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(54) **SOFTWARE INTERFACE TOOL FOR
BREAST CANCER SCREENING**

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See application file for complete search history.

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Primary Examiner — Jennifer To

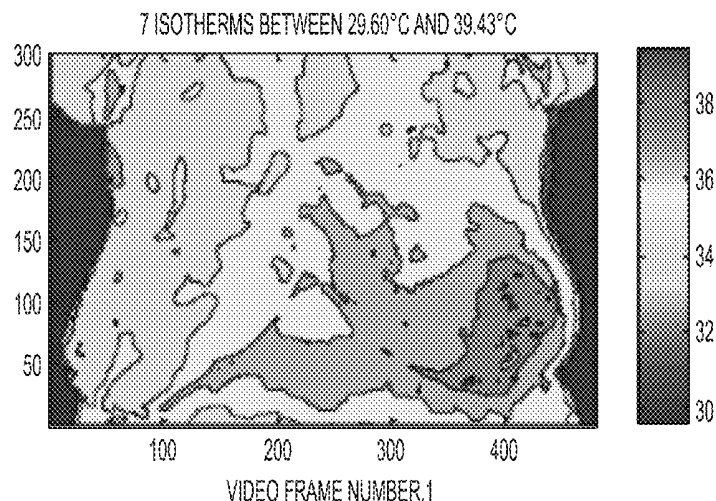
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(57) **ABSTRACT**

What is disclosed is a software interface tool for breast
cancer screening that is designed for medical professionals
to view and analyze suspicious regions for hot spots and
hence facilitate a determination of whether identified areas
of breast tissue are cancerous. Isotherm maps are con-
structed at designated temperature resolution. Maps are
displayed on the screen. Point & click on the isotherm map
can extract temperature values of pixels within the region
covered by the isotherm contours. Also provided are iso-
thermic views at different viewing angles which is advan-
tageous for visual detection. Additional functionalities for
hotspot selection, cropping, zooming, viewing at different
angles, etc. are also enabled by the present software inter-
face. The present software interface further utilizes a tumor
detection method which is also disclosed herein.

23 Claims, 10 Drawing Sheets



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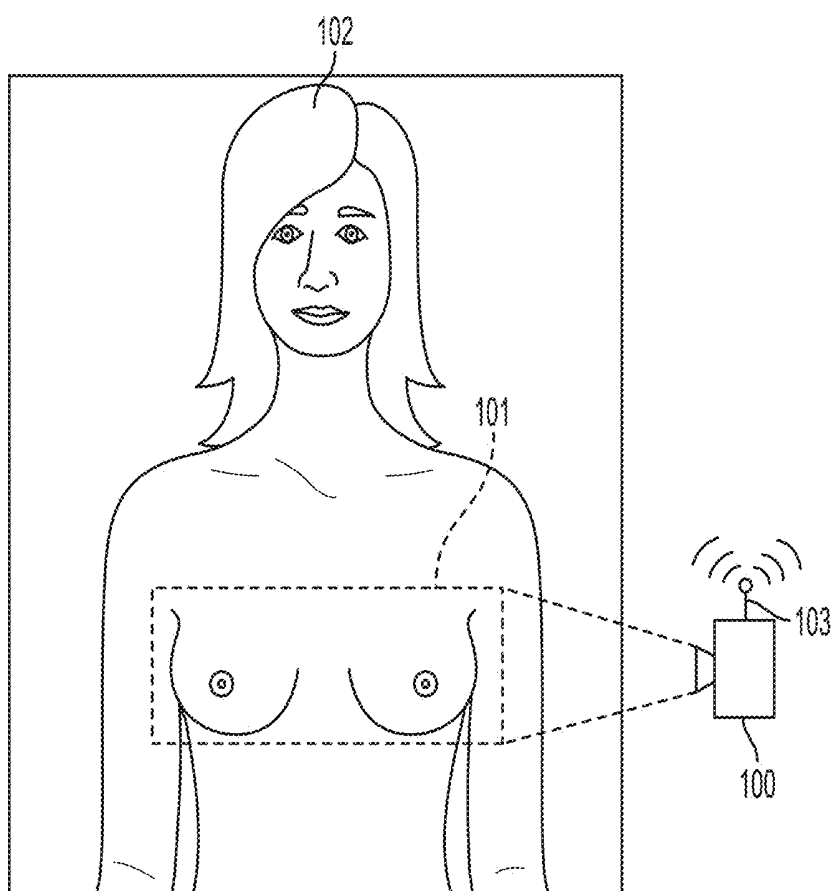


