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(54) Title: SYSTEM AND METHOD FOR VISUALIZING A STRUCTURE OF INTEREST

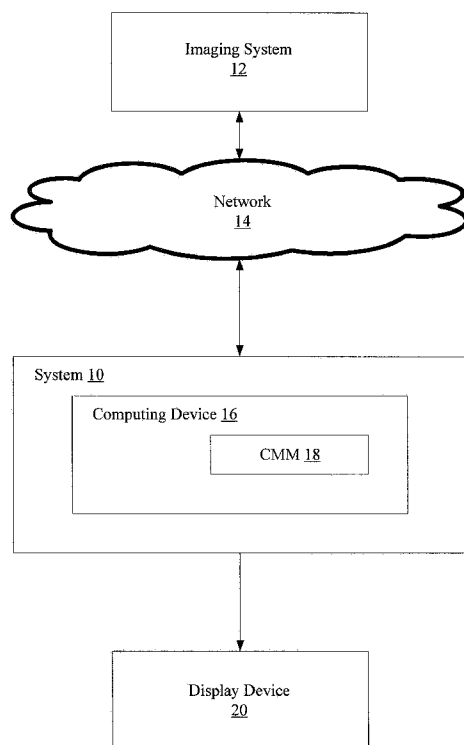


FIG. 6

(57) Abstract: A system. The system includes a computing device configured for communication with an imaging system and with a display device. The computing device includes a contour modeling module. The contour modeling module is configured for superimposing reference anchors on a cross-sectional image generated from 3D image data, for generating a line which connects the reference anchors, for sampling the 3D image data in a variable thickness plane defined by the connecting line, and for generating a contour-modeled C-mode image from the sampled 3D image data.

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SYSTEM AND METHOD FOR VISUALIZING A STRUCTURE OF INTEREST

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CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit under 35 U.S.C. §119(e) of the earlier filing date of United States Patent Application No. 60/951,488 filed on July 24, 2007.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

[0002] This invention was made with United States Government support in the form of Grant Numbers R01-EY013178-07, R01-EY013516-04, and R01-EY011289-20 from the National Institutes of Health. The United States Government may have certain rights in the invention.

BACKGROUND

[0003] This application discloses an invention which is related, generally and in various embodiments, to a system and method for visualizing a structure of interest.

[0004] Medical imaging has long played a critical role in diagnosing and assessing various pathologies. Especially during the last decade, along with a rapid evolution of computer technologies, many new imaging modalities providing three-dimensional (3D) image datasets have been introduced and proven to be clinically useful. This broad spectrum of 3D image modalities is used to image a wide variety of internal features of patients.

[0005] One of the advantages of 3D image datasets, when compared to previous two dimensional (2D) datasets, is the flexible image visualization capability with which 3D datasets are characterized. Specifically, when utilizing a full 3D dataset, an operator can

mathematically “slice” the target tissue along any arbitrary plane or other surface. This flexibility allows clinicians to observe pathologies from the exact point (or points) of view that are most useful for a given clinical situation.

[0006] One commonly employed imaging modality, optical coherence tomography (OCT), is a non-invasive, interferometric imaging modality that provides millimeter penetration at micrometer-scale axial and lateral resolution. OCT is particularly adaptable to ophthalmologic applications. First generation OCT techniques provided 2D cross-sectional views of human retinas at a microscopic resolution ($\sim 10\ \mu\text{m}$) in vivo. Due to its non-contact, non-invasive scanning, OCT quickly became an indispensable clinical test for retinal abnormalities including the leading causes of blindness: age-related macular degeneration, diabetic retinopathy, and glaucoma.

[0007] Spectral domain optical coherence tomography (SD-OCT) has gained increased utilization in ophthalmologic applications. Compared to first generation OCT techniques, SD-OCT scans 60 times faster with a resolution ($\sim 5\ \mu\text{m}$) that is twice as fine. With its fast scanning, SD-OCT allows 3D image dataset acquisition in a reasonably short period of time (e.g., approximately 1.5 seconds).

[0008] In conventional OCT techniques, when the eye is scanned, raw data (i.e., 3D OCT data) corresponding to the structure of the eye is captured. The raw data is subsequently processed into 3D image data (e.g., universal time-domain intensity data), from which various images associated with the eye can be generated. Such images include an OCT fundus image (FIG. 1), a conventional C-mode image (FIG. 2), a horizontal (x-z) cross-sectional image (FIG. 3), and a vertical (y-z) cross-sectional image (FIG. 4).

[0009] The natural spherical curvature of the eye (as well as certain other target structures) presents unique problems for ophthalmologic applications of OCT, including applications of SD-OCT. Conventional C-mode images along the planes perpendicular to the

scanning axis can provide an interesting perspective. However, due to the natural spherical curvature of the eye, and to various layered structures within the eye (e.g., retinal layers, choroid, etc.), a conventional C-mode image associated with an eye often includes multiple different structures, thereby making the conventional C-mode images very difficult to accurately interpret, even by a highly trained ophthalmologist.

[0010] Additionally, the natural spherical curvature of the eye is not the only source of artifactual distortion when attempting these types of image dataset acquisitions. Certain target structures, such as the eye, often experience rapid and involuntary movement. Such movement often distorts the raw data, which in turn distorts the 3D image data. When a conventional C-mode image is generated from the distorted 3D image data, the conventional C-mode image is very difficult to accurately interpret, even by a highly trained ophthalmologist.

[0011] Although a given conventional C-mode image may appear to be satisfactory for accurate interpretation, an associated cross-sectional image (e.g., a horizontal cross-sectional image, a vertical cross-sectional image, etc.) may show that the 3D image data utilized to generate the conventional C-mode image is distorted. For example, FIG. 5 shows four images generated from the same 3D image data set. The image in the upper left is a conventional C-mode image, the image in the upper right is a horizontal cross-sectional image, the image in the lower right is a vertical cross-sectional image, and the image in the lower left is the same conventional C-mode image as the one in the upper left. Even though the conventional C-mode images and the horizontal cross-sectional image appear to be satisfactory, the fair amount of eye movement shown in the vertical cross-sectional image indicates that the 3D image data set used to generate the images was distorted.

[0012] One approach utilized to try to reduce the problems caused by the natural curvature of the eye and/or movement of the eye during the scan is segmentation.

Segmentation algorithms operate to segment the 3D image data into segments, where each segment corresponds to a given structure of interest (e.g., the retinal pigment epithelium, the internal limiting membrane, etc.). After the structure of interest is identified, the 3D image data is sampled along the corresponding segment (which has an arbitrary thickness). The sampled 3D image data is utilized to generate a “segmented” C-mode image which only contains structures from the same segment. In general, the segmented C-mode images provide more accurate visualization than conventional C-mode images. However, it is well known that segmentation algorithms frequently fail to detect proper structures, especially in cases where retinal pathologies are present, leading to the poor quality segmented C-mode images.

SUMMARY

[0013] In one general respect, this application discloses a system for visualizing a structure of interest. According to various embodiments, the system includes a computing device configured for communication with an imaging system and with a display device. The computing device includes a contour modeling module. The contour modeling module is configured for superimposing reference anchors on a cross-sectional image generated from 3D image data, for generating a line which connects the reference anchors, for sampling the 3D image data in a variable thickness plane defined by the connecting line, and for generating a contour-modeled C-mode image from the sampled 3D image data.

[0014] In another general respect, this application discloses a method for visualizing a structure of interest. According to various embodiments, the method is implemented at least in part by a computing device. The method includes superimposing reference anchors on a cross-sectional image generated from 3D image data, generating a line connecting the reference anchors, sampling the 3D image data in a variable thickness plane defined by the

connecting line, and generating a contour-modeled C-mode image from the sampled 3D image data.

[0015] Aspects of the invention may be implemented by a computing device and/or a computer program stored on a computer-readable medium. The computer-readable medium may comprise a disk, a device, and/or a propagated signal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Various embodiments of the invention are described herein in by way of example in conjunction with the following figures, wherein like reference characters designate the same or similar elements.

[0017] FIG. 1 is an example of an OCT fundus image generated from 3D image data;

[0018] FIG. 2 is an example of a conventional C-mode image generated from 3D image data;

[0019] FIG. 3 is an example of a horizontal cross-sectional image generated from 3D image data;

[0020] FIG. 4 is an example of a vertical cross-sectional image generated from 3D image data;

[0021] FIG. 5 shows several images generated from the same 3D image data.

[0022] FIG. 6 illustrates various embodiments of a system for visualizing a structure of interest;

[0023] FIG. 7 illustrates various embodiments of a method for visualizing a structure of interest;

[0024] FIG. 8 illustrates a conventional C-mode image generated by the method of FIG. 7;

[0025] FIG. 9 illustrates a horizontal cross-sectional image generated by the method of FIG. 7;

[0026] FIG. 10 illustrates user movable reference anchors and a line connecting them superimposed on a horizontal cross-sectional image generated by the method of FIG. 7;

[0027] FIG. 11 illustrates a contour-modeled C-mode image generated by the method of FIG. 7;

[0028] FIG. 12 illustrates a vertical cross-sectional image generated by the method of FIG. 7;

[0029] FIG. 13 illustrates user movable reference anchors and a line connecting them superimposed on a vertical cross-sectional image generated by the method of FIG. 7;

[0030] FIG. 14 illustrates a contour-modeled C-mode image generated by the method of FIG. 7;

[0031] FIG. 15 illustrates a final vertical cross-sectional image generated by the method of FIG. 7; and

[0032] FIG. 16 illustrates a final contour-modeled C-mode image generated by the method of FIG. 7.

DETAILED DESCRIPTION

[0033] It is to be understood that at least some of the figures and descriptions of the invention have been simplified to illustrate elements that are relevant for a clear understanding of the invention, while eliminating, for purposes of clarity, other elements that those of ordinary skill in the art will appreciate may also comprise a portion of the invention. However, because such elements are well known in the art, and because they do not facilitate a better understanding of the invention, a description of such elements is not provided herein.

