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(54) METHOD AND APPARATUS FOR AUTOMATIC VESSEL TRACKING IN ULTRASOUND IMAGING

VERFAHREN UND GERÄT ZUR AUTOMATISCHEN VERFOLGUNG VON BLUTGEFÄSSEN BEI ULTRASCHALLBILDDARSTELLUNG

PROCEDE ET APPAREIL DE SUIVI AUTOMATIQUE DE VAISSEAU SANGUIN EN IMAGERIE ULTRASONORE

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Description

FIELD OF THE INVENTION

[0001] This invention generally relates to the imaging of moving ultrasound scatterers. In particular, the invention relates to methods for tracking the position and/or orientation of a blood vessel in medical diagnostic ultrasound imaging.

BACKGROUND OF THE INVENTION

[0002] Premium medical diagnostic ultrasound imaging systems require a comprehensive set of imaging modes. These are the major imaging modes used in clinical diagnosis and include timeline (spectral) Doppler, color flow Doppler, B mode and M mode. In the B mode, such ultrasound imaging systems create two-dimensional images of tissue in which the brightness of a pixel is based on the intensity of the returned echo. Alternatively, in a color flow imaging mode, the movement of fluid (e.g., blood) or tissue can be imaged. Measurement of blood flow in the heart and vessels using the Doppler effect is well known. The phase shift of backscattered ultrasound waves may be used to measure the velocity of the backscatterers from tissue or blood. The Doppler shift may be displayed using different colors to represent speed and direction of flow. In the spectral Doppler imaging mode, the power spectrum of these Doppler frequency shifts are computed for visual display as velocity-time waveforms.

[0003] One of the primary advantages of Doppler ultrasound is that it can provide noninvasive and quantitative measurements of blood flow in vessels. Given the angle θ between the insonifying beam and the flow axis (hereinafter referred to as the "Doppler angle"), the magnitude of the velocity vector can be determined by the standard Doppler equation:

$$\nu = cf_d/(2f_0\cos\theta)$$

where c is the speed of sound in blood, f_0 is the transmit frequency and f_d is the motion-induced Doppler frequency shift in the backscattered ultrasound signal.

[0004] In conventional ultrasound scanners that perform B-mode and spectral Doppler imaging either simultaneously or in a segmented fashion, the angle between the Doppler beam cursor (beam centerline) and a vessel slope cursor in the B-mode image is used to convert Doppler frequency shifts into velocity units according to the Doppler equation. The operator is required to manually adjust (e.g., via a toggle switch) the vessel slope cursor based on the orientation of the vessel wall(s) in the B-mode image. The Doppler angle value is usually displayed along with the graphic. Since the Doppler angle adjustments are based on visual judgment, they are susceptible to error, especially if the angle step size is coarse. If fine angle adjustments are possible, the process can become time consuming.

[0005] An automatic method of adjusting the vessel slope cursor is taught in EP-A-1 005 834, which is prior art in the sense of Art. 54(3) EPC, entitled "Method and Apparatus for Automatic Doppler Angle Estimation in Ultrasound Imaging". The Doppler angle is estimated automatically based on the B-mode and color flow (if available) image. The method uses an algorithm for automatic vessel slope measurement which first finds an optimal initial point within the sample volume or range gate, and then searches for the most reliable pixel points (near or far wall) based on a combination of intensity-only and intensity-difference thresholds, before performing a slope estimation. B-mode intensity data and, optionally, color flow velocity or power data (before gray/color mapping) are used. The algorithm may also be applied to methods for automatic tracking of vessel diameter and flow rate calculations.

[0006] In clinical ultrasound imaging studies, sometimes it is necessary to examine the blood flow at multiple sites along a segment of a blood vessel. With conventional scanners, if the vessel depth changes as the probe is moved along the vessel, the range gate needs to be maintained inside the vessel by manual control (e.g., using a trackball). When examining a flow at a preselected vessel position, the range gate can slide off of the vessel and may sometimes even shift outside the vessel due to tissue and/or probe motion.

[0007] Thus there is a need for a method by which the range gate can be automatically maintained inside a moving blood vessel being examined.

SUMMARY OF THE INVENTION

[0008] The invention is defined in claims 1, 10 and 19.

[0009] The present invention is directed to a method and an apparatus for automatically maintaining the range gate inside a moving blood vessel during ultrasound imaging. The range gate can be maintained at the vessel center, or at a certain distance from one of the vessel boundaries, or at a certain ratio of the respective distances from the two boundaries.

[0010] In accordance with the method of the preferred embodiment, the user first places the range gate on the blood flow being examined. Instead of pushing a control key or button to activate the automatic Doppler angle estimation based on a particular B-mode image frame (and color flow data if available), an algorithm processes each successive image frame and automatically updates the information about vessel boundary positions and the vessel orientation angle in the vicinity of the range gate. If the range gate position relative to the vessel boundaries is different than that in the previous frame by more than a predetermined amount, the position of the range gate graphic and the orientation of the vessel slope cursor (and the Doppler angle) are automatically adjusted to the new values. Optionally, the steering angle of the transmitted beam can also be automatically updated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011]

FIG. 1 is a schematic showing a block diagram showing the general architecture of an ultrasound imaging system which supports the preferred embodiments of the present invention.

FIG. 2 is a schematic depicting an ultrasound image of a portion of a blood vessel with a Doppler beam cursor superimposed thereon.

FIG. 3 is a schematic depicting the ultrasound image of FIG. 2 with edge point search information in accordance with the preferred embodiment of the invention superimposed thereon.

FIG. 4 is a schematic depicting segmentation of the edge points in accordance with the preferred embodiment of the invention.

FIG. 5 is a schematic depicting the ultrasound image of FIG. 2 with a Doppler beam cursor and a vessel slope cursor superimposed thereon.

FIG. 6 is a schematic depicting the step of determining which pixels, along a line perpendicular to the vessel slope cursor, display the vessel wall.

FIG. 7 is a flowchart depicting the algorithm for automatically adjusting the range gate position in accordance with the preferred embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] One conventional ultrasound imaging system is generally depicted in FIG. 1. The main data path begins with the analog RF inputs to the beamformer board 4 from the transducer 2. The beamformer board 4 is responsible for the transmit and receive beamforming. The beamformer's signal inputs are the low-level analog RF signals from the transducer elements. The beamformer board 4, which comprises a beamformer, a demodulator and filters, outputs two summed digital baseband I (in-phase) and Q (quadrature) receive beams formed from acquired data samples. These data samples are derived from the reflected ultrasound from respective focal zones of the transmitted beams. The received data is sent to filters which are programmed with filter coefficients to pass a band of frequencies centered at the fundamental frequency f_0 of the transmit waveform or a (sub)harmonic frequency thereof.

[0013] The I/Q data output from the filters is sent to the midprocessor subsystem, where it is processed according to the acquisition mode and output as processed vector data. Typically, the midprocessor subsystem comprises a color flow processor 6, a B-mode processor 8 and a spectral Doppler processor 10. Alternatively, a digital signal processor or array of such processors can be programmed to process signals for all three modes.

[0014] The B-mode processor 8 converts the baseband I and Q data from the beamformer board 4 into a log-compressed version of the signal envelope. The B-mode function images the time-varying amplitude of the envelope of the signal as a gray scale. The envelope of a baseband signal is the magnitude of the vector which I and Q represent. The I,Q phase angle is not used in the B-mode display. The magnitude of the signal is the square root of the sum of the squares of the orthogonal components, i.e., $(I^2 + Q^2)^{1/2}$. The B-mode intensity data is output to a B-mode acoustic line memory (not shown) in the scan converter 12.

[0015] The scan converter 12 accepts the processed B-mode vector data, interpolates where necessary, and converts the data into *X-Y* format for video display. The scan-converted frames are passed to a video processor 14, which maps the video data to a grayscale mapping for video display. A conventional ultrasound imaging system typically employs a variety of gray maps, which are simple transfer functions of the raw image data to display gray levels. The grayscale image frames are then sent to the display monitor 16 for display.

[0016] The B-mode images displayed by monitor 16 are produced from an image frame of data in which each datum indicates the intensity or brightness of a respective pixel in the display. An image frame may, e.g., comprise a 400×400 data array in which each intensity datum is an 8-bit binary number that indicates pixel brightness. Each pixel has an intensity value which is a function of the backscatter cross section of a respective sample volume in response to interrogating ultrasonic pulses and the gray map employed. The displayed image represents the tissue and/or blood flow in a plane through the body being imaged.