FIG. 1

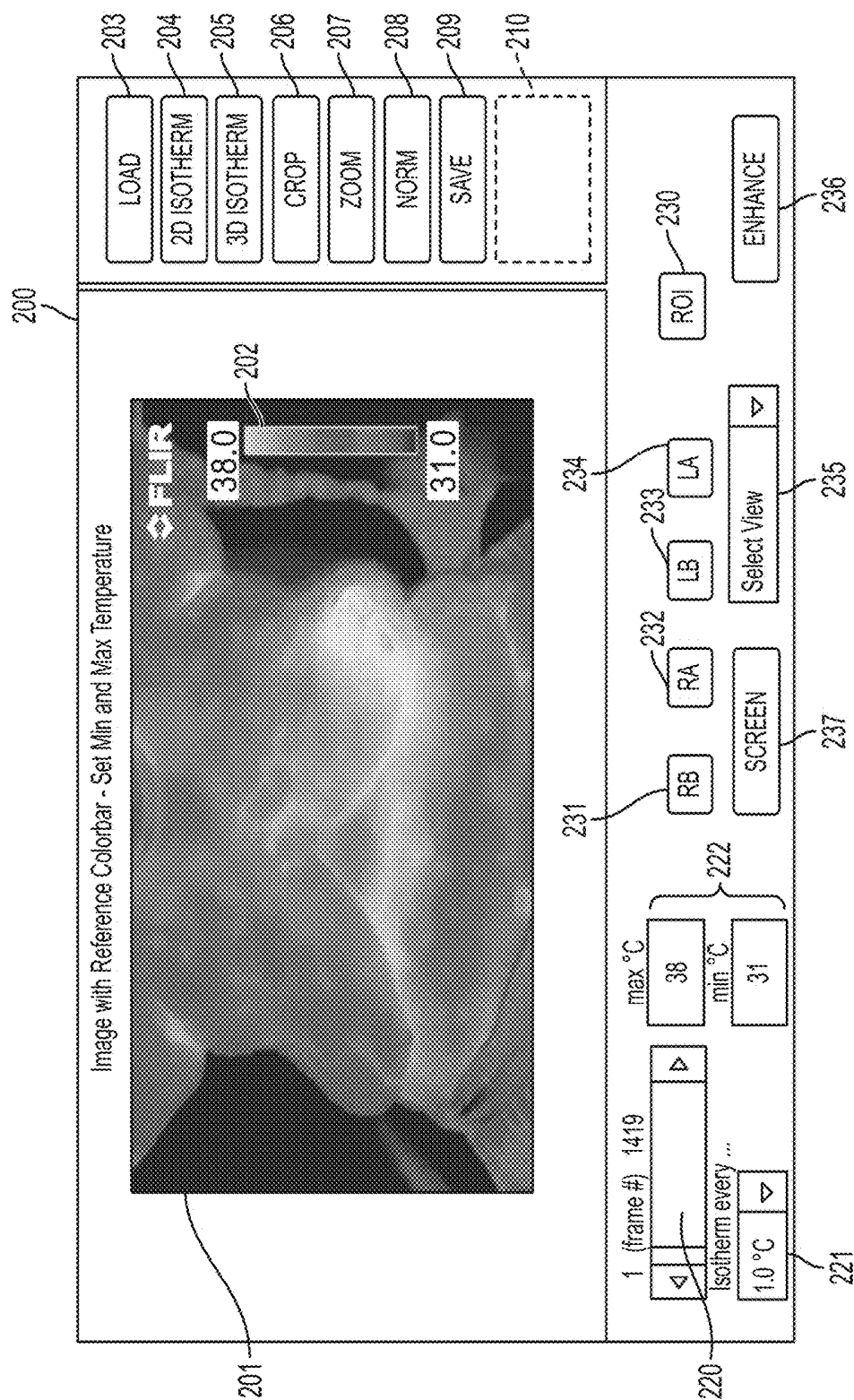


FIG. 2

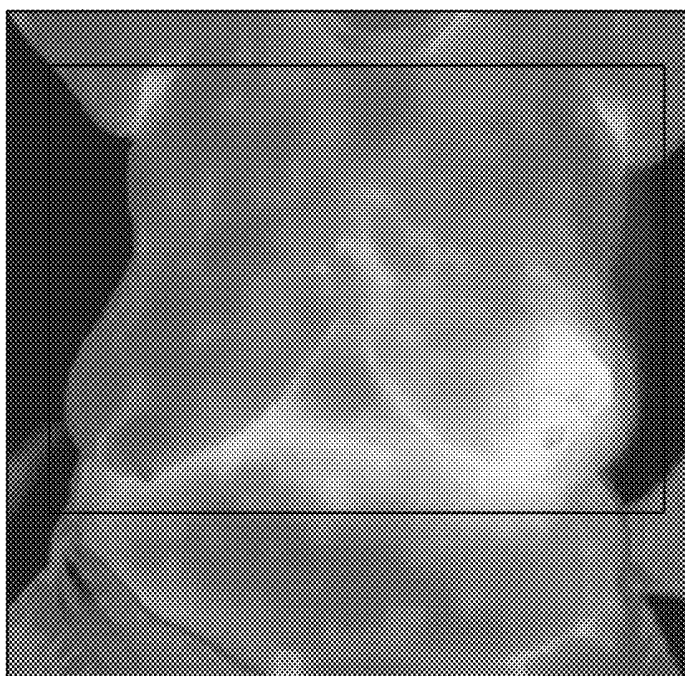


FIG. 3

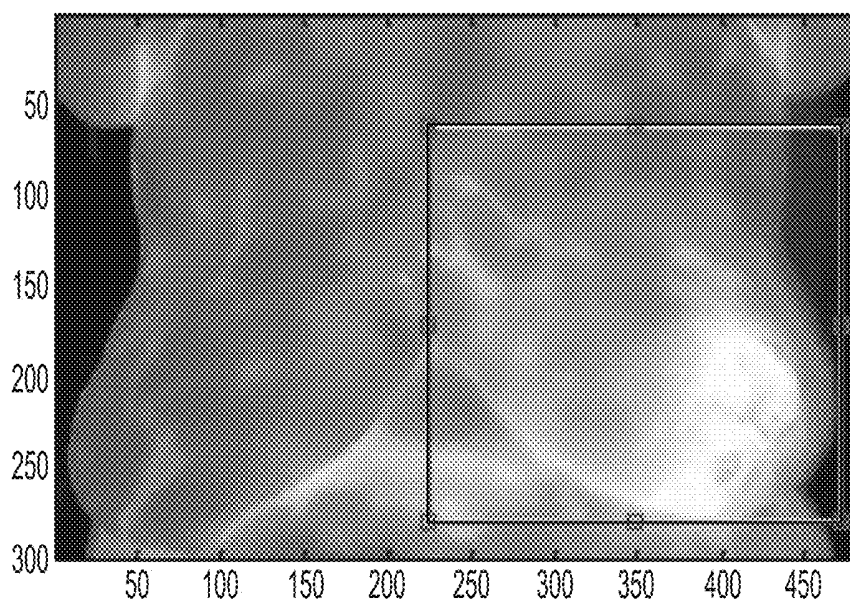


FIG. 4