[0034] For purposes of simplicity, the invention will be described in the context of its use with a spectral domain optical coherence tomography (SD-OCT) system that generates three-dimensional image data associated with a human eye. However, it is understood that the invention may also be utilized with any of a wide variety of different imaging modalities to visualize any of a wide variety of different structures of interest.

[0035] FIG. 6 illustrates various embodiments of a system **10** for visualizing a structure of interest. The system **10** is communicably connected to an imaging system **12**. The system **10** may be connected to the imaging system **12** in any suitable manner. According to various embodiments, the system **10** is communicably connected to the imaging system **12** via a network **14** as shown in FIG. 6. According to other embodiments, the system **10** may form a portion of the imaging system **12**.

[0036] The imaging system **12** is configured to generate raw data associated with a scanned target, to process the raw data into 3D image data, and in some embodiments, to generate images based on the 3D image data. The generated images may be, for example, an OCT fundus image, a conventional C-mode image, a horizontal (x-z) cross-sectional image, a vertical (y-z) cross-sectional image, etc.

[0037] The imaging system **12** may be embodied as any of a number of different types of imaging systems configured for generating three-dimensional image data. For example, according to various embodiments, the imaging system **12** may be an optical coherence tomography system (e.g., a spectral domain optical coherence tomography system), a magnetic resonance imaging system, etc. For purposes of simplicity, only one imaging system **12** is shown in FIG. 6. However, it is understood that the system **10** may be connected to any number of imaging systems **12**.

[0038] In general, the system **10** and the imaging system **12** each include hardware and/or software components for communicating with the network **14** and with each other.

The system **10** and the imaging system **12** may be structured and arranged to communicate through the network **14** via wired and/or wireless pathways using various communication protocols (e.g., HTTP, TCP/IP, UDP, WAP, WiFi, Bluetooth) and/or to operate within or in concert with one or more other communications systems.

[0039] The network **14** may include any type of delivery system including, but not limited to, a local area network (e.g., Ethernet), a wide area network (e.g. the Internet and/or World Wide Web), a telephone network (e.g., analog, digital, wired, wireless, PSTN, ISDN, GSM, GPRS, and/or xDSL), a packet-switched network, a radio network, a television network, a cable network, a satellite network, and/or any other wired or wireless communications network configured to carry data. The network **14** may include elements, such as, for example, intermediate nodes, proxy servers, routers, switches, and adapters configured to direct and/or deliver data. For purposes of simplicity, only one network **14** is shown in FIG. 6. However, it is understood that the system **10** may be connected to any number of networks **14**.

[0040] The system **10** includes a computing device **16** in communication with the imaging system **12**. The computing device **16** may be embodied as any suitable type of computing device. The computing device **16** includes a contour modeling module **18** configured for superimposing reference anchors on a first cross-sectional image generated from 3D image data, for generating a line which connects the reference anchors, for sampling the 3D image data in a variable thickness plane defined by the connecting line, and for generating a contour-modeled C-mode image from the sampled 3D image data. For purposes of simplicity, only one computing device **16** is shown in FIG. 6. However, it will be appreciated that the system **10** may include any number of computing devices **16**.

[0041] The contour modeling module **18** may be implemented in either hardware, firmware, software or combinations thereof. For embodiments utilizing software, the

software may utilize any suitable computer language (e.g., C, C++, Java, JavaScript, Visual Basic, VBScript, Delphi) and may be embodied permanently or temporarily in any type of machine, component, physical or virtual equipment, storage medium, or propagated signal capable of delivering instructions to a device. The contour modeling module **18** (e.g., software application, computer program) may be stored on computer-readable medium in communication with the computing device **16** such that when the mediums are read, the functions described herein are performed.

[0042] According to various embodiments, the contour modeling module **18** may reside at the computing device **16**, at other devices within the system **10**, or combinations thereof. For embodiments where the system **10** includes more than one computing device **16**, the contour modeling module **18** may be distributed across a plurality of computing devices **16**.

[0043] As shown in FIG. 6, the system **10** may also be communicably connected to a display device **20**. The display device **20** may be any suitable type of display device, and is configured for displaying one or more images generated from the 3D image data. For example, the display device **20** may be configured to display a C-mode image generated from the 3D image data (e.g., a C-mode image of a human eye), a horizontal cross-sectional image generated from the 3D image data (e.g., a horizontal cross-section associated with a human eye), a vertical cross-sectional image generated from the 3D image data (e.g., a vertical cross-section associated with a human eye), etc. In general, the display device **20** is configured to display the images in any suitable arrangement. For example, according to various embodiments, a single image may be displayed on the display device **20**. According to other embodiments, a C-mode image may be displayed on the “left” side of the display device **20** and a cross-sectional image may be displayed on the “right” side of the display device **20**.

Thus, it is understood that the display device **20** may display images in a variety of different arrangements.

[0044] For purposes of simplicity, only one display device **20** is shown in FIG. 6. However, it is understood that the system **10** may include any number of display devices **20**. For example, according to various embodiments, the system **10** may include two display devices **20** – one for displaying the C-mode images and the other for displaying the cross-sectional images.

[0045] FIG. 7 illustrates various embodiments of a method **30** for visualizing a structure of interest. The structure of interest may any type of structure of interest (e.g., striation of retinal nerve fibers, a retinal capillary network, a choroidal capillary network, major choroidal vasculatures, etc.). The method **30** may be implemented by the system **10** of FIG. 6. For purposes of simplicity, the method **30** will be described in the context of the system **10** of FIG. 6, where the structure of interest is associated with a human eye.

[0046] Prior to the start of the process **30**, a structure of interest is chosen, and a SD-OCT system is utilized to perform a scan on a human eye. The scan is typically performed in a lateral direction (e.g., “x” direction) and a vertical direction (e.g., “y” direction). In general, the scan rate for the lateral direction may be in the range of approximately two-hundred to one-thousand times faster than the scan rate for the vertical direction. Based on raw data acquired during the scan, the SD-OCT system generates 3D image data. As explained previously, due to the natural curvature of the human eye and to movement of the eye during the scanning process, in many instances the raw data, and the corresponding 3D image data, is somewhat distorted. Understandably, due to the disparity in the scan rates, the 3D image data tends to more distorted in the vertical direction than in the horizontal direction. The 3D image data may be stored at the imaging system **12**.

[0047] The process **30** starts at block **32**, where a user prompts the system **10** to access the 3D image data stored at the imaging system **12**. The user may prompt the system **10** in any suitable manner, and the system **10** may access the 3D image data in any suitable manner. For example, the system **10** may receive a “copy” of the 3D image data.

[0048] From block **32**, the process advances to block **34**, where a user prompts the system **10** to generate a conventional C-mode image from the 3D image data. The user may prompt the system **10** in any suitable manner. The prompt to generate the conventional C-mode image is a prompt to generate a conventional C-mode image which shows the chosen structure of interest. The generated conventional C-mode image is displayed on the display device **20**. An example of a conventional C-mode image generated at block **34** is shown in FIG 8. According to various embodiments, the system **10** may automatically superimpose a user movable horizontal line and a user movable vertical line on the conventional C-mode image.

[0049] From block **34**, the process advances to block **36**, where the user prompts the system **10** to generate a first cross-sectional image from the 3D image data. The user may prompt the system **10** in any suitable manner. For example, the user may prompt the system **10** by using a mouse or other pointing device connected to the computing device **16** to select the user movable horizontal line which is superimposed on the conventional C-mode image. The selection of the user movable horizontal line prompts the system **10** to generate a horizontal cross-sectional image which corresponds to the position of the user movable horizontal line. Alternatively, the user may prompt the system **10** by using the mouse or other pointing device to select the user movable vertical line which is superimposed on the conventional C-mode image. The selection of the user movable vertical line prompts the system **10** to generate a vertical cross-sectional image which corresponds to the position of the user movable vertical line.

[0050] Although the first cross-sectional image can be a horizontal cross-sectional image or a vertical cross-sectional image, for purposes of simplicity, the description will proceed as if the horizontal cross-section was selected. The generated horizontal cross-sectional image is displayed on the display device **20**. An example of a horizontal cross-sectional image generated at block **36** is shown in FIG 9. According to various embodiments, the system **10** may automatically superimpose user movable reference anchors, and a line connecting the user movable references, on the horizontal cross-sectional image. The user movable reference anchors are shown as square boxes in FIG. 9.

[0051] From block **36**, the process advances to block **38**, where the user utilizes the mouse or other pointing device to move one or more of the user movable reference anchors on the horizontal cross-sectional image, to superimpose one or more additional user movable reference anchors on the horizontal cross-sectional image, or a combination of both. In general, the reference anchors are positioned at various locations which correspond to the structure of interest. Any number of reference anchors may be superimposed on the horizontal cross-sectional image.

[0052] From block **38**, the process advances to block **40**, where the system **10** generates a line which connects all of the user movable reference anchors which are superimposed on the horizontal cross-sectional image. The connecting line may be generated in any suitable manner. According to various embodiments, the system **10** employs cubic spline interpolation to generate the connecting line. An example of repositioned user movable reference anchors and the line connecting them is shown in FIG. 10. Although the connecting line is shown as three separate lines in FIG. 10, it is understood that the connecting line can be shown as a single thicker line, as two lines (e.g., the “uppermost” line and the “lowermost” line of FIG. 10), as four lines, etc. As shown, the user movable anchors

are positioned such that the line connecting them follows the contour of a structure of interest.

[0053] From block 40, the process advances to block 42, where the system 10 samples the 3D image data in a variable thickness plane defined by the connecting line. From block 42, the process advances to block 44, where the system 10 generates a contour modeled C-mode image from the 3D image data sampled at block 42. The contour-modeled C-mode image is displayed on the display device 20. An example of a contour-modeled C-mode image generated at block 44 is shown in FIG 11. According to various embodiments, the system 10 may automatically superimpose a user movable horizontal line and a user movable vertical line on the contour-modeled C-mode image. According to various embodiments, the processes described at blocks 38-44 occurs in real-time. Thus, when another user movable reference anchor is added at block 38, the contour-modeled C-mode image at block 44 is changed accordingly in real-time.