[0017] The color flow processor 6 is used to provide a real-time two-dimensional image of blood velocity in the imaging plane. The frequency of sound waves reflecting from the inside of blood vessels, heart cavities, etc. is shifted in proportion to the velocity of the blood cells: positively shifted for cells moving towards the transducer and negatively for those moving away. The blood velocity is calculated by measuring the phase shift from firing to firing at a specific range gate. Instead of measuring the Doppler spectrum at one range gate in the image, mean blood velocity from multiple vector positions and multiple range gates along each vector are calculated, and a two-dimensional image is made from this information. The color flow processor 6 receives the summed left and right, complex I/Q data from the beamformer board 4 and processes it to calculate the mean blood velocity, variance (representing blood turbulence) and total prenormalization power for all sample volumes within an operator-defined region. These three output values are then combined into two final outputs, one primary and one secondary. The primary output will be either velocity or power. The secondary output can be either variance or power. Which two values will be displayed is determined by the operator-selected display mode. Both values are sent to a color acoustic line memory (not shown) in the scan converter 12. The change or shift in backscattered frequency increases when blood flows toward the transducer and decreases when blood flows away from the transducer. Typically, color flow mode displays hundreds of adjacent sample volumes simultaneously, all laid over a B-mode image and color-coded to represent each sample volume's velocity.

[0018] In the color flow mode of the conventional ultrasound imaging system being described here, an ultrasound transducer array is activated to transmit a series of multi-cycle (typically 4-8 cycles) tone bursts which are focused at the same transmit focal position with the same transmit characteristics. These tone bursts are fired at a pulse repetition frequency (PRF). The PRF is typically in the kilohertz range. A series of transmit firings focused at the same transmit focal position are referred to as a "packet". Each transmit beam propagates through the object being scanned and is reflected by ultrasound scatterers such as blood cells. The return signals are detected by the elements of the transducer array and then formed into a receive beam by a beamformer.

[0019] For example, the traditional color firing sequence is a series of firings (e.g., tone bursts) along the same position, which firings produce the respective receive signals:

$$F_1\ F_2\ F_3\ F_4\ \ldots\ F_M$$

where F_i is the receive signal for the i-th firing and M is the number of firings in a packet. These receive signals are loaded into a corner turner memory, and a high pass filter (wall filter) is applied to each down range position across firings, i.e., in "slow time". In the simplest case of a (1, -1) wall filter, each range point is filtered to produce the respective difference signals:

$$(F_1 - F_2)\ (F_2 - F_3)\ (F_3 - F_4)\ \ldots\ (F_{M-1} - F_M)$$

and these differences are input to a color flow velocity estimator. Typically, the corner turner memory, wall filter and parameter (e.g., velocity) estimators are incorporated into the color flow processor 6.

[0020] The color and B-mode acoustic line memories in scan converter 12 respectively accept processed digital data from the color flow and B-mode processors. These components of the scan converter also perform the coordinate transformation of the color flow and B-mode data from polar coordinate (R-θ) sector format or Cartesian coordinate linear format to appropriately scaled Cartesian coordinate display pixel data, which is stored in an X-Y display memory (not shown) in the scan converter. Color flow images are produced by superimposing a color image of the velocity of moving material, such as blood, over a black and white anatomical B-mode image.

[0021] If the image to be displayed is a combination of one B-mode frame and one color flow frame, then both frames are passed to the video processor 14, which maps the B-mode data to a gray map and maps the color flow data to a color map for video display. In the final displayed image, the color pixel data is superimposed on the grayscale pixel data.

[0022] In spectral Doppler imaging, the I/Q components are integrated (summed) over a specific time interval and then sampled by the spectral Doppler processor 10. The summing interval and the transmit burst length together define the length of the sample volume as specified by the user. A "sum and dump" operation effectively yields the Doppler signal backscattered from the sample volume. The Doppler signal is passed through a wall filter which rejects any clutter in the signal corresponding to stationary or very slow-moving tissue. The filtered output is then fed into a spectrum analyzer, which typically takes Fast Fourier Transforms (FFTs) over a moving time window of 32 to 128 samples. Each FFT power spectrum is compressed and then output by the spectral Doppler processor 10 to a timeline display memory 18. The video processor 14 maps the compressed spectral Doppler data to a gray scale for display on the monitor 16 as a single spectral line at a particular time point in the Doppler velocity (frequency) versus time spectrogram.

[0023] System control is centered in a host computer 20, which accepts operator inputs through an operator interface 22 (e.g., a control panel) and in turn controls the various subsystems. The host computer 20 performs system level control functions. It accepts inputs from the operator via the operator interface 22 as well as system status changes (e.g., mode changes) and makes appropriate system changes. A system control bus (not shown) provides the interface from the host computer to the subsystems. A scan controller (not shown) provides real-time (acoustic vector rate) control inputs to the various subsystems. The scan controller is programmed by the host computer with the vector sequences and synchronization options for acoustic frame acquisitions. Thus, the scan controller controls the beam distribution and the beam density. The scan controller transmits the beam parameters defined by the host computer to the subsystems via a scan control bus (not shown).

[0024] The conventional system has the capability to superimpose graphical symbols on any ultrasound image. The superimposition of graphics on the image frame is accomplished in the video processor 14, which receives the ultrasound image frame from the X-Y display memory in the scan converter 12 and the graphics data from a graphics processor 24. The graphics processor generates data corresponding to graphical symbols to be displayed in the image frame, e.g., the range gate graphics, the Doppler beam cursor and the vessel slope cursor described in detail below, in response to instructions from the host computer 20. In the preferred embodiment, the vessel slope, Doppler angle and range gate position are computed in the host computer. The host computer then sends instructions to the graphics processor for generating graphics representing those positional parameters. Alternatively, the host computer may be programmed to generate the graphical data and then store that graphical data in a graphics display memory for subsequent transfer to the video processor.

[0025] In the system depicted in FIG. 1, the Doppler angle is estimated automatically by the host computer 20. The estimated Doppler angle value is then used by the host computer to estimate the flow velocity as a function of the Doppler frequency shift. Referring to FIG. 5, the angle between a Doppler beam cursor (beam centerline) 26 and a vessel slope cursor 28 on a vessel 30 in the B-mode image 32 is used to convert Doppler frequency shifts into velocity units according to the Doppler equation. The Doppler angle value is usually displayed along with the graphic.

[0026] To accomplish the foregoing, the user requests an automatic Doppler angle estimation by pressing a rotary knob on the operator interface 22 (see FIG. 1) after the user has placed the Doppler range gate (sample volume) graphic, consisting of a range gate top graphic 36 and a range gate bottom graphic 34, on the vessel 30 in the image 32, as seen in FIG. 2, also via the operator interface. The host computer 20 automatically reads the current frame of B-mode and color flow (if available) image data from the display memory in the scan converter 12 (or from a cine memory not shown) (step 40 in FIG. 7). Based on that image data, a Doppler angle is computed, and the Doppler angle value and graphic are updated. If the user is not satisfied with the automatically estimated Doppler angle, the user can adjust the vessel slope cursor by dialing the rotary knob that he pressed to initiate the automatic Doppler angle estimation.

[0027] To automatically compute a Doppler angle, the host computer performs the algorithm shown in FIG. 7 on the frame of image data read in step 40. A center point of a search area is identified in step 42 as follows. Referring to FIG. 2, if the average of a number of B-mode intensity values in a small area 66 about the center point 68 of the Doppler range gate is at or below some threshold, then that location is used as the center point of the searching algorithm. If the B-mode intensity values are above the threshold, then the host computer searches outward from that point by 1/2 of the total range gate width in all directions to determine the area with the minimum average B-mode intensity values (typical of scattering from blood). If that area of minimum average intensity is below the intensity at the original center point area by some percentage, then the center point is moved to the center 70 of this minimum area, as seen in FIG. 3.

[0028] The host computer then determines (step 44 in FIG. 7) whether the image frame being processed includes color flow data at pixel addresses corresponding to the location of the center point 70 (see FIG. 3). If the image frame includes color flow data corresponding to the center point, then the host computer searches out from the center point 70 along radial lines 72 which are angularly spaced S degrees apart over an entire 360° range, as shown in FIG. 3. The distance to search from the center is D cm. This edge search area is indicated by circle 74 in FIG. 3.