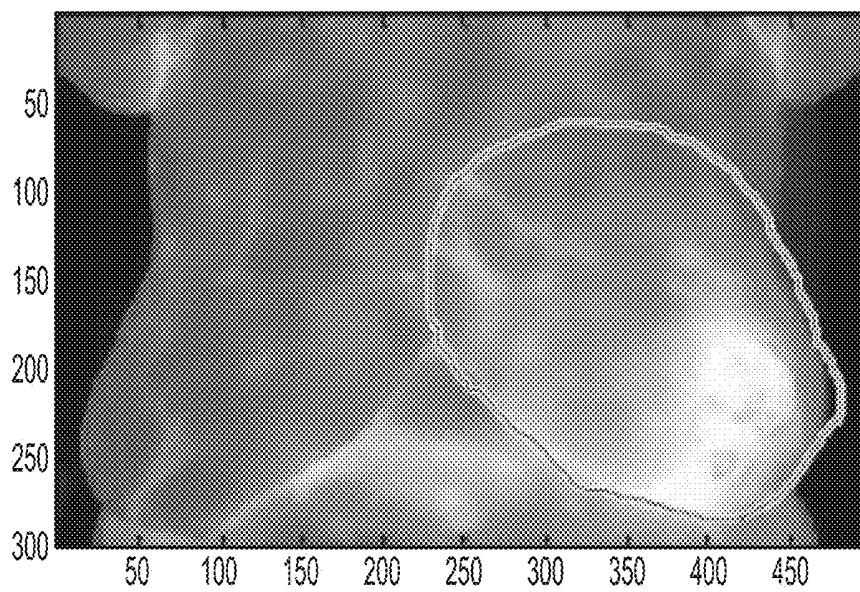


FIG. 5

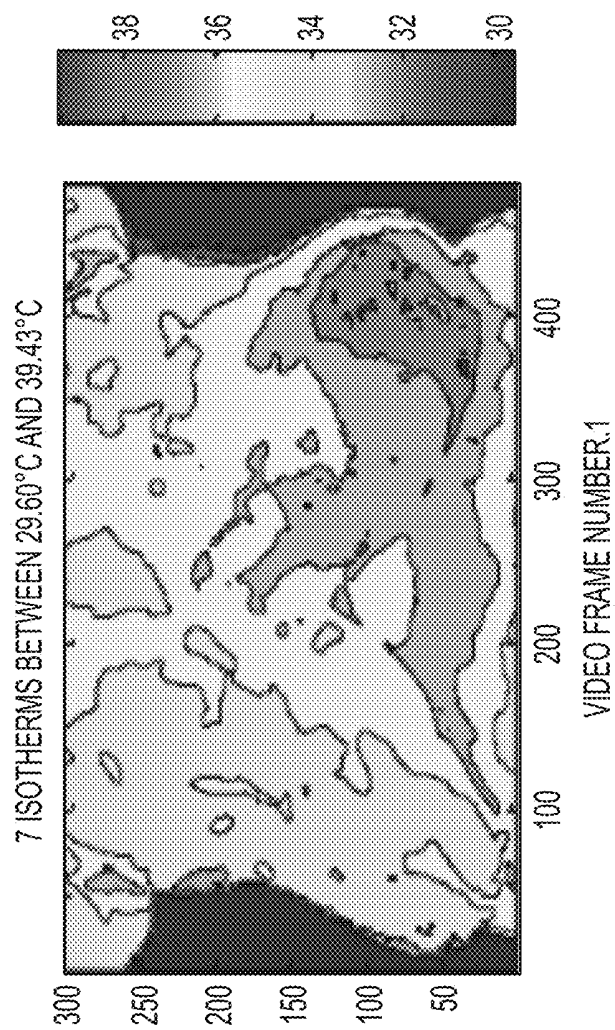


FIG. 6

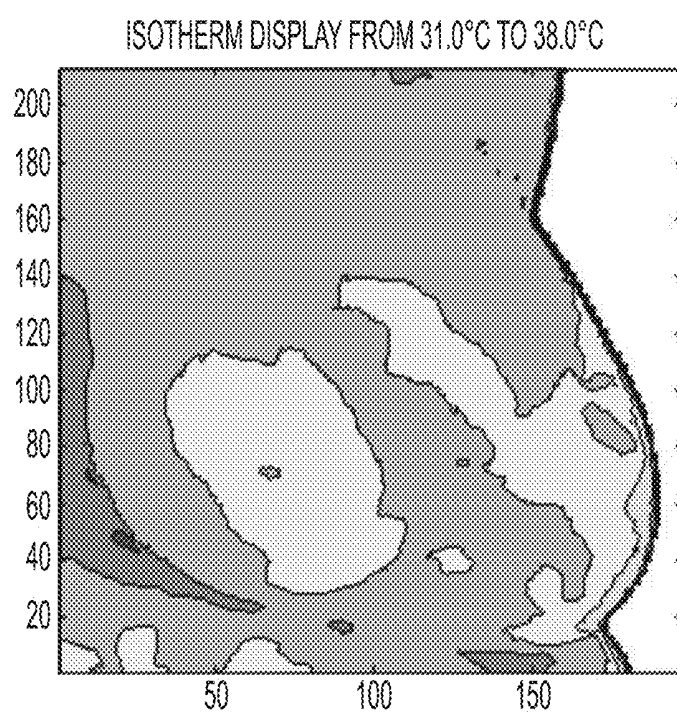
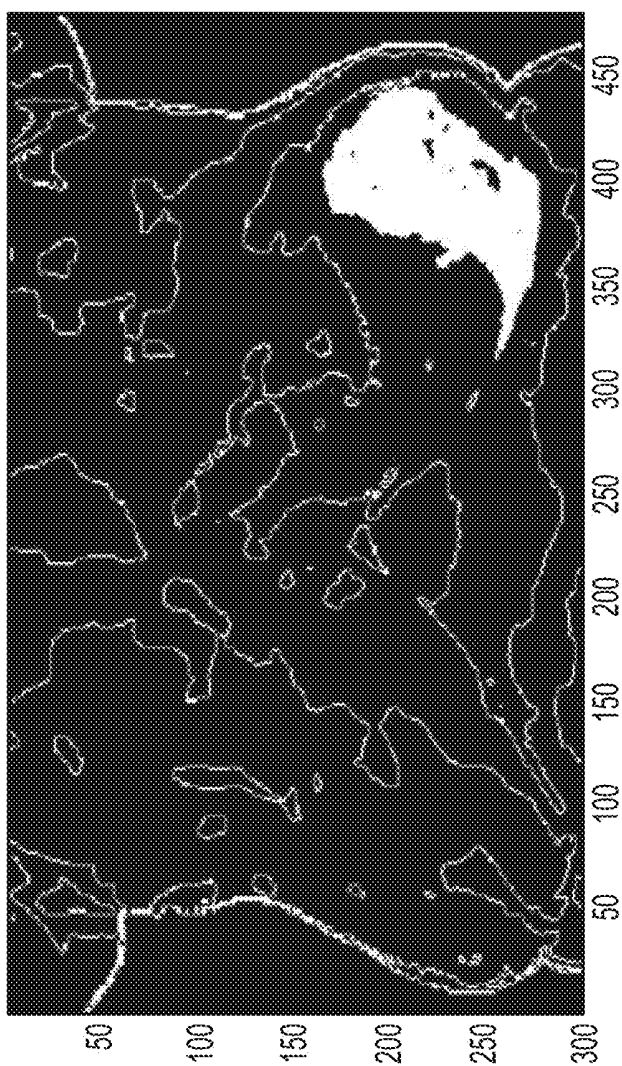