[0054] From block 44, the process advances to block 46, where the user prompts the system 10 to generate a second cross-sectional image from the 3D image data. In general, when the first cross-sectional image is a horizontal cross-sectional image, the second cross-sectional image is a vertical cross-sectional image. The user may prompt the system 10 in any suitable manner. For example, the user may prompt the system 10 by using a mouse or other pointing device connected to the computing device 16 to select the user movable vertical line which is superimposed on the contour-modeled C-mode image. The selection of the user movable vertical line prompts the system 10 to generate a vertical cross-sectional image which corresponds to the position of the user movable vertical line.

[0055] The generated vertical cross-sectional image is displayed on the display device 20. An example of a vertical cross-sectional image generated at block 46 is shown in FIG 12. According to various embodiments, the system 10 may automatically superimpose user

movable reference anchors, and a line connecting the user movable references, on the vertical cross-sectional image. The user movable reference anchors are shown as square boxes in FIG. 12.

[0056] From block **46**, the process advances to block **48**, where the user utilizes the mouse or other pointing device to move one or more of the user movable reference anchors on the vertical cross-sectional image, to superimpose one or more additional user movable reference anchors on the vertical cross-sectional image, or a combination of both. In general, the reference anchors are positioned at various locations which correspond to the structure of interest. Any number of reference anchors may be superimposed on the vertical cross-sectional image.

[0057] From block **48**, the process advances to block **50**, where the system **10** generates a line which connects all of the user movable reference anchors which are superimposed on the vertical cross-sectional image. The connecting line may be generated in any suitable manner. According to various embodiments, the system **10** employs cubic spline interpolation to generate the connecting line. An example of repositioned user movable reference anchors and the line connecting them is shown in FIG. 13. Although the connecting line is shown as three separate lines in FIG. 13, it is understood that the connecting line can be shown as a single thicker line, as two lines (e.g., the “uppermost” line and the “lowermost” line of FIG. 13), as four lines, etc. As shown, the user movable anchors are positioned such that the line connecting them follows the contour of a structure of interest.

[0058] From block **50**, the process advances to block **52**, where the system **10** samples the 3D image data in a variable thickness plane defined by the connecting line generated at block **50**. From block **52**, the process advances to block **54**, where the system **10** generates a second contour modeled C-mode image from the 3D image data sampled at block

52. The second contour-modeled C-mode image is displayed on the display device 20. An example of a contour-modeled C-mode image generated at block 54 is shown in FIG 14. According to various embodiments, the system 10 may automatically superimpose a user movable horizontal line and a user movable vertical line on the second contour-modeled C-mode image. According to various embodiments, the processes described at blocks 48-54 occurs in real-time. Thus, when another user movable reference anchor is added at block 48, the contour-modeled C-mode image at block 54 is changed accordingly in real-time.

[0059] If the second contour model C-mode image is satisfactory, the method 30 ends after the completion of the actions taken at block 54. However, if the second contour-modeled C-mode image is not satisfactory, the process returns from block 54 to block 36, where the process advances as described hereinabove. The sequence from block 36 to block 54 may be repeated any number of times until a given contour-modeled C-mode image is satisfactory. An example of a final vertical cross-sectional image generated after a number of iterations is shown in FIG. 15. As shown, the number of superimposed reference anchors is significantly more than the initial three superimposed reference anchors of FIG. 13, and the contour is much more complex. An example of a corresponding final contour-modeled C-mode image is shown in FIG. 16.

[0060] Nothing in the above description is meant to limit the invention to any specific materials, geometry, or orientation of elements. Many part/orientation substitutions are contemplated within the scope of the invention and will be apparent to those skilled in the art. The embodiments described herein were presented by way of example only and should not be used to limit the scope of the invention.

[0061] Although the invention has been described in terms of particular embodiments in this application, one of ordinary skill in the art, in light of the teachings herein, can generate additional embodiments and modifications without departing from the spirit of, or

exceeding the scope of, the claimed invention. Accordingly, it is understood that the drawings and the descriptions herein are proffered only to facilitate comprehension of the invention and should not be construed to limit the scope thereof.

CLAIMS

What is claimed is:

1. A system, comprising:
a computing device configured for communication with an imaging system and a display device, wherein the computing device comprises:
a contour modeling module, wherein the contour modeling module is configured for:
superimposing first reference anchors on a first cross-sectional image generated from 3D image data;
generating a first line which connects the first reference anchors;
sampling first 3D image data in a first variable thickness plane defined by the first connecting line; and
generating a first contour-modeled C-mode image from the sampled first 3D image data.
2. The system of claim 1, wherein the contour modeling module is further configured to generate a second cross-sectional image from the 3D image data.
3. The system of claim 1, wherein the contour modeling module is further configured for:
superimposing second reference anchors on a second cross-sectional image generated from the 3D image data;
generating a second line which connects the second reference anchors;

sampling second 3D image data in a second variable thickness plane defined by the second connecting line; and

generating a second contour-modeled C-mode image from the sampled second 3D image data.

4. The system of claim 1, wherein the computing device comprises a portion of the imaging system.

5. A method, implemented at least in part by a computing device, the method comprising:

superimposing first reference anchors on a first cross-sectional image generated from 3D image data;

generating a first line which connects the first reference anchors;

sampling first 3D image data in a first variable thickness plane defined by the first connecting line; and

generating a first contour-modeled C-mode image from the sampled first 3D image data.

6. The method of claim 5, wherein superimposing first reference anchors comprises superimposing user movable first reference anchors.

7. The method of claim 5, wherein generating the first line comprises performing cubic spline interpolation.

8. The method of claim 5, further comprising generating a second cross-sectional from the 3D image data.

9. The method of claim 5, further comprising:
superimposing second reference anchors on a second cross-sectional image generated from the 3D image data;

generating a second line which connects the second reference anchors;

sampling second 3D image data in a second variable thickness plane defined by the second connecting line; and

generating a second contour-modeled C-mode image from the sampled second 3D image data.

10. The method of claim 9, further comprising superimposing at least one additional reference anchor on at least one of the following:

the first cross-sectional image; and

the second cross-sectional image.