[0029] Along each radial line 72, the host computer searches from the center point 70 and stores the point as an edge point if it is the first of X (≥ 2) points displaying B-mode intensity data instead of color flow velocity or power data (step 46 in FIG. 7). Exemplary edge points are depicted as rectangles 76 in FIG. 4. If no such point is found before searching D cm or finding the edge of the color region of interest, then no edge point is marked along that radial line. Once each radial line is searched, all the edge points 76 in a certain segment of the edge point search area (e.g., Segment 1 indicated by dotted lines in FIG. 4) are grouped together (step 48) and fed to a line-fit algorithm which generates both a vessel slope estimate and a goodness-of-fit measurement (step 50). This is repeated for other segments (e.g., Segment 2 indicated by solid straight lines in FIG. 4) and in each case the slope of the vessel and the goodness of fit are recorded. The segments may overlap each other by some number of degrees, as do Segments 1 and 2 shown in FIG. 4. If a particular segment does not have some minimum number of edge points within it, then that segment is disregarded.

[0030] In addition to the foregoing, the algorithm also determines B-mode edge points (step 52) by searching the B-mode intensity data from the center point in radial lines spaced S degrees apart over an entire 360° range. The distance to search from the center is D cm. Along each radial line, each B-mode intensity value (corresponding to respective pixels) is replaced with the average of itself and its two neighbors along the radius. The peak and minimum intensities along the averaged radial line as well as the largest difference (from one pixel to the next) are each recorded. If the difference between the peak and minimum intensities does not exceed some threshold, then no edge point is specified for this ray. If the difference between the peak and minimum intensities exceeds the threshold, then a search is started at some number of points from the center and stops when a point (the edge point) is found to exceed a difference-only threshold, an intensity-only threshold or a combined difference and intensity threshold. For example, if the pixel location is 50% of the maximum intensity and 30% of the maximum difference, then it would pass the combined difference and intensity threshold. The intensity at the edge point is noted. If no such point is found before searching D cm or finding the edge of the B-mode image, then no edge point is marked along that radial line. Once each radial line has been searched, some percent of the edge points are disregarded. The disregarded edge points are those associated with the lowest intensities. All of the remaining edge points in a certain segment of the edge point search area are grouped (step 54) and then fed to a line-fit algorithm which generates both a vessel slope estimate and a goodness-of-fit measurement (step 54). This is repeated for other segments, and in each case the vessel slope and the goodness of fit are recorded. The segments may overlap each other by some number of degrees. If a particular segment does not have some minimum number of edge points within it, then that segment is disregarded.

[0031] If no B-mode or color flow mode segment generated enough edge points to get a vessel slope estimate, the distance D is increased and the algorithm is rerun. (If rerunning the algorithm still results in no vessel slope estimates, then the Doppler angle remains unchanged.)

[0032] At this point in the algorithm, estimates of the vessel slope and their corresponding goodness-of-fit measurements are known for some number of segments (for B mode and possibly color flow mode). The segment having the best goodness of fit is identified (step 58) and its vessel slope is combined (averaged) with all the other vessel slope estimates that have a goodness of fit measurement not exceeding some difference relative to the best one (step 60). However, if color is active and the best color vessel slope exceeds some number of degrees (indicating a vessel somewhat vertical), then only color data is used in this vessel slope-combining algorithm. This is done because somewhat vertical vessel walls are difficult to detect in B-mode due to the lateral smearing of the image data. On the other hand, if color is not active, steps 46, 48 and 50 in FIG. 7 are not performed and step 60 combines only vessel slopes derived from B-mode edge points.

[0033] The host computer determines the Doppler angle by calculating (step 62 in FIG. 7) the angle between the combined vessel slope 28 and the Doppler beam cursor 26, as shown in FIG. 5. The host computer then uses the calculated Doppler angle value to compute the velocity in accordance with the Doppler equation.

[0034] In accordance with the preferred embodiment of the invention, the host computer also automatically adjusts the position of the range gate so that it is maintained inside a blood vessel during relative motion of the tissue and probe. A pushbutton can be provided on the operator interface to enable a system user to select this automatic vessel tracking option. After the Doppler angle is calculated, the host computer detects whether the automatic vessel tracking option has been selected (step 64) in FIG. 7. The first step 66 in the vessel tracking algorithm is to compute the current position of the range gate relative to the vessel wall. For example, the host computer can determine the locations of the pixels, in a direction perpendicular to the vessel wall orientation, which respectively correspond to the vessel wall boundaries. As shown in FIG. 6, the host computer determines the addresses of pixels P1 and P2 lying along line A-B and overlying respective vessel wall boundaries. The line A-B is perpendicular to the current vessel slope, which is indicated by the vessel slope cursor 28 in FIG. 6. This can be accomplished, for example, by searching the B-mode intensity data from the center point in opposite directions along the line A-B and determining the B-mode edge points as previously described for step 52 shown in FIG. 7 or using already obtained edge points. The orientation of line A-B is determined by the current Doppler angle information.

[0035] The addresses of the pixels used to display the range gate graphics are sent to the host computer by the graphics processor. The addresses of pixels P1 and P2 establish the position of the vessel relative to the range gate. If the host computer determines that the range gate position relative to the vessel boundaries is displaced from its position in the previous frame by greater than a predefined amount, the host computer instructs the graphics processor to move the range gate to a new position. The graphics processor then computes the pixel addresses for the newly adjusted position of the range gate graphic. The range gate position can be maintained at the center of the vessel, at a predetermined distance from one of the vessel boundaries or at a predetermined ratio from the two vessel boundaries. The algorithm then returns to step 40 in FIG. 7 and retrieves a new image frame. The Doppler angle will then be re-estimated and updated based on the new image frame. As long as the vessel tracking option is in the active state, the entire vessel tracking and angle update process will be repeated.

[0036] Although the preferred embodiment has been disclosed in the context of an ultrasound imaging system having a host computer and a graphics processor, the functions of both can be performed by one processor. In particular, the functions shown in the flowchart of FIG. 7 can be performed by a single processor. Furthermore, although FIG. 1 shows the architecture of a conventional ultrasound imaging system having multiple processes and a host computer, all of the data processing and computing functions could be performed by a single computer, e.g., a personal computer, having sufficient processing power.

[0037] While the invention has been described with reference to preferred embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. For example, although along each radial line each B-mode intensity value (corresponding to respective pixels) can be replaced with the average of itself and its two neighbors along the radius, any suitable smoothing filter which reduces statistical variations can be used. In addition, many modifications may be made to adapt a particular situation to the teachings of the invention. Therefore it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the appended claims.

Claims

1. A method comprising the steps of:

(a) displaying an image of a blood vessel;

(b) storing a frame of image parameter values from which said image was derived, said image parameter values corresponding to respective pixels in said image;

(c) placing a graphic representing a range gate overlying said blood vessel in said image;

(d) determining a vessel slope of the blood vessel at or near said range gate based on said frame of image parameter values;

(e) placing a graphic representing said vessel slope overlying said blood vessel in said image;

(f) determining the position of a boundary of the blood vessel; and

(g) adjusting the position of said range gate if the change in the position of the boundary relative to said range gate is equal to or greater than a predetermined threshold.

2. The method as recited in claim 1, wherein said step (f) comprises the step of determining the address of a pixel on said boundary.

3. The method as recited in claim 2, wherein said pixel on said boundary is located along a line generally perpendicular to said vessel slope graphic.

4. The method as recited in claim 2, wherein said step (f) further comprises the step of searching for an edge point along a line in accordance with a search algorithm.

5. The method as recited in claim 3, wherein said step (f) further comprises the step of searching for an edge point along said line generally perpendicular to said vessel slope graphic in accordance with a search algorithm.

6. The method as recited in claim 1, wherein said step (g) comprises the step of displaying said range gate graphic at a predetermined position relative to said boundary.

7. The method as recited in claim 1, wherein said image parameter values comprise B-mode intensity values for at least some of said pixels.

8. The method as recited in claim 4, wherein said search algorithm comprises the steps of:

applying a smoothing filter to reduce statistical variations;

storing the peak and minimum image parameter values and the largest difference between image parameter values corresponding to adjacent pixels;

if a difference between said peak and minimum image parameter values exceeds a predetermined threshold, searching for a point along said line having an image parameter value which satisfies at least one of a difference criterion and a value criterion; and

identifying said point as said edge point.