FIG. 7



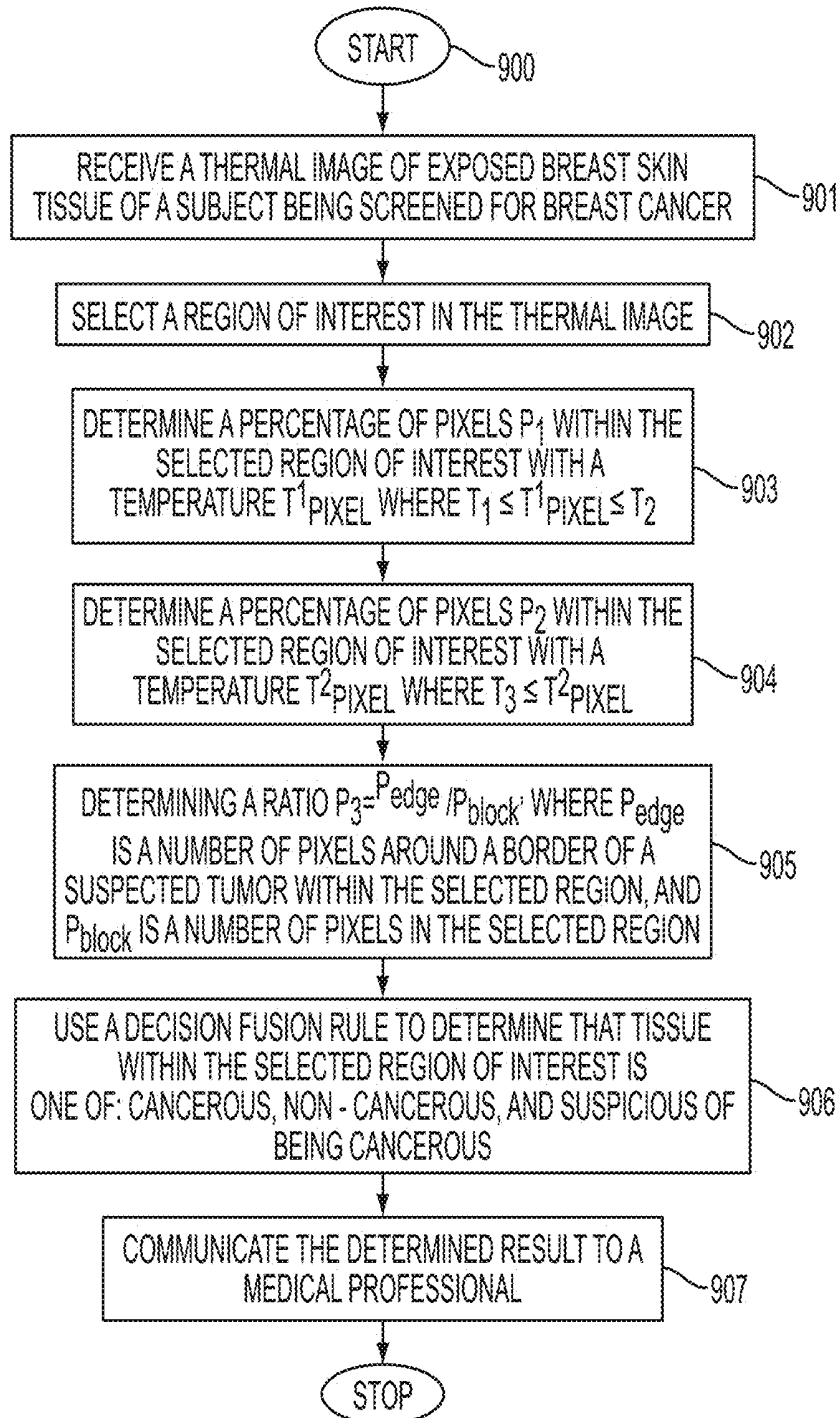


FIG. 9

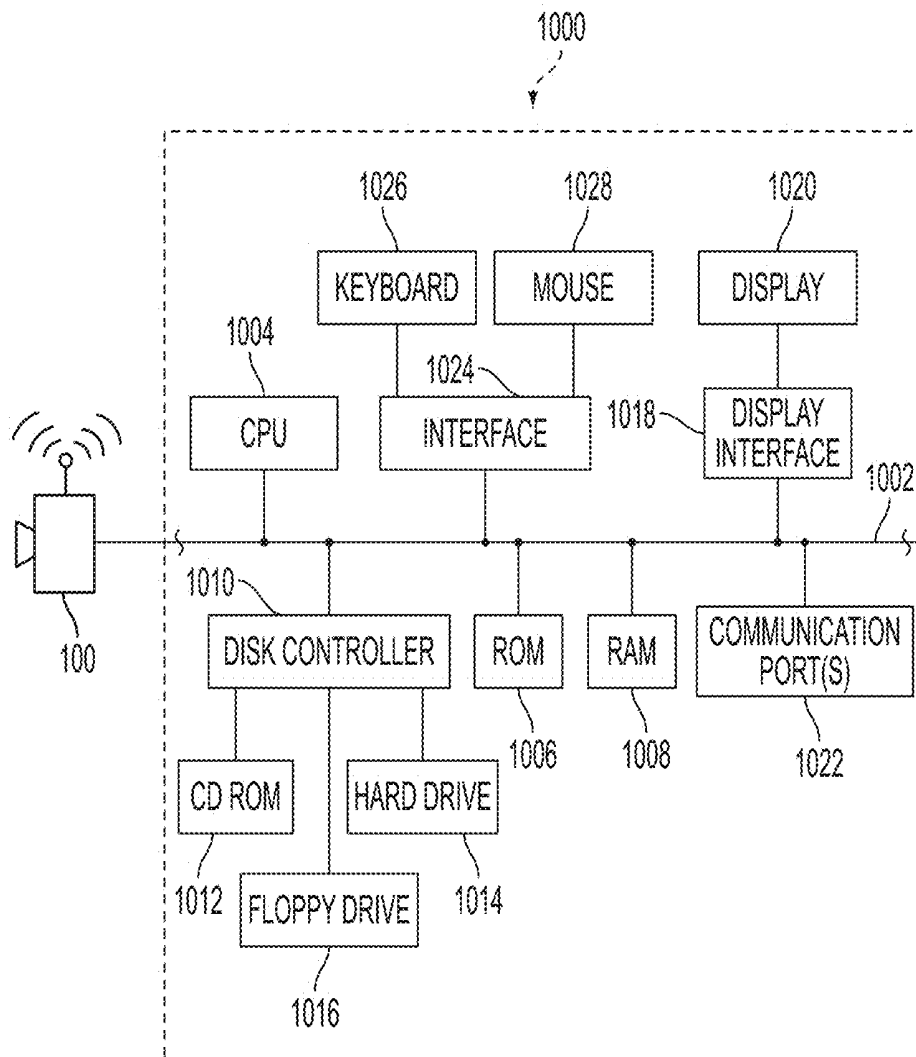


FIG. 10

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SOFTWARE INTERFACE TOOL FOR BREAST CANCER SCREENING

CROSS REFERENCE TO RELATED APPLICATIONS

This patent application is related to concurrently filed and commonly owned U.S. patent application Ser. No. 14/668,287, entitled: "Detecting Tumorous Breast Tissue In A Thermal Image", by Krithika Venkataramani, which is incorporated herein in its entirety by reference.

TECHNICAL FIELD

The present invention is specifically directed to a software interface tool for breast cancer screening and a method for detecting cancerous breast tissue in a thermal image of the breast.

BACKGROUND

Breast cancer incidence rates are relatively high in women. Nearly 1 in 8 women in the western world and nearly 1 in 11 women in India will have breast cancer. In the western world, it is the leading cancer in women. In India, for example, it is the second after cervical cancer. Early detection is key to survival as the mortality rates are high for advanced stages. Mammography is considered the gold standard for breast cancer screening. Screening for breast cancers are commonly done via manual detection of a lump in the breast tissue and/or by an in-office mammography exam followed by human interpretation of the image created during the examination. In the mammography exam, the subject is subjected to highly personal physical contact and a procedure which many subjects find discomforting. In subjects with dense breast tissue, the exam may not be as effective in spotting malignancies as for other subjects. Moreover, the equipment required for mammography is relatively large and relatively expensive. Since mammography is an x-ray machine it cannot be used at homes without supervision. The x-ray radiation itself may result in cancer. It is also not effective for younger women due to the dense breast tissue. There is also some evidence that the physical manipulation of the breast tissue during mammography could rupture the malignant cysts, thereby increasing risk of spreading the malignant cells to other tissues and into the subject's blood stream.

