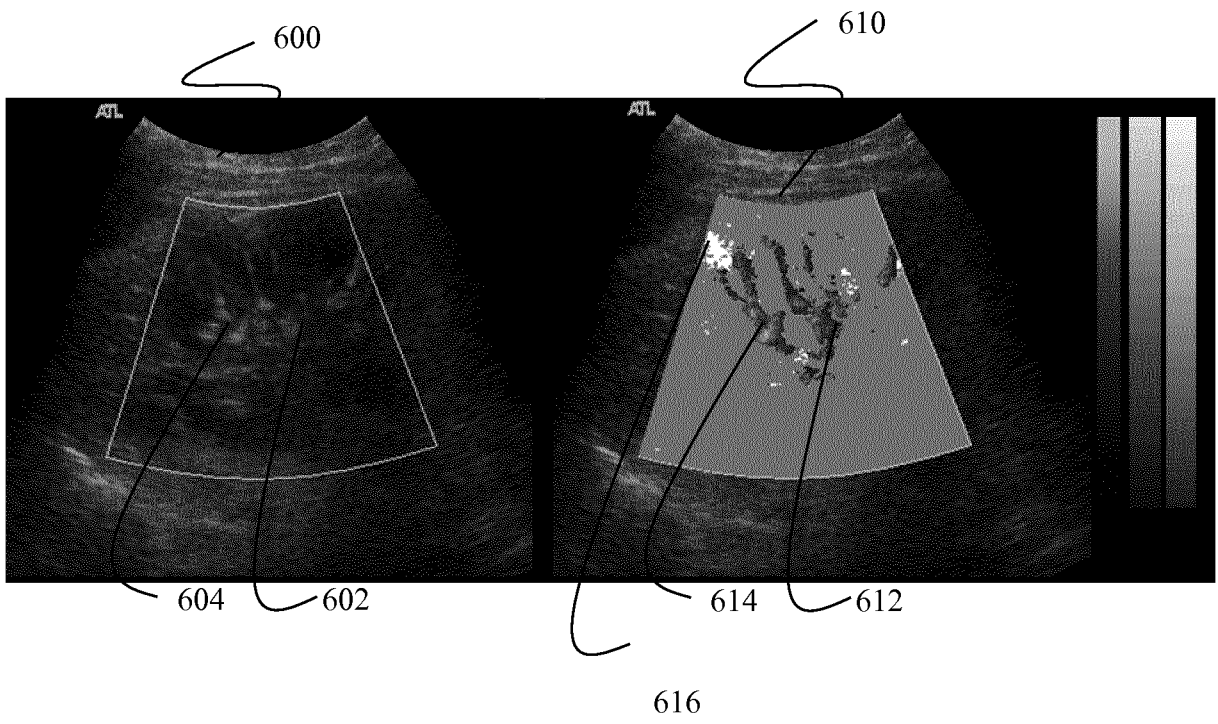


FIG. 6

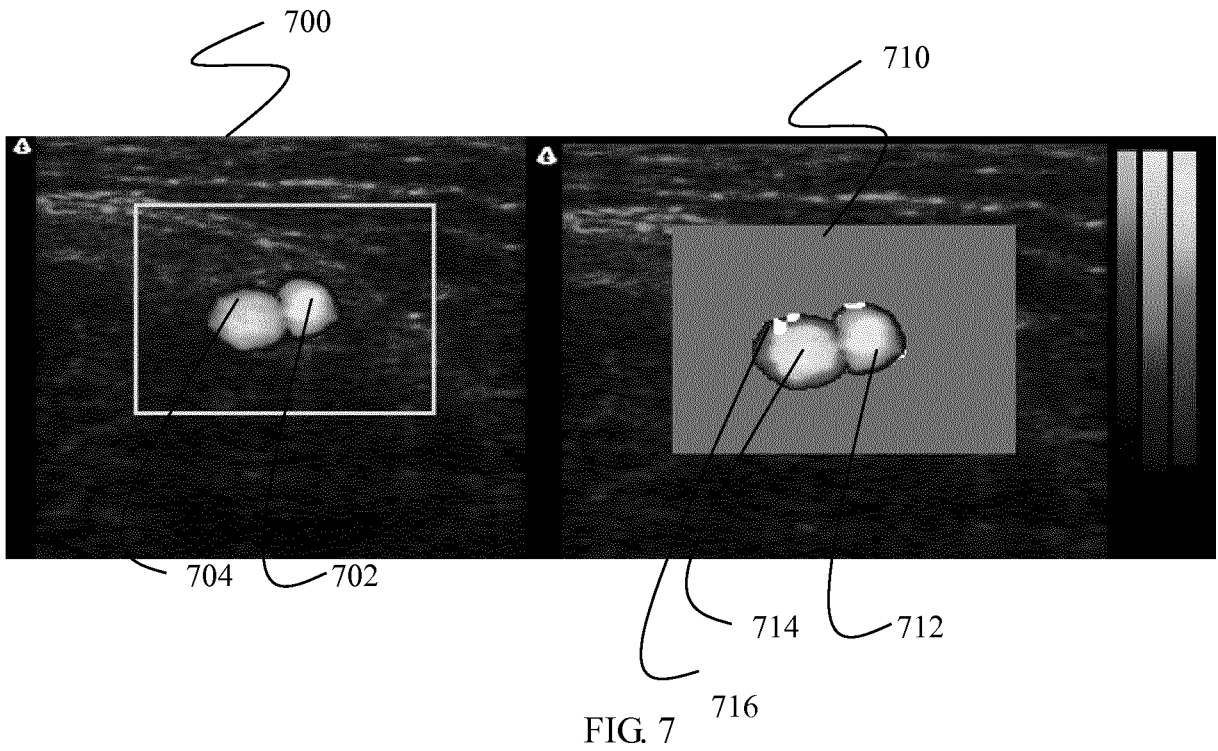


FIG. 7

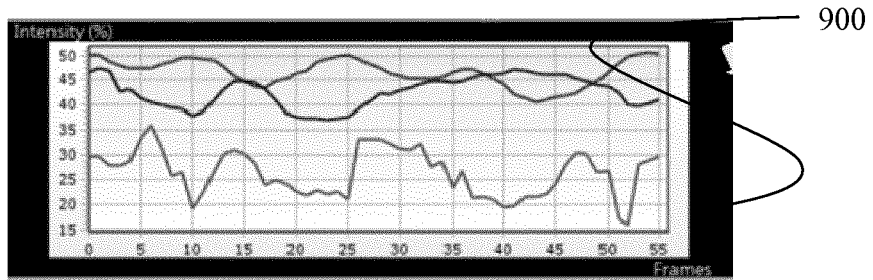


FIG. 9

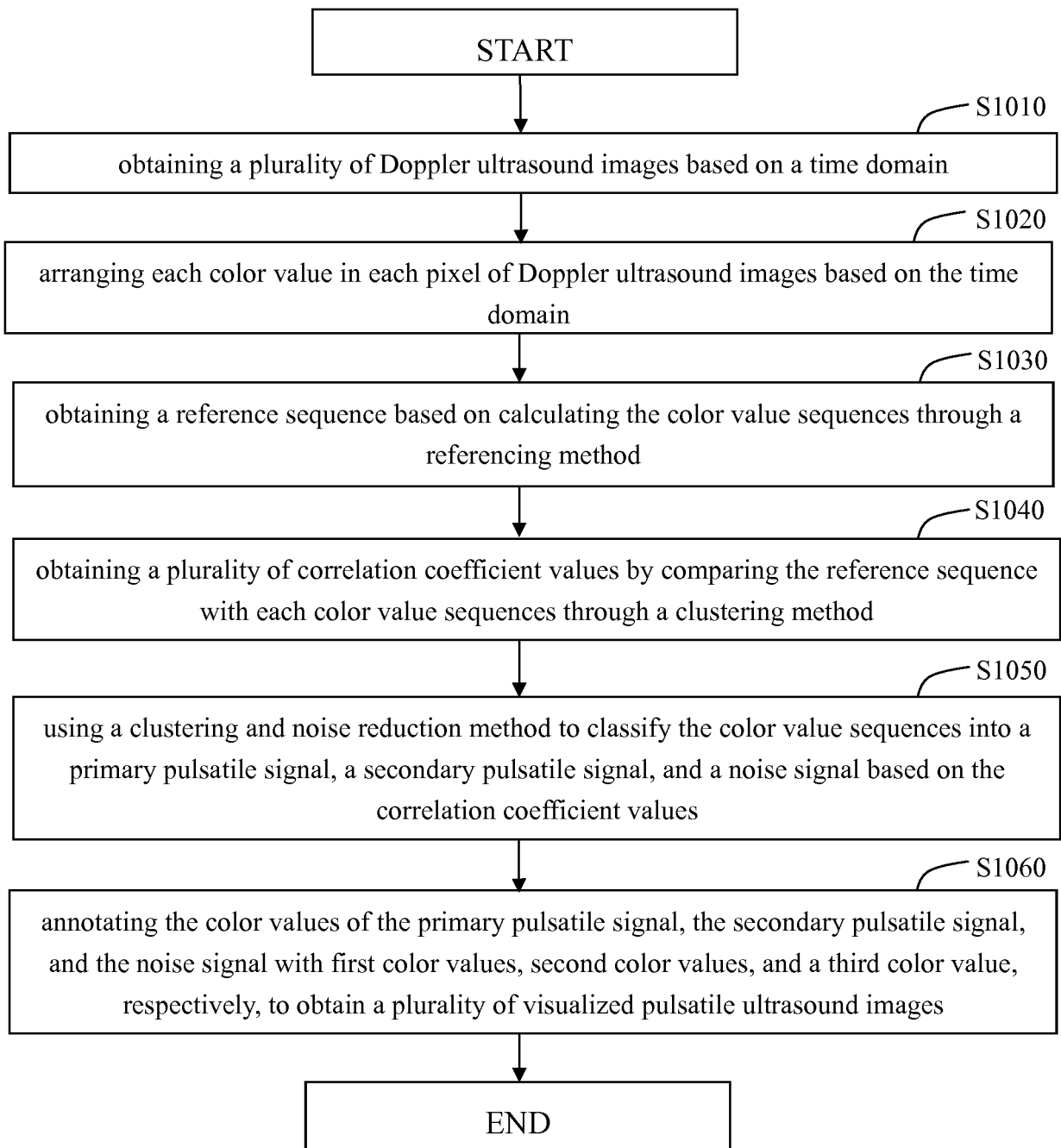


FIG. 10

REFERENCES CITED IN THE DESCRIPTION

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- TW 1275383 [0003] [0005]
- US 8047993 B2 [0003] [0004] [0005]
- US 8777860 B2 [0005]
- US 5279302 A [0005]

专利名称(译)	多普勒超声图像的聚类，降噪和可视化方法		
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[标]申请(专利权)人(译)	美国医科华股份有限公司		
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外部链接	Espacenet		

摘要(译)

本发明提供一种多普勒超声图像分析系统，包括：捕获设备，处理设备和输出设备。捕获设备获得多个多普勒超声图像。处理装置基于时域在图像的每个像素中排列颜色值，并通过参考方法获得参考序列，进一步执行聚类方法以获得多个相关系数值，然后使用聚类和降噪分类为初级脉动信号，次级脉动信号和噪声信号的方法最后分别注释初级脉动信号，次级脉动信号和具有不同颜色值的噪声信号。输出设备显示多个可视化脉动超声图像以用于可视化。