9. The method as recited in claim 4, wherein said image parameter values comprise B-mode intensity values for some of said pixels and color flow estimates for others of said pixels in said frame, and said step of searching for an edge point comprises the steps of:

searching for a point which is the first of *X* points having B-mode intensity values instead of color flow estimates; and

identifying said point as said edge point.

10. A system comprising:

a display device comprising a multiplicity of pixels;

a memory for storing a frame of image parameter values from which said ultrasound image was derived, said image parameter values corresponding to respective pixels in said image;

a computer programmed to perform the steps of:

(a) controlling said display device to display an ultrasound image of a blood vessel with a graphic representing a range gate overlying said blood vessel;

(b) determining a vessel slope of the blood vessel at or near said range gate based on said frame of image parameter values;

(c) controlling said display device to place a graphic representing said vessel slope overlying said blood vessel in said image;

(d) determining the position of a boundary of the blood vessel; and

(e) controlling said display device to adjust the position of said range gate if the change in the position of the boundary relative to said range gate is equal to or greater than a predetermined threshold.

11. The system as recited in claim 10, wherein said step (d) comprises the step of determining the address of a pixel on said boundary.

12. The system as recited in claim 11, wherein said pixel on said boundary is located along a line generally perpendicular to said vessel slope graphic.

13. The system as recited in claim 11, wherein said step (d) further comprises the step of searching for an edge point along a line in accordance with a search algorithm.

14. The system as recited in claim 12, wherein said step (d) further comprises the step of searching for an edge point along said line generally perpendicular to said vessel slope graphic in accordance with a search algorithm.

15. The system as recited in claim 10, wherein said image parameter values comprise B-mode intensity values for at least some of said pixels.

16. The system as recited in claim 13, wherein said search algorithm comprises the steps of:

applying a smoothing filter to reduce statistical variations;

storing the peak and minimum image parameter values and the largest difference between image parameter values corresponding to adjacent pixels;

if a difference between said peak and minimum image parameter values exceeds a predetermined threshold, searching for a point along said line having an image parameter value which satisfies at least one of a difference criterion and a value criterion; and

identifying said point as said edge point.

17. The system as recited in claim 13, wherein said image parameter values comprise B-mode intensity values for some of said pixels and color flow estimates for others of said pixels in said frame, and said step of searching for an edge point comprises the steps of:

searching for a point which is the first of *X* points having B-mode intensity values instead of color flow estimates; and

identifying said point as said edge point.

18. The system as recited in claim 10, further comprising:

an ultrasound transducer array comprising a multiplicity of transducer elements;

a transmit beamformer for pulsing selected transducer elements to transmit a series of ultrasound transmit beams in a scan plane;

a receive beamformer coupled to selected transducer elements of said transducer array for acquiring respective receive signals subsequent to respective beam transmits;

a signal processor for forming vectors of image parameter values from said receive signals;

a scan converter for converting said vectors into a frame of image parameter values and storing said frame of image parameter values in said memory; and

a video processor comprising a grayscale mapping for mapping said frame of image parameter values retrieved from said memory into grayscale pixel values.

19. A system comprising:

means for displaying an image of a blood vessel;

means for storing a frame of image parameter values from which said ultrasound image was derived, said image parameter values corresponding to respective pixels in said image;

means for placing a graphic representing a range gate overlying said blood vessel in said image;

means for determining a vessel slope of the blood vessel at or near said range gate based on said frame of image parameter values;

means for placing a graphic representing said vessel slope overlying said blood vessel in said image;

means for determining the position of a boundary of the blood vessel; and

means for adjusting the position of said range gate if the change in the position of the boundary relative to said range gate is equal to or greater than a predetermined threshold.

Patentansprüche

1. Verfahren mit den Schritten:

a) Darstellung eines Bildes eines Blutgefäßes;

b) Abspeicherung eines Frames Bildparameterwerte, von denen das Bild abgeleitet worden ist, wobei die Bildparameterwerte jeweiligen Pixeln in dem Bild entsprechen;

c) Platzierung einer Grafik, die einen anvisierten Bereich kennzeichnet, in einer über dem Blutgefäß liegenden Weise in dem Bild;

d) Bestimmung einer Gefäßsteigung des Blutgefäßes in dem oder in der Nähe des anvisierten Bereiches basierend auf dem Frame Bildparameterwerte;

e) Platzierung einer Grafik, die die Gefäßsteigung kennzeichnet, in einer über dem Blutgefäß liegenden Weise in dem Bild;

f) Bestimmung der Position einer Grenze des Blutgefäßes; und

g) Anpassung der Position des anvisierten Bereiches, falls die Änderung der Position der Grenze in Bezug auf den anvisierten Bereich gleich oder größer ist als eine vorbestimmte Schwelle.

2. Verfahren nach Anspruch 1, wobei der Schritt (f) den Schritt einer Bestimmung der Adresse eines Pixels auf der Grenze aufweist.

3. Verfahren nach Anspruch 2, wobei das Pixel auf der Grenze auf einer Linie angeordnet ist, die im Wesentlichen senkrecht zu der Gefäßsteigungsgrafik verläuft.

4. Verfahren nach Anspruch 2, wobei der Schritt (f) ferner den Schritt aufweist, dass längs einer Linie entsprechend einem Suchalgorithmus ein Kantenpunkt gesucht wird.

5. Verfahren nach Anspruch 3, wobei der Schritt (f) ferner den Schritt aufweist, dass entsprechend einem Suchalgorithmus nach einem Kantenpunkt entlang der Linie gesucht wird, die im Wesentlichen senkrecht zu der Gefäßsteigungsgrafik verläuft.

6. Verfahren nach Anspruch 1, wobei der Schritt (g) den Schritt aufweist, dass die Grafik des anvisierten Bereiches in einer vorbestimmten Position relativ zu der Grenze angezeigt wird.

7. Verfahren nach Anspruch 1, wobei die Bildparameterwerte B-Modus-Intensitätswerte für wenigstens einige der Pixel aufweisen.

8. Verfahren nach Anspruch 4, wobei der Suchalgorithmus die Schritte aufweist, dass:

ein Glättungsfilter angewandt wird, um statistische Variationen zu verringern;
der Spitzenwert und der minimale Wert der Bildparameterwerte sowie die größte Differenz zwischen Bildparameterwerten, die benachbarten Pixeln entsprechen, abgespeichert werden;
falls eine Differenz zwischen dem Spitzenwert und dem minimalen Wert der Bildparameterwerte einen vorbestimmten Schwellenwert übersteigt, entlang der Linie nach einem Punkt gesucht wird, der einen Bildparameterwert aufweist, der wenigstens ein Kriterium aus einem Differenzkriterium und einem Wertekriterium erfüllt; und
der Punkt als der Eckpunkt identifiziert wird.

9. Verfahren nach Anspruch 4, wobei die Bildparameterwerte B-Modus-Intensitätswerte für einige der Pixel sowie Farbbild-Strömungsschätzwerte für weitere der Pixeln in dem Frame aufweisen und wobei der Schritt der Suche nach einem Eckpunkt die Schritte aufweist:

Suche nach einem Punkt, der der erste von X-Punkten ist, die B-Modus-Intensitätswerte anstelle von Farbbild-Strömungsschätzwerten aufweisen;

Identifizierung des Punktes als der Eckpunkt.

10. System:

mit einer Anzeigevorrichtung, die mehrere Pixel aufweist;

mit einem Speicher zur Abspeicherung eines Frames Bildparameterwerte, aus denen ein Ultraschallbild abgeleitet worden ist, wobei die Bildparameterwerte jeweiligen Pixeln in dem Bild entsprechen;

mit einem Computer, der programmiert ist, um die Schritte durchzuführen:

a) Steuerung der Anzeigevorrichtung, um ein Ultraschallbild eines Blutgefäßes gemeinsam mit einer Grafik anzuzeigen, die ein anvisiertes Bereichsfenster kennzeichnet und über dem Blutgefäß liegt;

b) Bestimmung einer Gefäßsteigung des Blutgefäßes in dem Bereichsfenster oder in der Nähe des Bereichsfensters basierend auf dem Frame Bildparameterwerte;

c) Steuerung der Anzeigevorrichtung, um eine Grafik zu platzieren, die die Gefäßsteigung kennzeichnet und in dem Bild über dem Blutgefäß liegt;

d) Bestimmung der Position einer Grenze des Blutgefäßes; und

e) Steuerung der Anzeigevorrichtung, um die Position des Bereichsfensters anzupassen, falls die Änderung der Position der Grenze in Bezug auf das Bereichsfenster gleich oder größer als eine vorbestimmte Schwelle ist.