Thermography is an emerging alternative non-invasive and non-contact screening method for breast cancer detection. Thermal imaging captures the infra-red emissivity from the human body in the 7-10 μm wavelength range. Thermal imaging devices are useful for the detection of thermal activity in breast tissue due to a tumor's growth being enabled by causing new blood vessels to grow disproportionately through angiogenesis in the area of the tumor relative to surrounding tissue. This increased biophysical activity beneath the skin surface associated with tumor growth results in a higher metabolic rate which, in turn, results in an elevated temperature in that tissue. This appears as a hotspot in a thermal image containing that tissue. Recently, interest has been rekindled in thermography as a breast cancer screening approach with the improvement in thermal camera resolution and technology.

Trained radiologists and thermographers look for these abnormalities in thermal images to make a determination whether tissue is cancerous or is suspicious of being cancerous. If so, the subject may need to undergo additional

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tests, such as sonomammography followed by cancer diagnosis through histopathology by fine needle aspiration cytology or tissue biopsy. Thermographers and radiologists are increasingly demanding more powerful visualization software interface tools to assist them. Moreover, since medical practitioners trained in thermography are not readily available in rural areas in emerging markets like India, automatic screening tools will help open up these market for software applications for breast cancer screening and detection.

Accordingly, what is needed in this art are increasingly software tools which enable subjects as well as medical practitioners to manually or automatically analyze a thermal image of an area of breast tissue for the presence of cancerous tissue.

BRIEF SUMMARY

What is disclosed is a software interface tool for breast cancer screening that is designed for medical professionals to view and analyze suspicious regions for hot spots and hence facilitate a determination of whether identified areas of breast tissue are cancerous. Isotherm maps are constructed at designated temperature resolution. Maps are displayed on the screen. Point & click on the isotherm map can extract temperature values of pixels within the region covered by the isotherm contours. Also provided are isothermic views at different viewing angles which is advantageous for visual detection. Additional functionalities for hotspot selection, cropping, zooming, viewing at different angles, etc. are also enabled by the present software interface. The present software interface further utilizes a tumor detection method which is also disclosed herein. In one embodiment, the present tumor detection method involves selecting a region of interest in the thermal image to be processed for breast cancer screening. Thereafter, a percentage of pixels p_1 in the selected region having a temperature T_{pixel}^1 , where $T_1 \leq T_{pixel}^1 \leq T_2$, is determined. A percentage of pixels p_2 in the selected region having a temperature T_{pixel}^2 , where $T_3 \leq T_{pixel}^2$, is determined. A ratio $p_3 = P_{edge}/P_{block}$ is also determined, where P_{edge} is a number of pixels around a border of a suspected tumor within the selected region, and P_{block} is a number of pixels in the perimeter of the selected region. In a manner more fully disclosed herein, a decision fusion rule R is then utilized to determine whether tissue within that region is cancerous, non-cancerous, or is suspicious of being cancerous.

Features and advantages of the above-described software interface tool and tumor detection method will become readily apparent from the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other features and advantages of the subject matter disclosed herein will be made apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. 1 shows an example thermal imaging system capturing a thermal image of an area of the breast of a female subject;

FIG. 2 shows one example embodiment of the software interface tool disclosed herein;

FIG. 3 shows one example selected region of interest substantially comprising the right and left breasts of the subject in the image of FIG. 2;

FIG. 4 shows the subject's left breast having been selected as a region of interest;

FIG. 5 shows a region of interest substantially comprising the subject's left breast having been manually selected by a user;

FIG. 6 shows example displayed 2D contour lines of the regions of interest of FIG. 3;

FIG. 7 shows example displayed 2D contour lines of the regions of interest of FIG. 5;

FIG. 8 shows an area of the subject's left breast in the contour image of FIG. 6 having been visually enhanced;

FIG. 9 is a flow diagram which illustrates one example embodiment of a method for detecting tumorous breast tissue using a thermal image; and

FIG. 10 illustrates one embodiment of a functional block diagram of a special purpose computer system for implementing various aspect of the present software interface tool of FIG. 2 and the tumor detection method shown and described with respect to the flow diagram of FIG. 9.

DETAILED DESCRIPTION

What is disclosed is a software interface tool for breast cancer screening and a method for detecting cancerous tissue in a thermal image of a breast.

Non-Limiting Definitions

A "subject" refers to a living being. Although the term "person" or "patient" may be used throughout this disclosure, it should be appreciated that the subject may be something other than a human such as, for example, a primate. Therefore, the use of such terms is not to be viewed as limiting the scope of the appended claims strictly to humans. FIG. 1 shows an example human female patient 102.

A "thermal imaging system" is a camera with a lens that focuses infrared energy from objects in a scene onto an array of specialized sensors which convert infrared energy into electrical signals on a per-pixel basis and outputs a thermal image comprising an array of pixels with color values corresponding to surface temperatures of the objects in the image across a thermal wavelength band. FIG. 1 shows a thermal imaging system 100 capturing a thermal image 101 of a female subject 102 which, in turn, is communicated to a workstation via a wireless transmissive element 103, shown as an antenna. Although the subject in FIG. 1 is female, the subject may be male. The thermal imaging system can be any of: a single-band infrared camera, a multi-band infrared camera in the thermal range, and a hyperspectral infrared camera in the thermal range. Specialized processors inside the thermal camera associate pixel color values with different temperatures and provide output color values of each pixel in the resulting thermal image. The resolution for a thermal camera is effectively the size of the pixel. Smaller pixels mean that more pixels will go into the image for the same region of interest giving the resulting image higher resolution and thus better spatial definition. Because the amount of black-body radiation emitted by an object increases with the object's temperature, variations in temperatures of objects are observable in a thermal image. Thermal cameras generally consist of five primary components: 1) optics comprising specialized focal plane arrays (FPAs) that respond to defined wavelengths of the infrared range of the electromagnetic (EM) spectrum (≈ 7.5 to ≈ 14 μm); 2) a detector for detecting radiation in the infrared range; 3) an amplifier for amplifying the received radiation; 4) a display for viewing the captured images; and 5) signal processing hardware such as: a CPU, memory, storage, for performing mathematical algorithms which interpret data and construct an IR image. Common thermal imaging systems include: InSb, InGaAs, HgCdTe, and QWIP FPA.