1/16

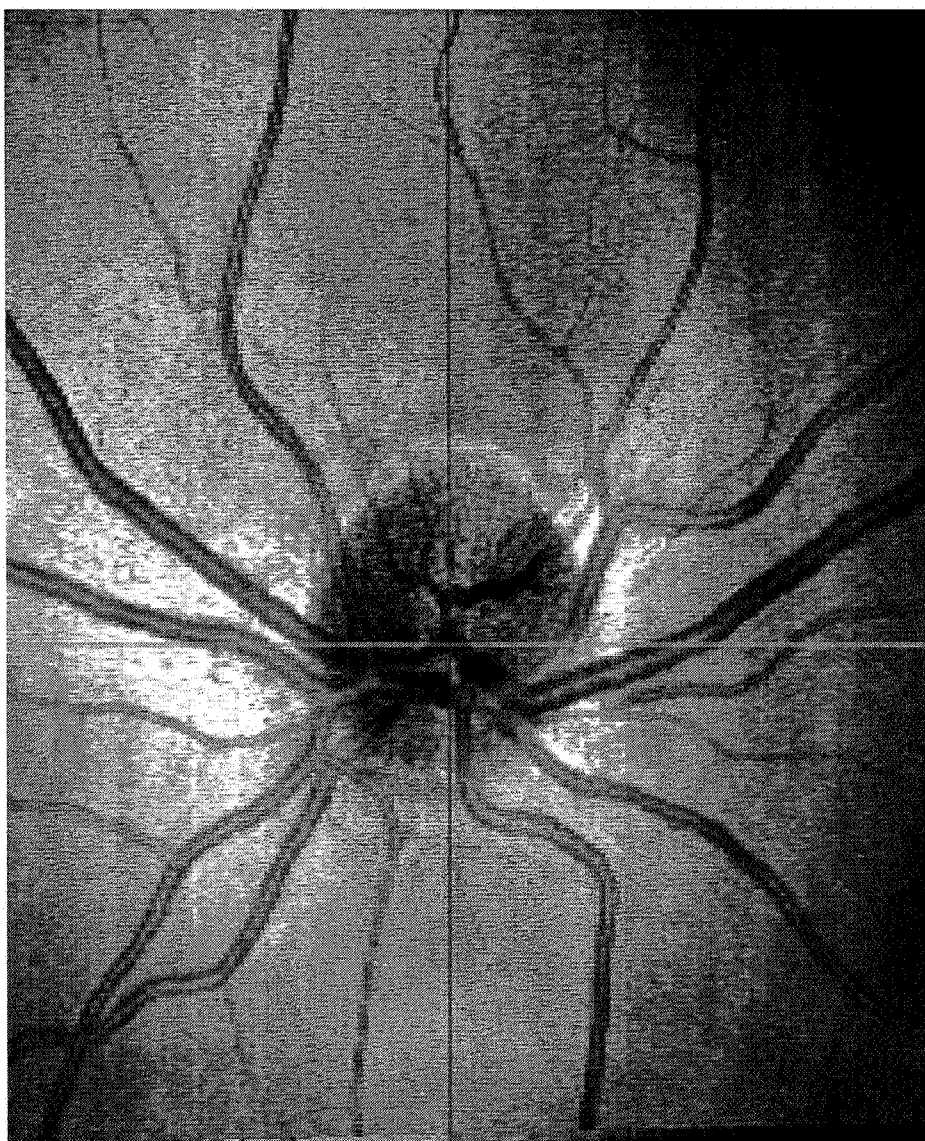


Fig. 1

2/16

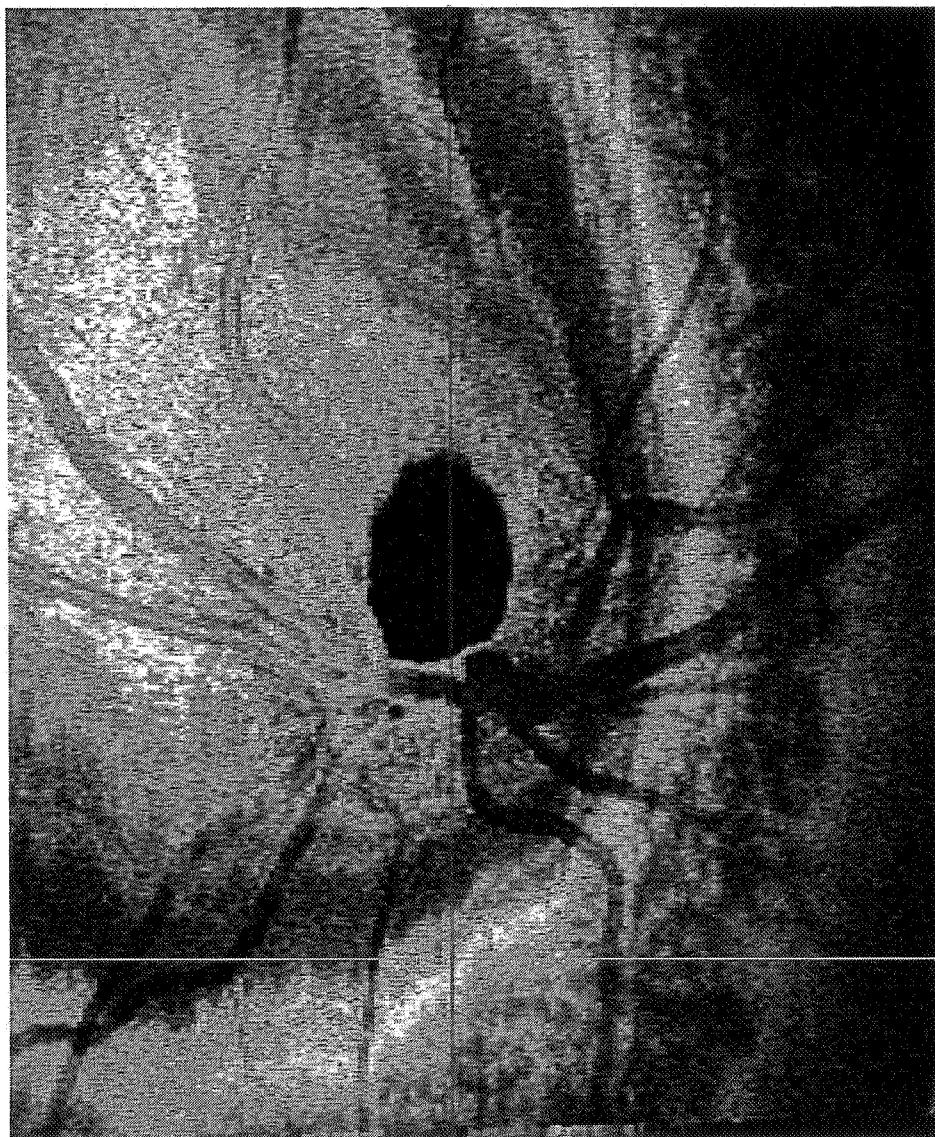


Fig. 2

3/16

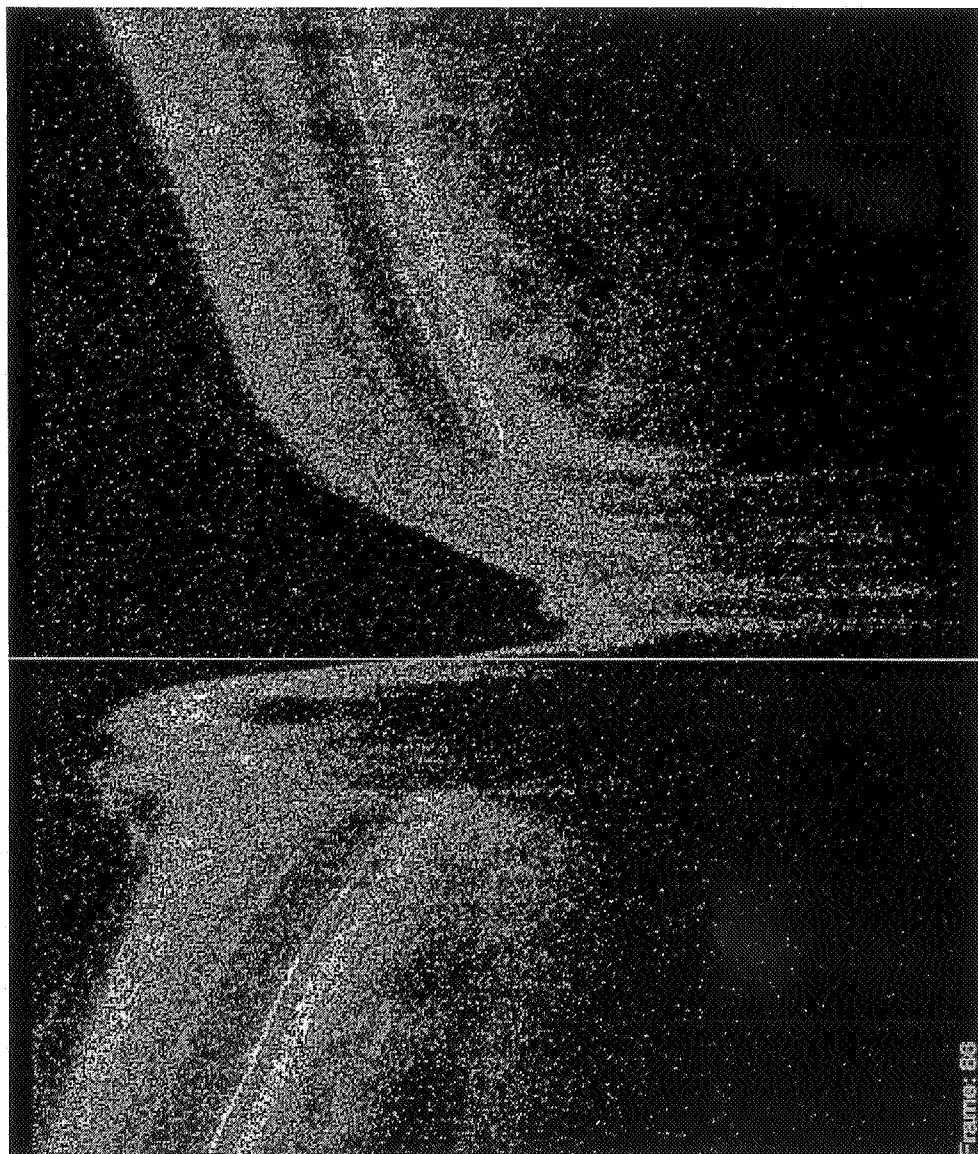


Fig. 3

4/16

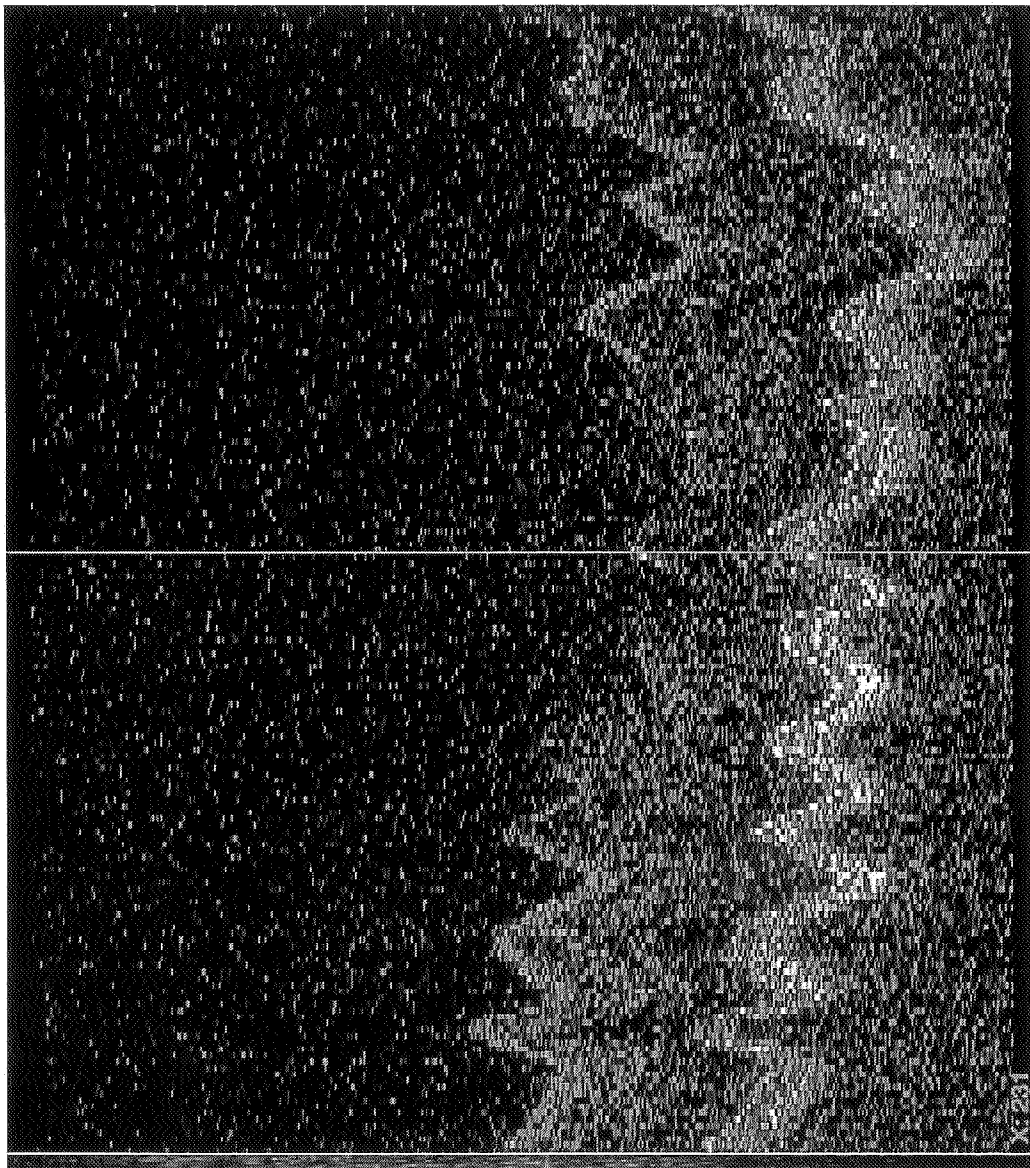


Fig. 4

5/16

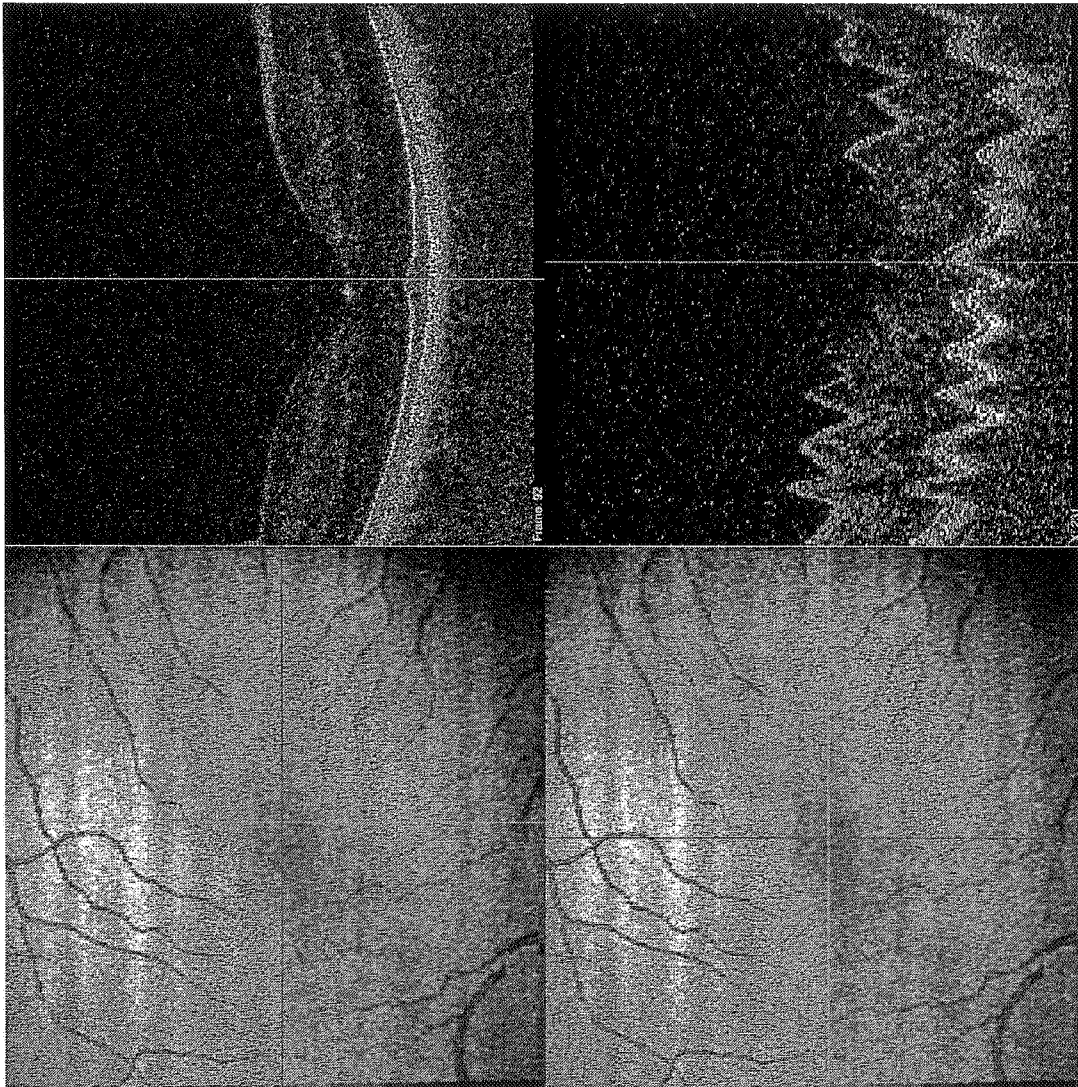


Fig. 5

6/16

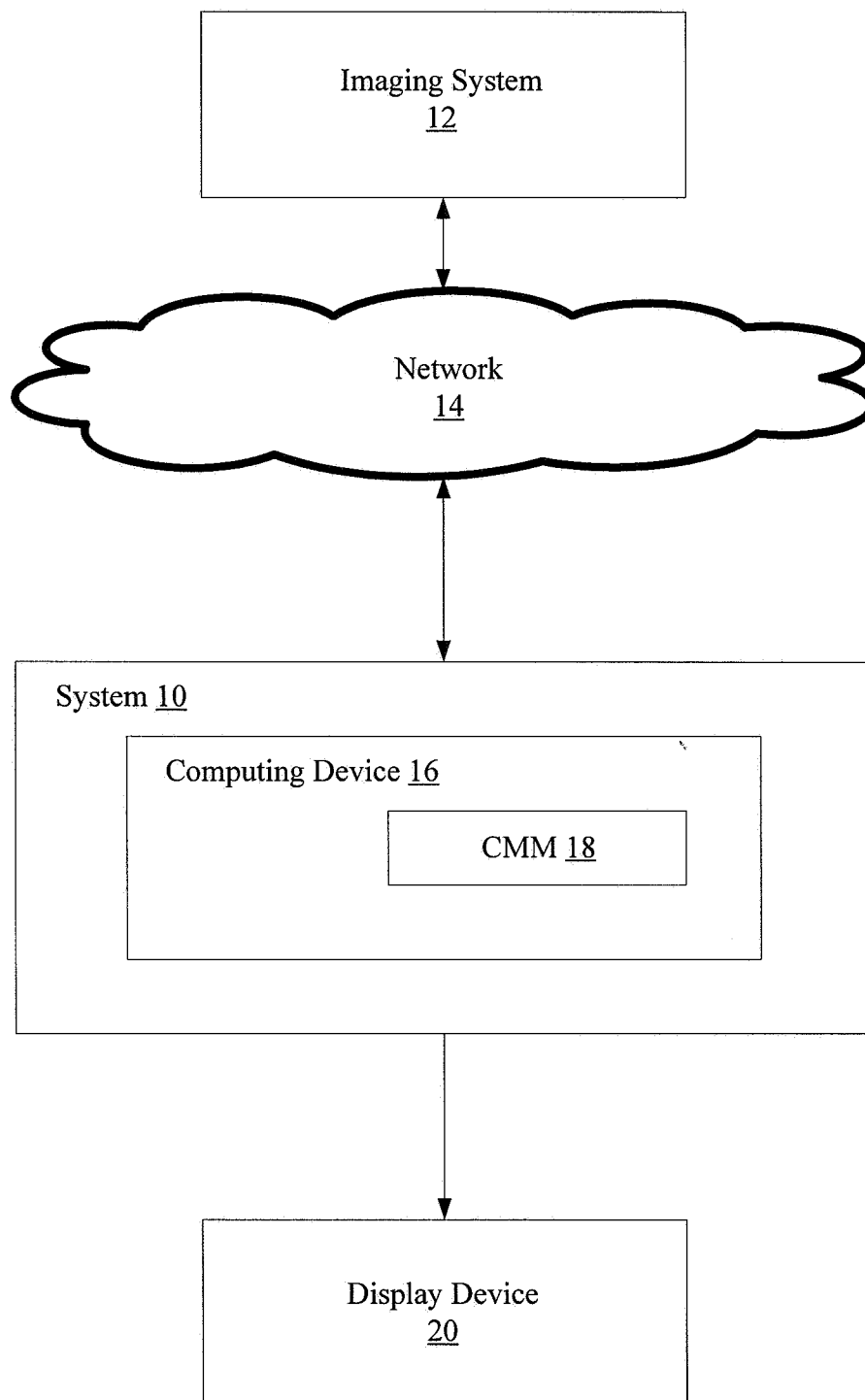


FIG. 6

7/16

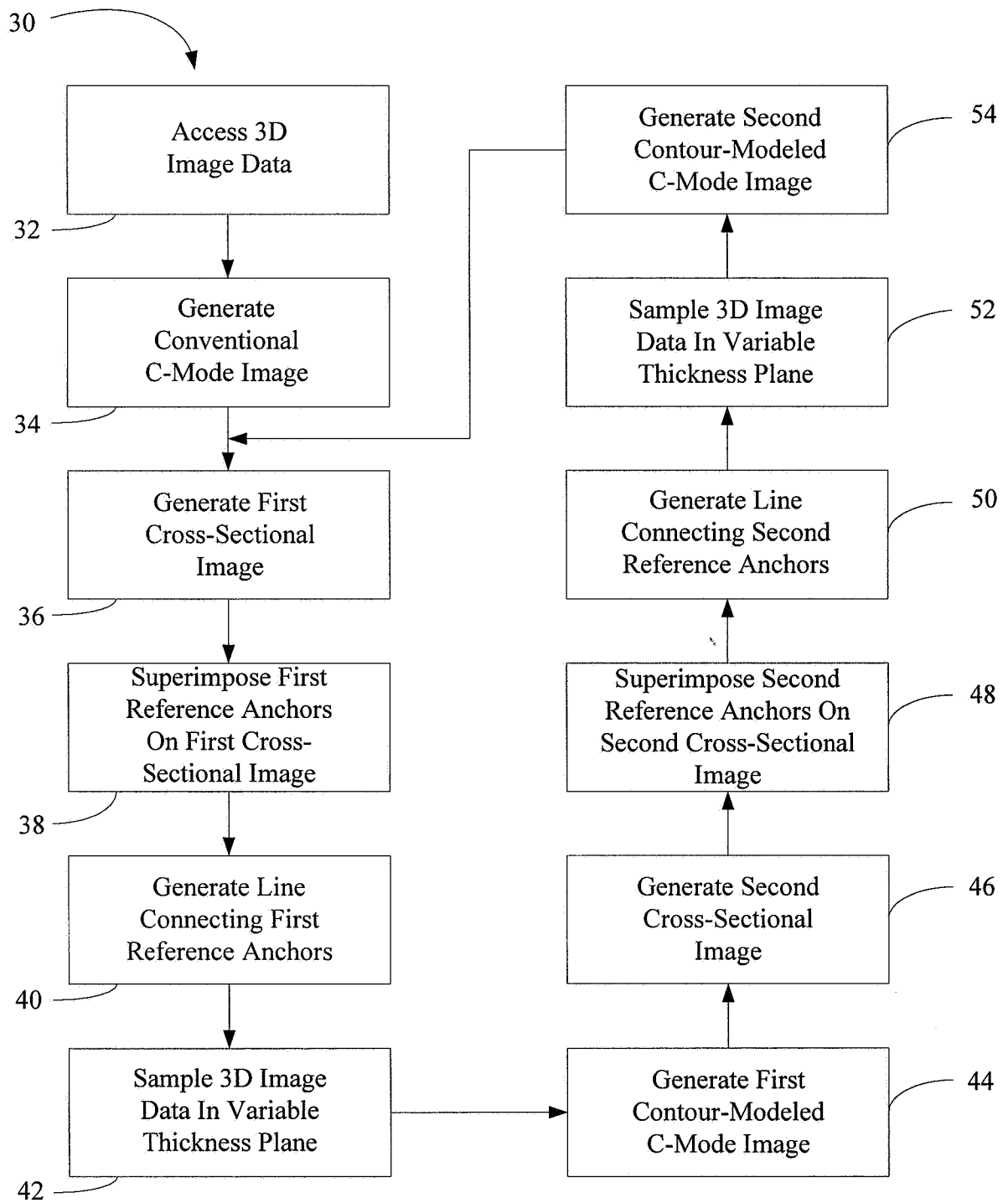


FIG. 7

8/16

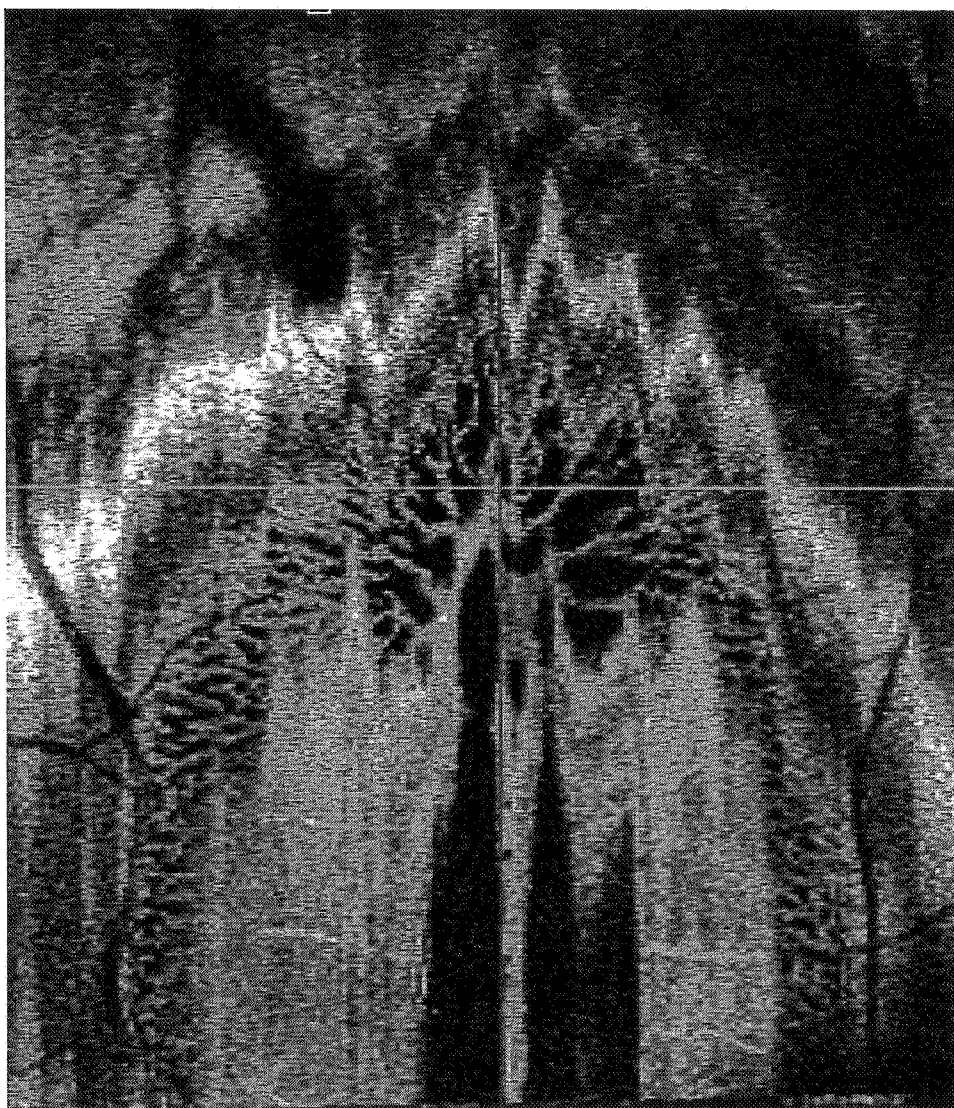


Fig. 8

9/16



Fig. 9