11. System nach Anspruch 10, wobei der Schritt (d) den Schritt einer Bestimmung der Adresse eines Pixels auf der Grenze aufweist.

12. System nach Anspruch 11, wobei das Pixel auf der Grenze auf einer Linie angeordnet ist, die im Wesentlichen senkrecht zu der Gefäßsteigungsgrafik verläuft.

13. System nach Anspruch 11, wobei der Schritt (d) ferner den Schritt einer Suche nach einem Eckpunkt entlang einer Linie entsprechend einem Suchalgorithmus aufweist.

14. System nach Anspruch 12, wobei der Schritt (d) ferner den Schritt aufweist, dass nach einem Eckpunkt entlang der Linie, die im Wesentlichen senkrecht zu der Gefäßsteigungsgrafik verläuft, entsprechend einem Suchalgorithmus gesucht wird.

15. System nach Anspruch 10, wobei die Bildparameterwerte B-Modus-Intensitätswerte für wenigstens einige der Pixel aufweisen.

16. System nach Anspruch 13, wobei der Suchalgorithmus die Schritte aufweist:

Anwendung eines Glättungsfilters, um statistische Variationen zu verringern;

Abspeicherung des Spitzenwertes und des minimalen Wertes der Bildparameterwerte sowie der größten Differenz zwischen den Bildparameterwerten, die benachbarten Pixeln entsprechen;

falls eine Differenz zwischen dem Spitzenwert und dem minimalen Wert der Bildparameterwerte größer ist als ein vorbestimmter Schwellenwert, Suche nach einem Punkt entlang der Linie, der einen Bildparameterwert aufweist, der wenigstens einem Kriterium aus einem Differenzkriterium und einem Wertekriterium genügt; und

Identifizierung des Punktes als der Eckpunkt.

17. System nach Anspruch 13, wobei die Bildparameterwerte B-Modus-Intensitätswerte für einige der Pixel sowie Farbbild-Flussschätzwerte für andere Pixel in dem Frame aufweisen und wobei der Schritt der Suche nach einem Eckpunkt die Schritt aufweist:

Suche nach einem Punkt, der der erste von X-Punkten ist, die B-Modus-Intensitätswerte anstelle von Farbbild-Flussschätzwerten aufweisen; und

Identifizierung des Punktes als der Eckpunkt.

18. System nach Anspruch 10, das ferner aufweist:

ein Ultraschall-Wandlerarray mit mehreren Wandlerelementen;

einen Sende-Strahlbündelformer zur Beaufschlagung ausgewählter Wandlerelemente mit Impulsen, um eine Reihe von Ultraschallsendestrahlbündeln in einer Abtastebene auszusenden;

einen Empfangs-Strahlbündelformer, der mit gewählten Wandlerelementen des Wandlerarrays verbunden ist, um auf jeweilige Strahlbündelaussendungen folgend jeweilige Empfangssignale zu akquirieren;

einen Signalprozessor zur Bildung von Vektoren der Bildparameterwerte aus den Empfangssignalen;

einen Abtastwandler zur Umwandlung der Vektoren in einen Frame Bildparameterwerte und zur Abspeicherung des Frames Bildparameterwerte in dem Speicher und

einen Bildprozessor, der eine Grauskalaabbildung aufweist, um den aus dem Speicher wiedergewonnen Frame Bildparameterwerte in Grauskalapixelwerte zu transformieren.

19. System:

mit Mitteln zur Darstellung eines Bildes eines Blutgefäßes;

mit Mitteln zur Abspeicherung eines Frames Bildparameterwerte, aus denen das Ultraschallbild abgeleitet worden ist, wobei die Bildparameterwerte jeweiligen Pixeln in dem Bild entsprechen;

mit Mitteln zur Platzierung einer Grafik, die einen anvisierten Bereich kennzeichnet, über dem Blutgefäß in dem Bild;

mit Mitteln zur Bestimmung einer Gefäßsteigung des Blutgefäßes in dem oder in der Nähe des anvisierten Bereiches basierend auf dem Frame Bildparameterwerte;

mit Mitteln zur Platzierung eines Grafik, die die Gefäßsteigung kennzeichnet, über dem Blutgefäß in dem Bild;

mit Mitteln zur Bestimmung der Position einer Grenze des Blutgefäßes und

mit Mitteln zur Anpassung der Position des anvisierten Bereiches für den Fall, dass die Änderung der Position der Grenze in Bezug auf den anvisierten Bereich gleich oder größer als ein vorbestimmter Schwellenwert ist.

Revendications

1. Procédé comprenant les étapes consistant à :

(a) afficher une image d'un vaisseau sanguin ;
(b) mémoriser une trame de valeurs de paramètres d'image à partir de laquelle ladite image a été obtenue, lesdites valeurs de paramètres d'image correspondant aux pixels respectifs de ladite image ;
(c) placer un graphique représentant une porte d'intervalle recouvrant ledit vaisseau sanguin dans ladite image ;
(d) déterminer une pente de vaisseau du vaisseau sanguin au niveau de ou près de ladite porte d'intervalle d'après ladite trame de valeurs de paramètres d'image ;
(e) placer un graphique représentant ladite pente de vaisseau recouvrant ledit vaisseau sanguin dans ladite image ;
(f) déterminer la position d'une limite du vaisseau sanguin ; et
(g) ajuster la position de ladite porte d'intervalle si le changement de position de la limite par rapport à ladite porte d'intervalle est supérieur ou égal à un seuil prédéterminé.

2. Procédé selon la revendication 1, dans lequel ladite étape (f) comprend l'étape consistant à déterminer l'adresse d'un pixel sur ladite limite.

3. Procédé selon la revendication 2, dans lequel ledit pixel de ladite limite est situé sur une ligne généralement perpendiculaire audit graphique de pente de vaisseau.

4. Procédé selon la revendication 2, dans lequel ladite étape (f) comprend en outre l'étape consistant à rechercher un point de bord sur une ligne selon un algorithme de recherche.

5. Procédé selon la revendication 3, dans lequel ladite étape (f) comprend en outre l'étape consistant à rechercher un point de bord sur ladite ligne généralement perpendiculaire audit graphique de pente de vaisseau selon un algorithme de recherche.

6. Procédé selon la revendication 1, dans lequel ladite étape (g) comprend l'étape consistant à afficher ledit graphique de porte d'intervalle en une position prédéterminée par rapport à ladite limite.

7. Procédé selon la revendication 1, dans lequel lesdites valeurs de paramètres d'image comprennent des valeurs d'intensité en mode B pour au moins certains desdits pixels.

8. Procédé selon la revendication 4, dans lequel ledit algorithme de recherche comprend les étapes consistant à :

appliquer un filtre de lissage pour réduire les variations statistiques ;
mémoriser les valeurs de paramètres d'image maximale et minimale et la plus grande différence entre les valeurs de paramètres d'image correspondant aux pixels voisins ;
si une différence entre lesdites valeurs de pa-

ramètres d'image maximale et minimale dépasse un seuil prédéterminé, rechercher un point sur ladite ligne ayant une valeur de paramètre d'image qui satisfait au moins un critère parmi un critère de différence et un critère de valeur ; et

identifier ledit point comme étant ledit point de bord.

9. Procédé selon la revendication 4, dans lequel lesdites valeurs de paramètres d'image comprennent des valeurs d'intensité en mode B pour certains desdits pixels et des estimations de couleur pour les autres desdits pixels de ladite trame, et ladite étape de recherche d'un point de bord comprend les étapes consistant à :

rechercher un point qui est le premier de X points ayant des valeurs d'intensité en mode B au lieu d'estimations de couleur ; et

identifier ledit point comme étant ledit point de bord.

10. Système comprenant :

un dispositif d'affichage comprenant une multitude de pixels ;

une mémoire pour mémoriser une trame de valeurs de paramètres d'image à partir de laquelle ladite image a été obtenue, lesdites valeurs de paramètres d'image correspondant aux pixels respectifs de ladite image ;

un ordinateur programmé pour effectuer les étapes consistant à :

(a) commander ledit dispositif d'affichage pour afficher une image par ultrasons d'un vaisseau sanguin avec un graphique représentant une porte d'intervalle recouvrant ledit vaisseau sanguin ;

(b) déterminer une pente de vaisseau du vaisseau sanguin au niveau de ou près de ladite porte d'intervalle d'après ladite trame de valeurs de paramètres d'image ;

(c) commander ledit dispositif d'affichage pour placer un graphique représentant ladite pente de vaisseau recouvrant ledit vaisseau sanguin dans ladite image ;

(d) déterminer la position d'une limite du vaisseau sanguin ; et

(e) commander ledit dispositif d'affichage pour ajuster la position de ladite porte d'intervalle si le changement de position de la limite par rapport à ladite porte d'intervalle est supérieur ou égal à un seuil prédéterminé.