Newer technologies utilize an uncooled Microbolometer as FPA sensors. Thermal cameras offer a relatively large dynamic range of temperature settings. However, for the purposes hereof, it is preferable that the camera's temperature range be relatively small centered around subject's body surface temperature so that small temperature variations are amplified in terms of pixel color changes to provide a better measure of temperature variation. The reader is directed to any of a variety of texts on thermal imaging including: *"Infrared Thermal Imaging: Fundamentals, Research and Applications"*, Michael Vollmer, Klaus Peter Möllmann, Wiley-VCH; 1st Ed. (2010) ISBN-13: 978-3527407170, which is incorporated herein in its entirety by reference. A method for enhancing a spatial resolution of a thermal image or a portion thereof, is disclosed in: "Processing A Video For Spatial And Temporal Magnification With Minimized Image Degradation", U.S. patent application Ser. No. 13/708,125, by Mestha et al., which is incorporated herein in its entirety by reference. Thermal cameras are readily available in various streams of commerce. Thermal images are captured using a thermal imaging system.

A "thermal image" is an image captured using a thermal camera. Each thermal image comprises a plurality of pixels with each pixel having an associated corresponding temperature value. A thermal image of a subject's breasts is shown in the visualization screen 201 of FIG. 2. The thermal images are received by the workstation for manipulation by various aspects of the functionality of the software interface disclosed herein. Although the thermal images herein are shown in black/white, it should be appreciated that thermal images are in color.

"Receiving a thermal image" is intended to be widely construed and includes: retrieving, receiving, capturing, acquiring, or otherwise obtaining a thermal image or a video comprising a plurality of thermal images for processing in accordance with the methods disclosed herein. Thermal images can be retrieved from a memory or storage device of the thermal imaging device, or obtained from a remote device over a network. Thermal images may be retrieved from a media such as a CDROM or DVD. Thermal images may be downloaded from a web-based system which makes such images available for processing. Thermal images can also be retrieved using an application such as those which are widely available for handheld cellular devices and processed on the user's cellphone or other handheld computing device such as an iPad or tablet. Thermal images are of a breast area of a subject.

A "breast area of the subject" encompasses tissue of the breast itself and may further include portions of surrounding non-breast tissue as are needed for breast cancer screening and detection. Regions of breast tissue are automatically or manually identified in the thermal image for analysis.

A "software interface tool" is a composite of user-selectable functionality displayed on a display device such as a touchscreen display of a computer workstation. FIG. 2 shows one example embodiment of the present software interface tool 200. Various embodiments of the present software interface tool comprise a visualization screen, a temperature bar, and a plurality of selectable software objects.

A "VISUALIZATION SCREEN" refers to a portion of the software interface tool (shown at 201) wherein at least one thermal image of at least one breast of a subject is displayed.

A "TEMPERATURE BAR" refers to a portion of the present software interface tool (shown at 202) wherein

temperature values which are associated with the various colors comprising the displayed thermal image are shown.

A “selectable software object” refers to a graphical widget which can take a variety of forms such as, for instance, a button, a pull-down menu, a slidable bar, and the like, as are commonly known and widely understood in the software arts. Specialized machine readable/executable program instructions associated with a particular “button” is designed to perform functionality represented by that particular widget. Once selected by a user clicking a mouse thereon or manually touching that particular button on a touch-sensitive display device, causes a central processor unit (CPU) to retrieve those program instructions from memory and execute those instructions.

The “LOAD” object (shown at **203**) is a widget which, when selected, effectuates a display of an infrared image on the visualization screen **201**. Pixels in the image having a highest temperature value are displayed in first color and pixels having a lowest temperature are displayed in second color. Pixels with temperature values between the lowest and highest temperatures are displayed in gradations of color between the first and second colors. Temperature values associated with the displayed colors appear on the temperature bar **202**.

A “2D ISOTHERM” object **204** is a widget which, when selected, effectuates a 2D display of contour lines on the visualization screen **201**. The contour lines circumscribe or “bound” various groups of colored pixels in the image which have substantially similar temperature values.

A “3D ISOTHERM” object **205** is a widget which, when selected, effectuates a 3D display of contour lines on the visualization screen **201** wherein an increasing height of the contour lines is associated with an increase in temperature values of pixels in the displayed thermal image.

A “CROPPING” object **206** enables a user to selectively crop any portion of the displayed thermal image.

A “ZOOMING” object **207** enables a user to enlarge any portion of the displayed image. In one embodiment, zooming is performed using an embodiment of the image enhancement method disclosed in U.S. patent application Ser. No. 13/708,125 entitled: “Processing A Video For Spatial And Temporal Magnification With Minimized Image Degradation”, by Mestha et al. (Allowed Nov. 25, 2014).

A “NORMALIZATION” object **208** normalizes temperatures within an identified region of interest to a highest temperature or, alternatively, to a lowest temperature value.

A “SAVE” object **209** enables the user to save any portion of the displayed image to a memory or storage device.

A “TEXT AREA” at **210** wherein messages are displayed for the user such as, for example, a message indicating a probability that the tissue in the identified region of interest can be categorized as being any of thermal BIRADs category, thermos-biological category, non-cancerous category, suspicious of being cancerous category, and cancerous category.

A “FRAME SLIDER” object **220** enables a user to move forward and backward within a video such that a different image frame is displayed on the visualization screen.

An “ISOTHERM GRADATION” object **221** effectuates the selection of a temperature gradation for the displayed contour lines.

A “GRADATION” object **222** effectuates the selection of a temperature gradation for the displayed contour lines.

A “REGION OF INTEREST (ROI)” object **230** enables either the manual or automatic selection of at least one region of interest in the displayed thermal image. A region of interest can be identified in a thermal image using any of

a wide array of image processing techniques which include, for example, object identification, pattern recognition, pixel classification, color, texture, spatial relationships, and/or spatial features. A region of interest can be manually identified using, for instance, a mouse to draw a rubber-band box around a region of interest. One example region of interest, which substantially comprises the right and left breasts of the subject, is shown at **300** in FIG. 3. FIG. 4 shows the subject’s left breast having been selected as a region of interest. FIG. 5 shows a region of interest substantially comprising the subject’s left breast having been manually selected by a user. Example displayed 2D contour lines of the regions of interest of FIG. 3 are shown in FIG. 6. Example displayed 2D contour lines of the regions of interest of FIG. 5 are shown in FIG. 7. It should be appreciated that, in the absence of a selection of a region of interest, the entire thermal image becomes the region of interest by default.

A “RIGHT BREAST (RB)” object **231** enables the automatic identification of the right breast in the displayed image.

A “LEFT BREAST (LB)” object **232** enables the automatic identification and segmentation of the left breast in the displayed image.

A “RIGHT AXILLA (RA)” object **233** and a “LEFT AXILLA (LA)” object **234** effectuate automatic selection of a right and left regions of interest; specifically adjacent tissues containing lymph nodes.

A “VIEW ANGLE” object **235** enables a user to change a view angle of the displayed thermal image.

A “VISUAL ENHANCEMENT” object **236** enables a region of tissue to be visually enhanced by being displayed prominently in the displayed thermal image by subduing surrounding tissue. FIG. 8 shows an area of the subject’s left breast in the contour image of FIG. 6 having been visually enhanced by highlighting the desired area and subduing areas outside that area.