10/16



Fig. 10

11/16

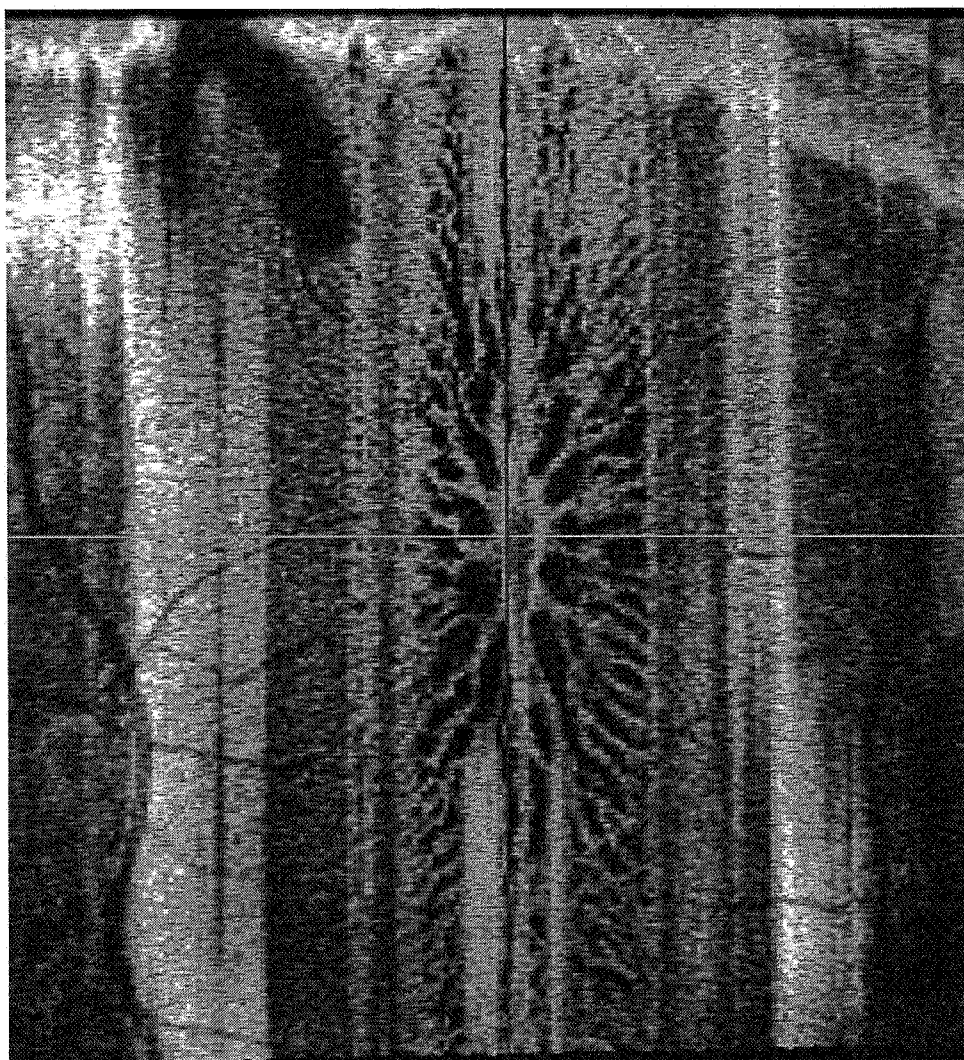


Fig. 11

12/16

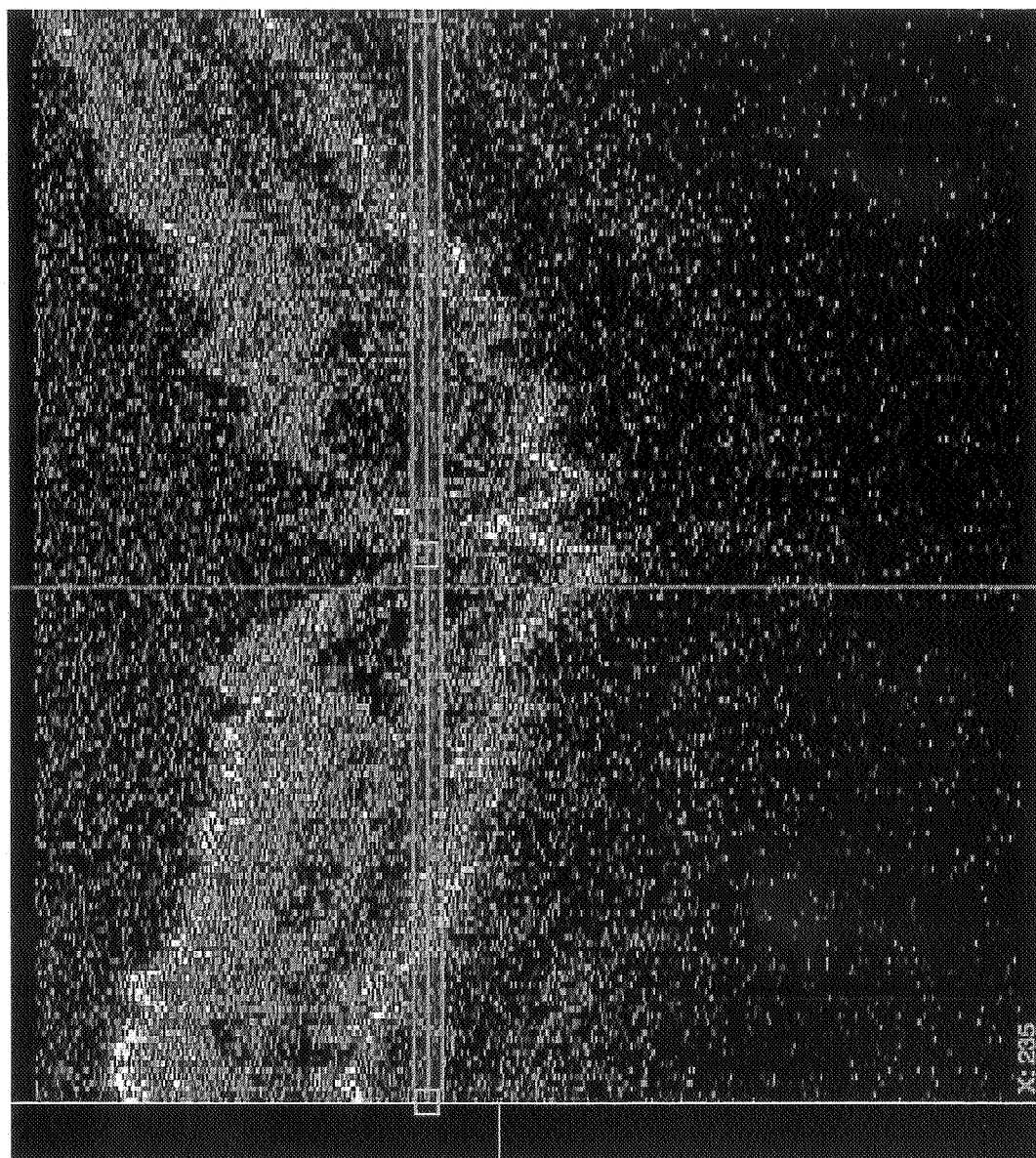


Fig. 12

13/16

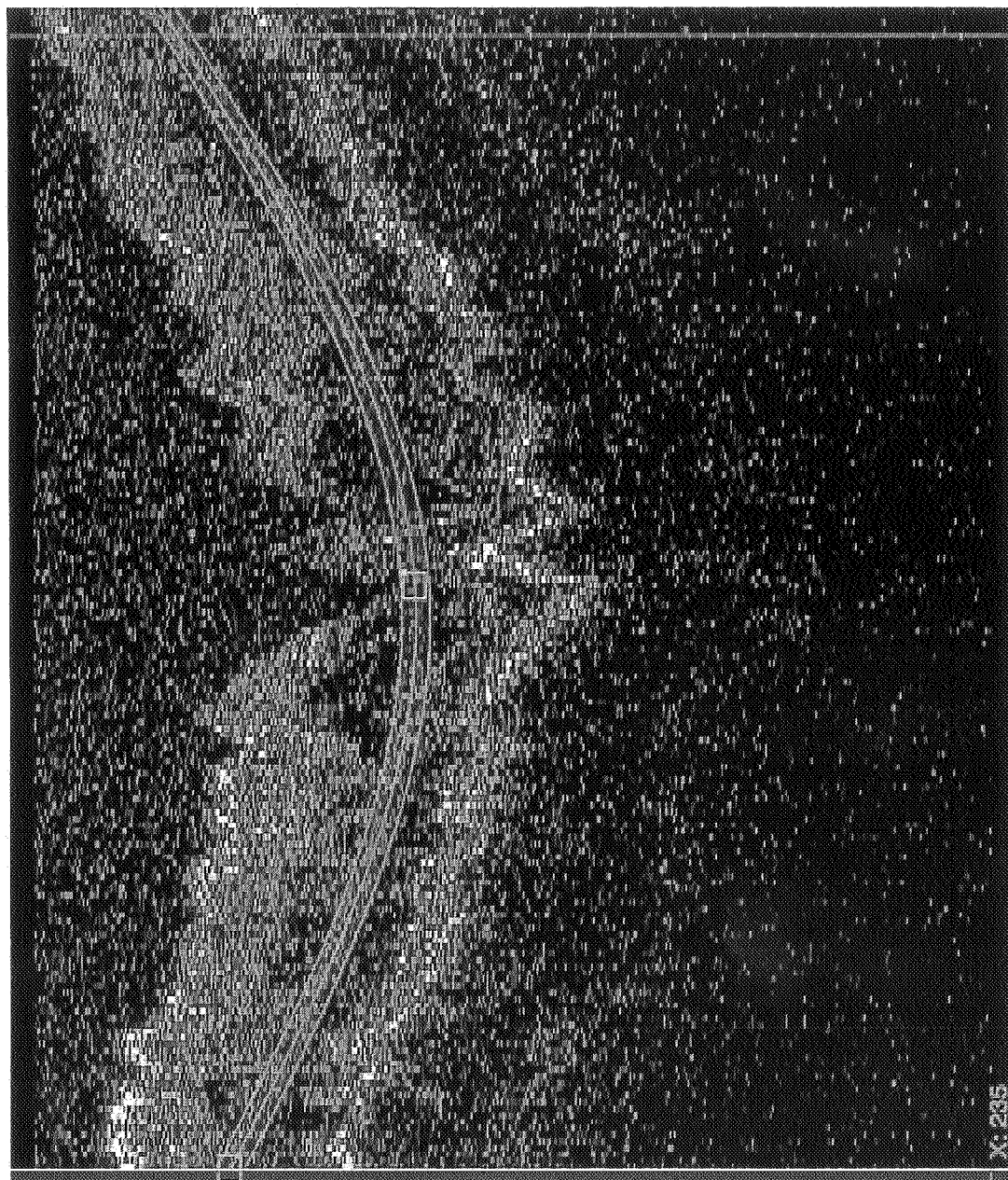


Fig. 13

14/16

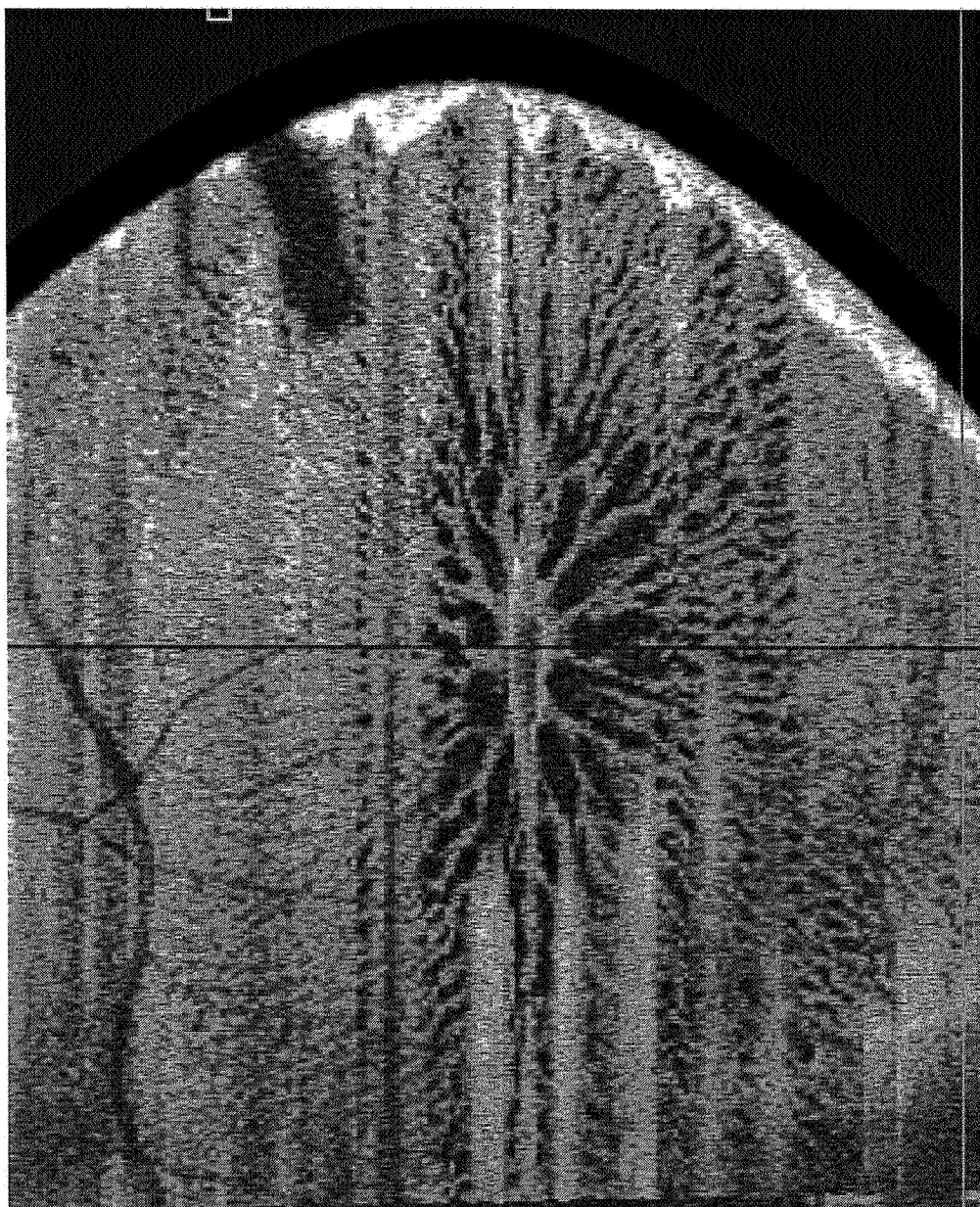


Fig. 14

15/16

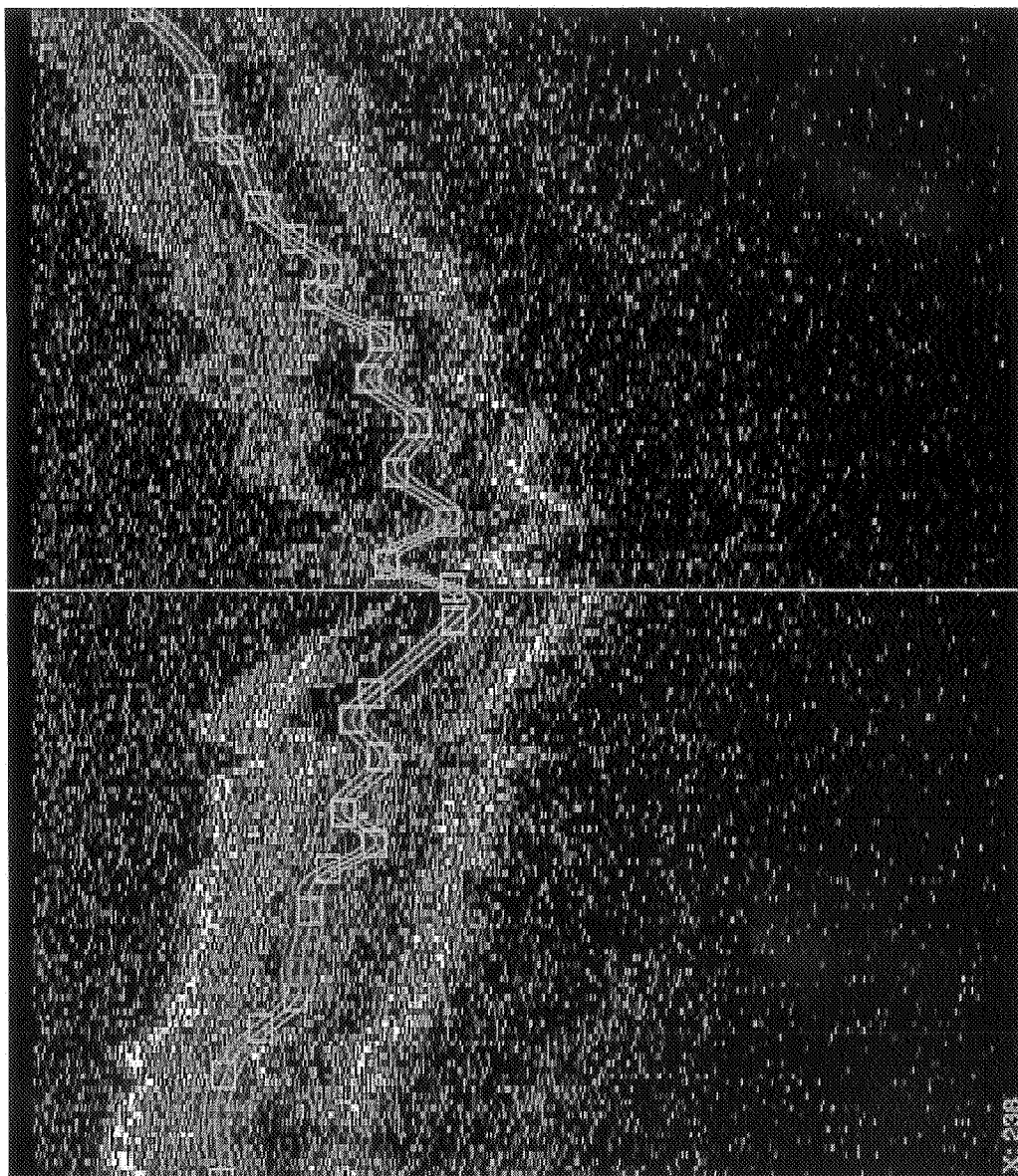


Fig. 15

16/16

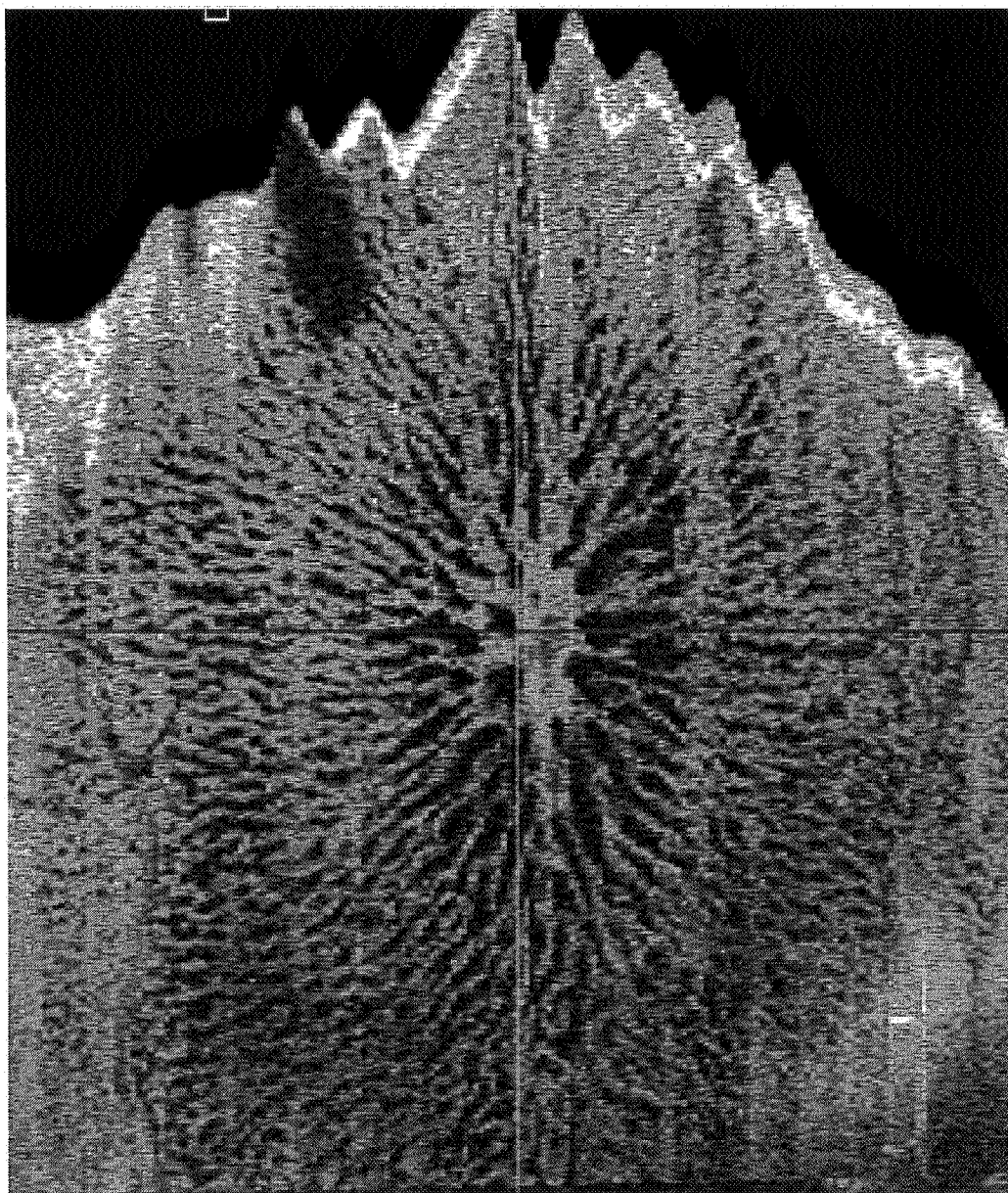


Fig. 16

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 08/1082

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G06T 17/00 (2008.04)