11. Système selon la revendication 10, dans lequel ladite étape (d) comprend l'étape consistant à déterminer l'adresse d'un pixel sur ladite limite.

12. Système selon la revendication 11, dans lequel ledit pixel de ladite limite est situé sur une ligne généralement perpendiculaire audit graphique de pente de vaisseau.

13. Système selon la revendication 11, dans lequel ladite étape (d) comprend en outre l'étape consistant à rechercher un point de bord sur une ligne selon un algorithme de recherche.

14. Système selon la revendication 12, dans lequel ladite étape (d) comprend en outre l'étape consistant à rechercher un point de bord sur ladite ligne généralement perpendiculaire audit graphique de pente de vaisseau selon un algorithme de recherche.

15. Système selon la revendication 10, dans lequel lesdites valeurs de paramètres d'image comprennent des valeurs d'intensité en mode B pour au moins certains desdits pixels.

16. Système selon la revendication 13, dans lequel ledit algorithme de recherche comprend les étapes consistant à :

appliquer un filtre de lissage pour réduire les variations statistiques ;

mémoriser les valeurs de paramètres d'image maximale et minimale et la plus grande différence entre les valeurs de paramètres d'image correspondant aux pixels voisins ;

si une différence entre lesdites valeurs de paramètres d'image maximale et minimale dépasse un seuil prédéterminé, rechercher un point sur ladite ligne ayant une valeur de paramètre d'image qui satisfait au moins un critère parmi un critère de différence et un critère de valeur ; et

identifier ledit point comme étant ledit point de bord.

17. Système selon la revendication 13, dans lequel lesdites valeurs de paramètres d'image comprennent des valeurs d'intensité en mode B pour certains desdits pixels et des estimations de couleur pour les autres desdits pixels de ladite trame, et ladite étape de recherche d'un point de bord comprend les étapes consistant à :

rechercher un point qui est le premier de X points ayant des valeurs d'intensité en mode B au lieu d'estimations de couleur ; et

identifier ledit point comme étant ledit point de bord.

18. Système selon la revendication 10, comprenant en outre :

un réseau de transducteurs à ultrasons comprenant une multitude d'éléments transducteurs ;
un dispositif de formation de faisceau émetteur pour pulser des éléments transducteurs choisis afin d'émettre une série de faisceaux d'émission à ultrasons dans un plan de balayage ;
un dispositif de formation de faisceau récepteur couplé à des éléments transducteurs choisis dudit réseau de transducteurs pour acquérir des signaux de réception respectifs faisant suite aux émissions de faisceau respectives ;
un processeur de signaux pour former des vecteurs de valeurs de paramètres d'image à partir desdits signaux de réception ;
un convertisseur de balayage pour convertir lesdits vecteurs en une trame de valeurs de paramètres d'image et mémoriser ladite trame de valeurs de paramètres d'image dans ladite mémoire ; et
un processeur vidéo comprenant une application d'échelle de gris pour transformer ladite trame de valeurs de paramètres d'image lue en mémoire en des valeurs de pixels d'échelle de gris.

19. Système comprenant :

un moyen permettant d'afficher une image d'un vaisseau sanguin ;
un moyen permettant de mémoriser une trame de valeurs de paramètres d'image à partir de laquelle ladite image a été obtenue, lesdites valeurs de paramètres d'image correspondant aux pixels respectifs de ladite image ;
un moyen permettant de placer un graphique représentant une porte d'intervalle recouvrant ledit vaisseau sanguin dans ladite image ;
un moyen permettant de déterminer une pente de vaisseau du vaisseau sanguin au niveau de ou près de ladite porte d'intervalle d'après ladite trame de valeurs de paramètres d'image ;
un moyen permettant de placer un graphique représentant ladite pente de vaisseau recouvrant ledit vaisseau sanguin dans ladite image ;
un moyen permettant de déterminer la position d'une limite du vaisseau sanguin ; et
un moyen permettant d'ajuster la position de ladite porte d'intervalle si le changement de position de la limite par rapport à ladite porte d'intervalle est supérieur ou égal à un seuil prédéterminé.

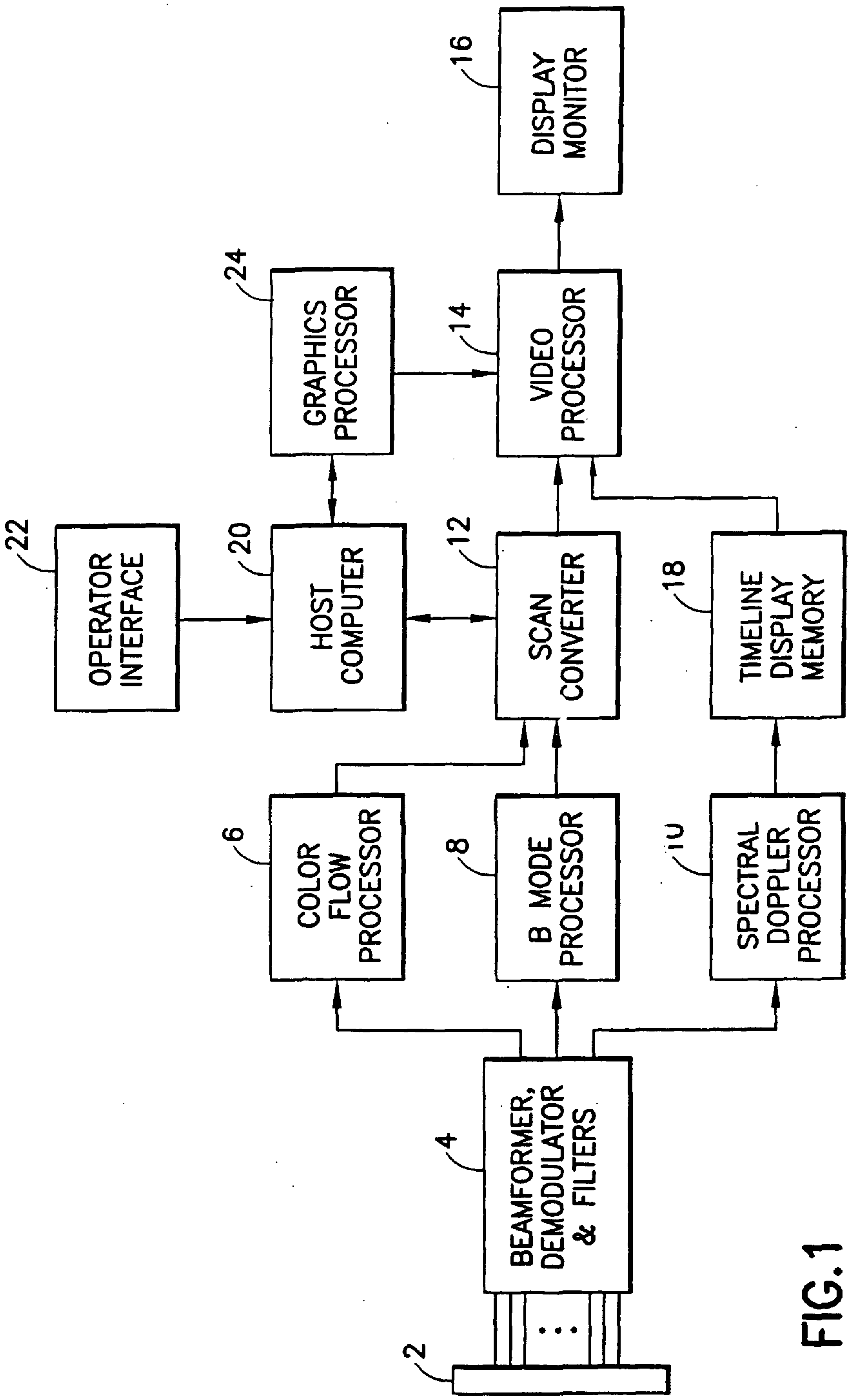
OPERATOR INTERFACE
22
HOST COMPUTER
20
GRAPHICS PROCESSOR
24
DISPLAY MONITOR
16
VIDEO PROCESSOR
14
SCAN CONVERTER
12
TIMELINE DISPLAY MEMORY
18
COLOR FLOW PROCESSOR
6
B MODE PROCESSOR
8
SPECTRAL DOPPLER PROCESSOR
10
BEAMFORMER, DEMODULATOR & FILTERS
4
2