A “SCREENING” object **237** effectuates the manual or automatic screening of the breast tissue in the identified region of interest for the presence of cancerous tissue, the absence of cancerous tissue, or the suspicion of cancerous tissue. In one embodiment, specialized machine readable/executable program instructions associated with the screening object effectuates a detection protocol which includes any combination of: a histogram distance method, fractal dimensions, texture based, deep learning, machine learning, neural network, bio heat-based, frequency domain based, 2D and 3D.

It should be appreciated that the steps of “determining”, “analyzing”, “identifying”, “receiving”, “processing”, “selecting”, “performing” and the like, as used herein, include the application of various signal processing and mathematical operations applied to data and signals, according to any specific context or for any specific purpose. It should be appreciated that such steps may be facilitated or otherwise effectuated by a microprocessor executing machine readable program instructions retrieved from a memory or storage device.

Flow Chart of Tumor Detection

Reference is now being made to the flow diagram of FIG. 9 which illustrates one example embodiment of a method for detecting tumorous breast tissue using a thermal image. Flow processing starts at steps **900** and immediately proceeds to step **901**.

At step **901**, receive a thermal image of exposed breast skin tissue of a subject being screened for breast cancer. The thermal image has been captured by a thermal imaging

system. The received thermal image can be displayed on the visualization interface by a user having selected the LOAD object **203** of the software interface tool of FIG. 2. One example thermal imaging system is shown and discussed with respect to the example embodiment of FIG. 1. Example thermal images are shown in FIGS. 2-8.

At step **902**, select a region of interest (ROI) in the thermal image. Example selected regions of interest are shown in FIGS. 3-5. A region of interest can be manually or automatically selected by a user selection of the ROI object **230** of the software interface tool of FIG. 2. The following functionality would be implemented in response to a user having selected the SCREENING object **237** of the software interface tool of FIG. 2.

At step **903**, determine a percentage of pixels p_1 within the selected region of interest which have a temperature T_1^{pixel} such that $T_2 \leq T_1^{pixel} \leq T_1$. In this embodiment, $T_1 = T_{max}$ where T_{max} is a maximum temperature of said subject, and $T_2 = [T_1 - 1^\circ \text{C}]$.

At step **904**, determine a percentage of pixels p_2 within the selected ROI with a second temperature T_2^{pixel} such that $T_3 \leq T_2^{pixel} \leq T_2$. In this embodiment, $T_3 = T_{avg} + (T_{max} - T_{avg})/3$, where T_{avg} is an average temperature of the subject.

At step **905**, determining a ratio $p_3 = P_{edge}/P_{block}$, where P_{edge} is a number of pixels around a border of a suspected tumor within the selected region, and P_{block} is a number of pixels in the perimeter of the selected region.

At step **906**, using a decision rule R to determine that tissue within the selected region of interest is one of cancerous, non-cancerous or suspicious of being cancerous.

At step **907**, communicate the determined result to a medical professional. The determination may also be communicated to a memory, a storage device, a display device, a handheld wireless device, a handheld cellular device, and/or a remote device over a network. Thereafter, in this embodiment, further processing stops.

It should also be appreciated that the flow diagrams depicted herein are illustrative. One or more of the operations may be performed in a differing order. Other operations may be added, modified, enhanced, or consolidated. Variations thereof are intended to fall within the scope of the appended claims.

Example Special Purpose Computer

Reference is now being made to FIG. 10 which is a functional block diagram of a special purpose computer system **1000** for implementing various aspect of the present software interface tool of FIG. 2 and the tumor detection method shown and described with respect to the flow diagram of FIG. 9. Such a special purpose processor is capable of executing machine executable program instructions and may comprise any of a micro-processor, micro-controller, ASIC, electronic circuit, or any combination thereof.

In FIG. 10, communications bus **1002** is in communication with a central processing unit (CPU) **1004** capable of executing machine readable program instructions for performing any of the calculations, comparisons, logical operations, and other program instructions for performing any of the steps described above with respect to the flow diagrams and illustrated embodiments hereof. Processor **1004** is in communication with memory (ROM) **1006** and memory (RAM) **1008** which, collectively, constitute example storage devices. Such memory may be used to store machine readable program instructions and other program data and results to sufficient to carry out any of the functionality described herein. Disk controller **1010** interfaces with one or more storage devices **1014** which may comprise external memory,

zip drives, flash memory, USB drives, or other devices such as CD-ROM drive **1012** and floppy drive **1016**. Storage device stores machine executable program instructions for executing the methods hereof. Such storage devices may be used to implement a database wherein various records are stored. Display interface **1018** effectuates the display of information on display **1020** in various formats such as, for instance, audio, graphic, text, and the like. Interface **1024** effectuates a communication via keyboard **1026** and mouse **1028**, collectively a graphical user interface. Such a graphical user interface is useful for a user to enter information about any of the displayed information in accordance with various embodiments hereof. Communication with external devices may occur using example communication port(s) **1022**. Such ports may be placed in communication with any of the example networks shown and described herein, such as the Internet or an intranet, either by direct (wired) link or wireless link. Example communication ports include modems, network cards such as an Ethernet card, routers, a PCMCIA slot and card, USB ports, and the like, capable of transferring data from one device to another. Software and data is transferred via the communication ports in the form of signals which may be any of digital, analog, electromagnetic, optical, infrared, or other signals capable of being transmitted and/or received by the communications interface. Such signals may be implemented using, for example, a wire, cable, fiber optic, phone line, cellular link, RF, or other signal transmission means presently known in the arts or which have been subsequently developed.

The teachings hereof can be implemented in hardware or software using any known or later developed systems, structures, devices, and/or software by those skilled in the applicable art without undue experimentation from the functional description provided herein with a general knowledge of the relevant arts. Moreover, the methods hereof can be implemented as a routine embedded on a personal computer or as a resource residing on a server or workstation, such as a routine embedded in a plug-in, a driver, or the like. The teachings hereof may be partially or fully implemented in software using object or object-oriented software development environments that provide portable source code that can be used on a variety of computer, workstation, server, network, or other hardware platforms. One or more of the capabilities hereof can be emulated in a virtual environment as provided by an operating system and other specialized programs such Windows or Java.

One or more aspects of the teaching disclosed herein are intended to be incorporated in an article of manufacture, including one or more computer program products, having computer usable or machine readable media. The article of manufacture may be included on at least one storage device readable by a machine architecture embodying executable program instructions capable of performing the methods described herein. The article of manufacture may be shipped, sold, leased, or otherwise provided separately either alone or as part of an add-on, update, upgrade, or product suite.

It will be appreciated that the above-disclosed and other features and functionality, or alternatives thereof, may be desirably combined into many other different systems or applications. As such, various presently unforeseen or unanticipated alternatives, modifications, variations, or improvements therein may become apparent and/or subsequently made by those skilled in the art which are also intended to be encompassed by the following claims. Accordingly, the embodiments set forth above are illustrative and not limit-

ing. Changes to the above-described embodiments may be made without departing from the spirit and scope of the invention.