USPC - 345/420

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

USPC: 345/420

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

USPC: 345/419,619,424; 600/416

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PubWEST(USPT,PGPB,EPAB,JPAB), Google patent, Google Scholar

Search Terms: computing device, imaging system, display device, contour modeling module, superimposing, reference anchors, cross-sectional image, C-mode image, 3D image, first connecting line, second connecting line

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,920,573 A (Rhodes et al.) 24 April 1990 (24.04.1990) col 2, ln 24-27; col 3, ln 9-15; 3, ln 19-22; col 3, ln 24-25; col 3, ln 25-28; col 3, ln 43-46; col 3, ln 46-51; col 4, ln 2-4; col 5, ln 47-52;	1-10
A	US 6,816,607 B2 (O'Donnell et al.) 09 November 2004 (09.11.2004) col 2, ln 34-47; col 3, ln 18-28; col 7, ln 27-43; col 7, ln 43-58; Col 9, ln 16-36	1-10
A	US 2003/0227467 A1 (Hara) 11 December 2003 (11.12.2003) para[0015], [0034], [0036], [0038], [0046],[0048]	1, 2-5, 7-8

☐ Further documents are listed in the continuation of Box C.


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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

02 October 2008 (02.10.2008)

Date of mailing of the international search report

22 OCT 2008

Name and mailing address of the ISA/US

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