FIG.1

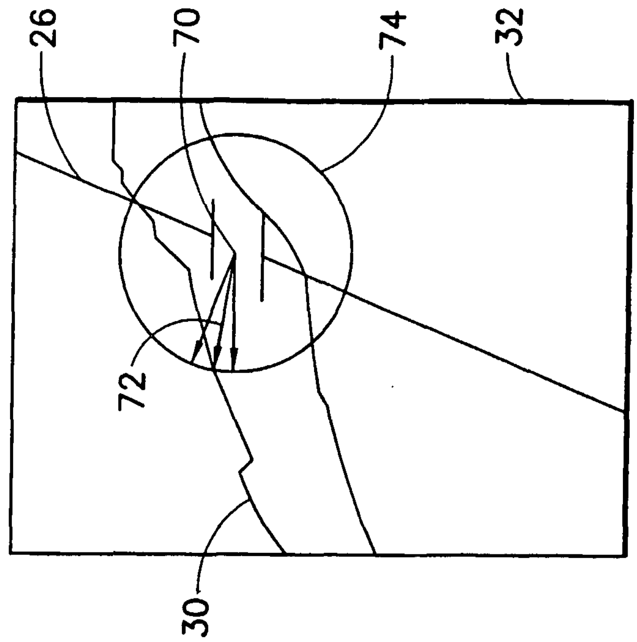

FIG.3

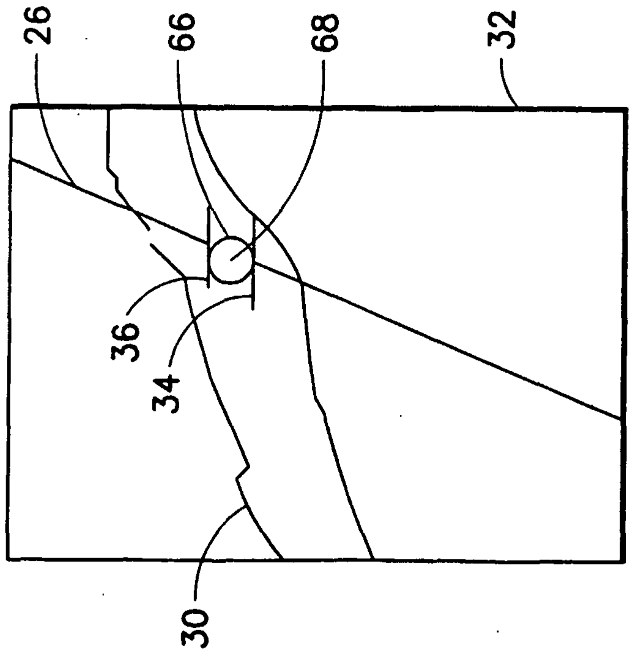

FIG.2

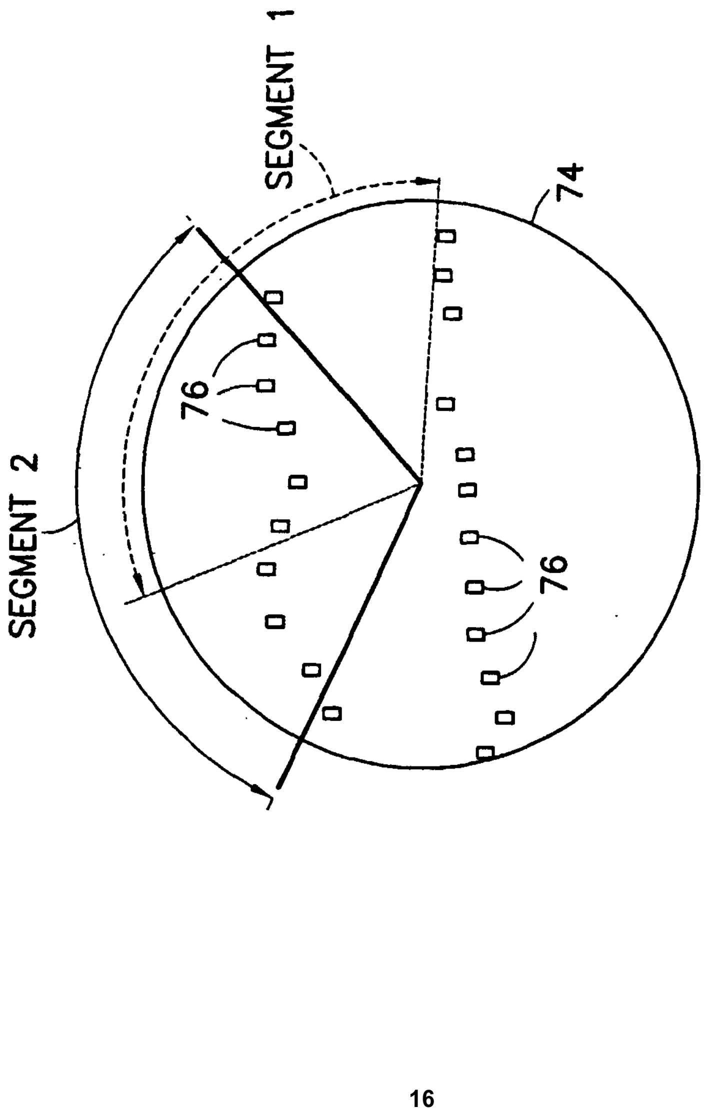

FIG.4

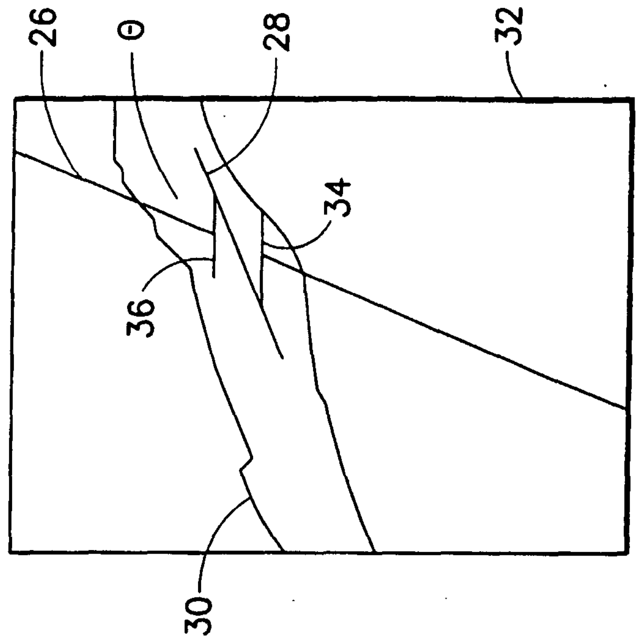

FIG.5

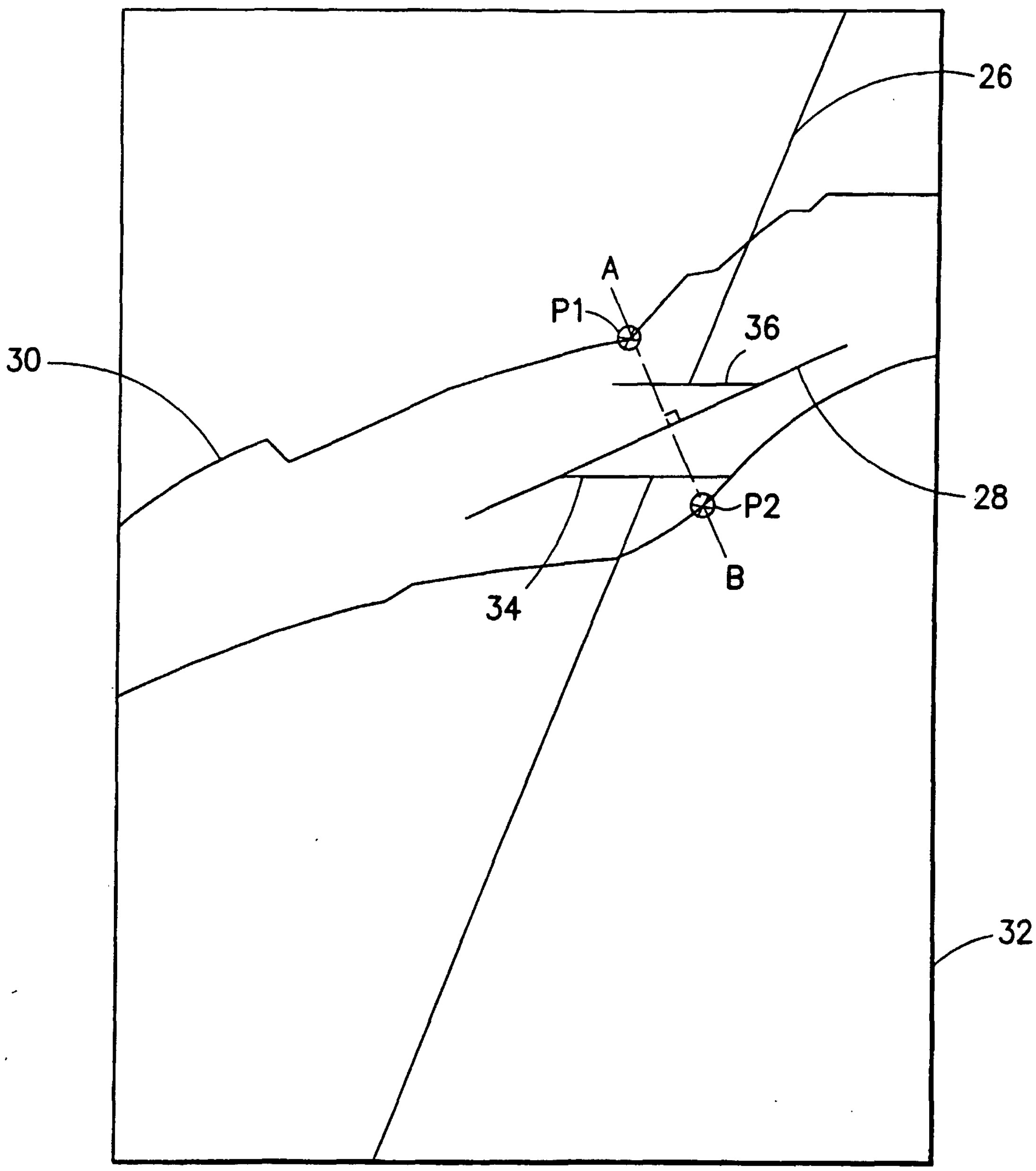

FIG.6

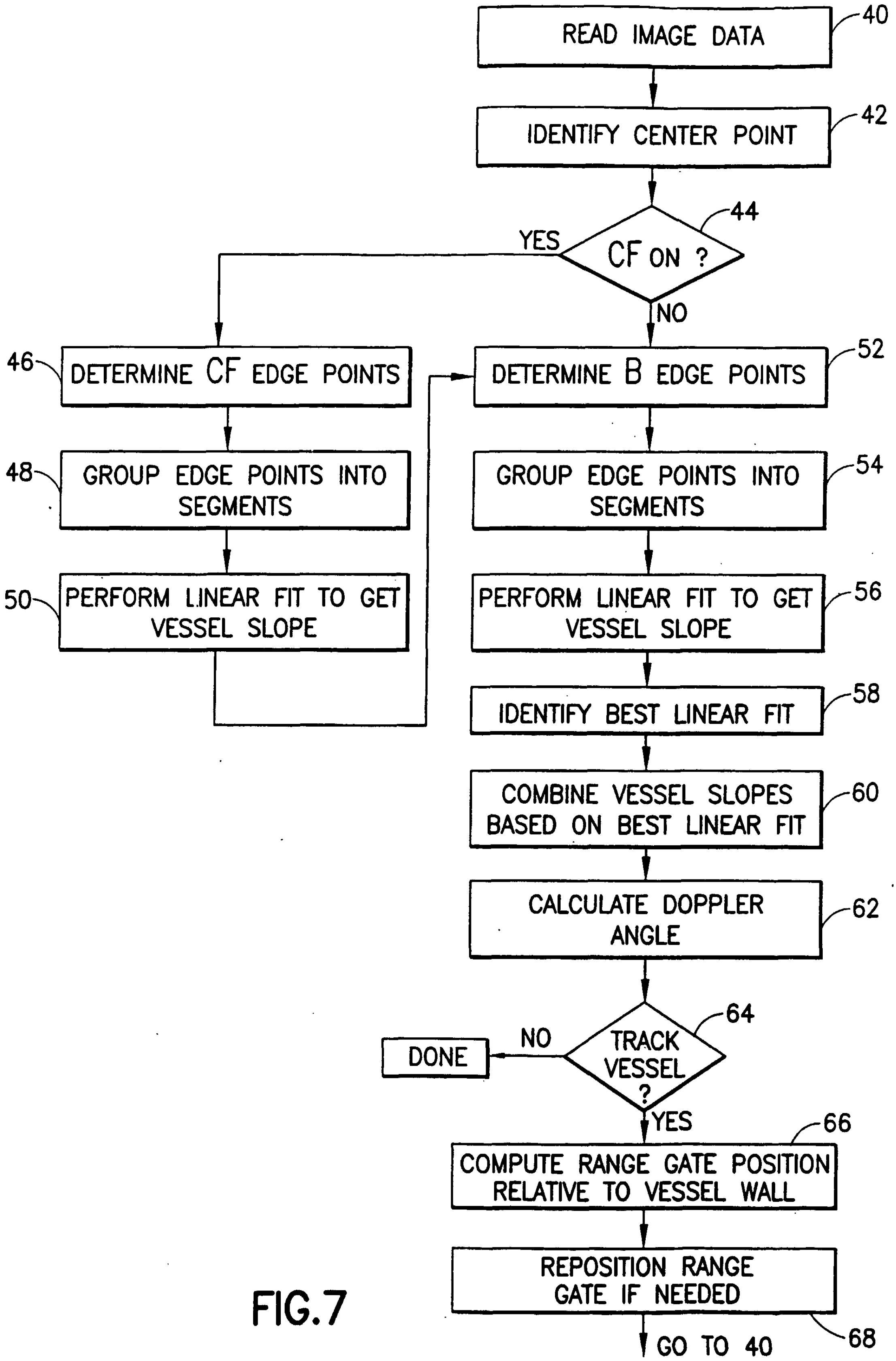
READ IMAGE DATA
40
IDENTIFY CENTER POINT
42
CF ON ?
44
YES
NO
DETERMINE CF EDGE POINTS
46
GROUP EDGE POINTS INTO SEGMENTS
48
PERFORM LINEAR FIT TO GET VESSEL SLOPE
50
DETERMINE B EDGE POINTS
52
GROUP EDGE POINTS INTO SEGMENTS
54
PERFORM LINEAR FIT TO GET VESSEL SLOPE
56
IDENTIFY BEST LINEAR FIT
58
COMBINE VESSEL SLOPES BASED ON BEST LINEAR FIT
60
CALCULATE DOPPLER ANGLE
62
TRACK VESSEL ?
64
NO
DONE
YES