The teachings of any printed publications including patents and patent applications, are each separately hereby incorporated by reference in their entirety.

What is claimed is:

1. One or more non-transitory computer readable storage mediums storing one or more sequences of instructions for causing a computing device to perform a method for breast cancer screening and detection, said method comprising: receiving a thermal video of a subject's breast captured in different views, wherein said thermal video is captured using a thermal imaging camera by focusing, using a lens of said thermal imaging camera, infrared energy from said subject's breast onto an array of sensors of said thermal imaging camera, wherein said array of sensors detect temperature values from said subject's breast; converting, using said array of sensors, said infrared energy into electrical signals on a per-pixel basis; and generating, using a specialized processor of said thermal imaging camera, said thermal video comprising an array of pixels with color values corresponding to surface temperatures of said subject's breast across a thermal wavelength band, wherein said generating of said thermal video comprising associating a first color value for a first set of pixel having highest temperature values and a second color value for a second set of pixel having lowest temperature values and providing output color values of each pixel in said thermal video; providing a visualization screen where said thermal video of said subject's breast is displayed, wherein pixels in said thermal video having a highest temperature value being displayed in a first color and pixels having a lowest temperature value being displayed in a second color, pixels with temperature values between said lowest and highest temperature values being displayed in gradations of color between said first and second colors; selecting a frame of said thermal video to obtain a thermal image to display in said visualization screen; implementing an automatic segmenting technique to identify a region of interest in said thermal image of said thermal video; implementing an automatic tumor detection method to detect cancerous tissue and non-cancerous tissue within selected said region of interest, wherein said automatic tumor detection method comprises: determining a percentage of pixels p_1 within said selected region of interest with a temperature T_1^{pixel} , where $T_2 \leq T_1^{pixel} \leq T_1$; determining a percentage of pixels p_2 within said selected region of interest with a temperature T_2^{pixel} , where $T_3 \leq T_2^{pixel}$; determining a ratio $p_3 = P_{edge} / P_{block}$, where P_{edge} is a number of pixels around a border of a suspected tumor within said region of interest, and P_{block} is a number of pixels in the perimeter of said region of interest; and determining, using a decision rule R, said tissue within said region of interest is one of: said cancerous tissue, said non-cancerous, or suspicious of being cancerous; and

displaying, in said visualization screen, pixels of said thermal image representing said cancerous tissue in said first color, and pixels of said thermal image representing said non-cancerous in said second color.

2. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises displaying of any combination of: 2D and 3D contour lines in said thermal image displayed on said visualization screen, wherein said 2D and 3D contour lines circumscribe various groups of colored pixels in said thermal image which have substantially similar temperature values.

3. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 2, wherein said method comprises providing an isotherm gradation object which enables isotherms to be displayed at a selected resolution.

4. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises providing a view angle object which enables a user to change a view angle of said thermal image displayed on said visualization screen along with a marking of said cancerous tissue.

5. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein, in response to said thermal image displayed on said visualization being a single image frame of said thermal video, said method comprises providing a frame slider object which enables a user to move forward and backward within said thermal video such that a different image frame is displayed on said visualization screen along with a marking of said cancerous tissue.

6. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises providing a region of interest (ROI) object which enables automatic selection of said region of interest, wherein said region of interest (ROI) object enables a user to direct an image segmentation technique to identify at least a portion of said breast in said displayed thermal image.

7. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises providing any of: a right breast identification object, a left breast identification object, a right axilla region identification object, and a left axilla region identification object.

8. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises providing a cropping object which enables a user to selectively crop any portion of said displayed thermal image.

9. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises providing a zooming object which enables a user to enlarge any portion of said displayed thermal image.

10. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 9, wherein zooming is performed via an image super-resolution method.

11. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises providing a normalization object which normalizes temperature display colors within said region of interest to have a value between said highest and lowest temperature values.

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12. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises providing a temperature bar for displaying temperature values associated with colors displayed on said visualization screen.

13. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises providing a visual enhancement object which enables a region of tumorous tissue to be visually enhanced in said thermal image by subduing surrounding non-tumorous tissue.

14. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said automatic tumor detection method detects at least one tumor if present in said displayed thermal image.

15. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said automatic tumor detection method further comprises any of: a histogram distance, fractal dimensions, texture based, deep learning, machine learning, neural network, bio heat-based, and frequency domain based techniques.

16. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises segmenting said region of interest using any combination of: region splitting and merging based segmentation, region growing segmentation, watershed segmentation, threshold based segmentation, edge based segmentation, and manual-based segmentation, said automatic tumor detection method being performed on at least one of said segmented regions.

17. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said decision rule R is based on any combination of R_1 , R_2 , R_3 , where: $R_1=(p_1>\text{Threshold}_1)$, $R_2=(p_2>\text{Threshold}_2)$, and $R_3=(p_3>\text{Threshold}_3)$.

18. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 17, wherein Threshold_1 , Threshold_2 , $\text{Thresh-$

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old₃ comprise user-defined threshold values based on any combination of: tumor characteristics, subject age, race, sex, and medical history.

19. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 17, where said decision rule, R, comprises any of: a majority rule of (R_1 , R_2 , R_3), and a weighted stun of (R_1 , R_2 , R_3).

20. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 17, wherein $T_3=T_{avg}+(T_{max}-T_{avg})/3$, where T_{max} is a maximum temperature of said subject, and T_{avg} is an average temperature of said subject.

21. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein said method comprises communicating any of said determinations to any of: a medical staff, a medical data repository, a memory, a storage device, a display device, a handheld wireless device, a handheld cellular device, and a remote device over a network.

22. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein, in response to having performed screening, said method comprises displaying said pixels p_1 , said pixels p_2 , and said ratio p_3 with a message indicating a probability that tissue in said region of interest can be categorized as being in any category of: thermal BIRADs category, thereto-biological category, non-cancerous category, suspicious of being cancerous category, and cancerous category.

23. The one or more non-transitory computer readable storage mediums storing one or more sequences of instructions of claim 1, wherein, in response to a determination that tissue in said region of interest is cancerous, said method comprises performing any of: initiating an alert, and signaling a medical professional.

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摘要(译)

所公开的是一种用于乳腺癌筛查的软件界面工具，其被设计用于医疗专业人员查看和分析可疑区域的热点，并因此有助于确定所识别的乳房组织区域是否是癌性的。等温线图以指定的温度分辨率构建。地图显示在屏幕上。点击等温线图可以提取等温线轮廓覆盖区域内像素的温度值。还提供了在不同视角下的等温视图，这对于视觉检测是有利的。本软件界面还支持用于热点选择，裁剪，缩放，以不同角度观看等的附加功能。本软件界面还利用了本文还公开的肿瘤检测方法。

