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Ultrasound diagnostic apparatus and ultrasound image processing method

Abstract

A mark that identifies a lesion site is displayed on a tomographic image. A two-dimensional map and a graph are displayed regardless of whether or not the mark is displayed. The two-dimensional map represents lesion site probability distribution. The graph represents temporal change of lesion site probabilities.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION
(1) This application claims priority to Japanese Patent Application No. 2021-204742 filed on Dec. 17, 2021, which is incorporated herein by reference in its entirety including the specification, claims, drawings, and abstract.
TECHNICAL FIELD
(2) The present disclosure relates to an ultrasound diagnostic apparatus and an ultrasound image

processing method and, in particular, relates to information generation and presentation for assisting with ultrasound inspection.

BACKGROUND

(3) When performing ultrasound inspection (ultrasonic examination) using an ultrasound diagnostic apparatus, an inspector observes an ultrasound image and simultaneously operates a probe (ultrasound probe). If a lesion site (to be more precise, a lesion site candidate), such as a tumor, appears in the ultrasound image, that lesion site is examined carefully.

(4) Some ultrasound diagnostic apparatuses have a function of automatically detecting a lesion site that has appeared in an ultrasound image and providing notification of the detected lesion site. This function is referred to as CADe (Computer Aided Detection). The CADe technique belongs to or is associated with CAD (Computer Aided Detection and Diagnosis). Typically, while CADe is being performed, a lesion site probability (such as a lesion site score or a lesion site similarity) is calculated, and a shape (mark) enclosing the lesion site is displayed when the lesion site probability exceeds a threshold value. No mark is displayed when the lesion site probability does not exceed the threshold value. Using a threshold value in this manner to control whether or not to display a mark avoids occurrence of a situation in which a mark is frequently displayed on an ultrasound image, or avoids occurrence of a situation in which multiple marks are displayed on an ultrasound image.

(5) Patent Document 1 (JP 2020-28680 A) discloses an ultrasound diagnostic apparatus that has an object detection function. Patent Document 1 does not disclose a technique of displaying spatial distribution of lesion site probabilities or temporal change of lesion site probabilities in the form of a dynamic image.

SUMMARY

(6) Although displaying a mark that provides notification of a lesion site on an ultrasound image enables the inspector to recognize that the lesion site is detected, spatial distribution of lesion site probabilities or temporal change of lesion site probabilities cannot be recognized through that mark. As no mark is displayed when the lesion site probability does not exceed the threshold value, even if something resembling a lesion site is actually detected, information indicative of it is not presented to the inspector. In addition to displaying a mark that provides notification of a lesion site, displaying more detailed information regarding the lesion site in an auxiliary manner is desired.

(7) The present disclosure is directed toward assisting an inspector with probe operation or image observation. In other words, the present disclosure is directed toward displaying, along with a mark, inspection assistance information that is different from the mark. Alternatively, the present disclosure is directed toward providing an inspector with auxiliary information for evaluating a lesion site.

(8) According to one aspect of the present disclosure, there is provided an ultrasound diagnostic apparatus comprising a detector unit configured to perform detection processing for detecting a lesion site in an ultrasound image; a mark generator unit configured to generate a mark based on output information from the detector unit, the mark providing notification of the lesion site; a reference information generator unit configured to generate reference information based on the output information as inspection assistance information that is different from the mark, the reference information representing at least one of spatial distribution of lesion site probabilities and temporal change of lesion site probabilities; and a display configured to display the ultrasound image, the mark, and the reference information in real time.