COMPUTE RANGE GATE POSITION RELATIVE TO VESSEL WALL
66
REPOSITION RANGE GATE IF NEEDED
68
GO TO 40

FIG.7

patsnap

专利名称(译)	用于超声成像中的自动血管跟踪的方法和设备		
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申请(专利权)人(译)	通用电气公司		
当前申请(专利权)人(译)	通用电气公司		
[标]发明人	PAN LIHONG MO LARRY Y L WASHBURN MICHAEL JOSEPH		
发明人	PAN, LIHONG MO, LARRY, Y., L. WASHBURN, MICHAEL, JOSEPH		
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其他公开文献	EP1176910A1		
外部链接	Espacenet		

摘要(译)

用于在超声成像期间自动维持移动血管内的距离门的方法和装置。范围门可以保持在容器中心，或者与容器边界之一保持一定距离，或者保持在距离两个边界的相应距离的特定比率。使用者首先将范围门放在正在检查的血流上。算法处理每个连续的图像帧并自动更新关于血管边界位置和距离门附近的血管取向角的信息。如果相对于血管边界的距离门位置不同于前一帧中的距离门位置超过预定量，则距离门图形的位置和血管斜率光标的方向（以及多普勒角度）自动调整为新的价值观。

$$v = cf_d/(2f_0\cos\theta)$$