(9) According to another aspect of the present disclosure, there is provided an ultrasound image processing method comprising performing detection processing for detecting a lesion site in an ultrasound image; generating a mark based on output information that represents a result of execution of the detection processing, the mark providing notification of the lesion site; generating reference information based on the output information as inspection assistance information that is

different from the mark, the reference information representing at least one of spatial distribution of lesion site probabilities and temporal change of lesion site probabilities; and displaying the ultrasound image, the mark, and the reference information in real time.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) Embodiments of the present disclosure will be described based on the following figures, wherein:
(2) FIG. **1** is a block diagram illustrating an ultrasound diagnostic apparatus according to an embodiment of the present disclosure;
(3) FIG. **2** illustrates an example of a display image;
(4) FIG. **3** is a conceptual illustration of detection processing and some associated steps of processing;
(5) FIG. **4** illustrates a first example of a map generation method;
(6) FIG. **5** illustrates a second example of a map generation method;
(7) FIG. **6** is an illustrative diagram of color conversion;
(8) FIG. **7** illustrates a modification example of a graph; and
(9) FIG. **8** illustrates an alternative example of a display image.
DESCRIPTION OF EMBODIMENTS
(10) Embodiments of the present disclosure will be described below with reference to the accompanying drawings.
(1) Overview of Embodiments
(11) An ultrasound diagnostic apparatus according to an embodiment of the present disclosure includes a detector unit, a mark generator unit, a reference information generator unit, and a display. The detector unit performs detection processing for detecting a lesion site in an ultrasound image. The mark generator unit generates a mark based on output information from the detector unit, the mark providing notification of the lesion site. The reference information generator unit generates reference information based on the output information as inspection assistance information that is different from the mark, the reference information representing at least one of spatial distribution of lesion site probabilities and temporal change of lesion site probabilities. The display displays the ultrasound image, the mark, and the reference information in real time.
(12) With the above-described structure, in addition to the mark, the reference information is displayed as inspection assistance information. In an embodiment, the reference information is displayed regardless of whether or not the mark is displayed. Through the observation of the reference image, an inspector can obtain more detailed information regarding a current inspection target (current ultrasound diagnosis target). This enables assistance in careful examination of a lesion site or enables verification of adequacy of mark display. The content of the ultrasound image can be evaluated even under circumstances where no mark is displayed.
(13) In an embodiment, the ultrasound image is a video image (moving image) that shows a current inspection target. A mark is displayed upon detection of a lesion site that satisfies a certain condition. The reference information is a reference image which indicates a response of the detector unit to the current inspection target, and which is a continuously displayed video image. As described above, the ultrasound image, the mark, and the reference information are displayed in real time during ultrasound inspection.
(14) Many items of information or various types of information displayed on the ultrasound image may hinder observation of the ultrasound image. However, presentation of more detailed information other than the mark is needed in order to evaluate the current inspection target in a comprehensive manner or in multiple manners. Therefore, in an embodiment, the mark is displayed

on the ultrasound image, and the reference information is displayed in the vicinity of the ultrasound image.

(15) In an embodiment, the reference information generator unit includes a map generator unit that generates, as the reference information, a two-dimensional map that represents spatial distribution of lesion site probabilities. A lesion site can be evaluated in detail through the observation of the two-dimensional map. A site for which notification is not provided can also be evaluated.

(16) In an embodiment, when the output information includes first information that satisfies a mark display condition and second information that does not satisfy the mark display condition, the mark generator unit generates the mark based on the first information, and the map generator unit generates the two-dimensional map based on the first information and the second information. Typically, the mark is displayed intermittently. On the other hand, the two-dimensional map is displayed continuously.

(17) In an embodiment, the reference information generator unit includes a graph generator unit that generates, as the reference information, a graph that represents temporal change of lesion site probabilities. Reference to the graph enables recognition of a lesion site detection frequency or facilitates searching for a lesion site. A plurality of graphs corresponding to a plurality of objects or a plurality of classes may be displayed.

(18) In an embodiment, the graph generator unit identifies, for each frame, a representative value of lesion site probabilities in the frame and generates a graph based on a plurality of representative values identified from a plurality of frames. For example, a representative value for each frame is a maximum value. The frames are reception frames or display frames.

(19) In an embodiment, the mark generator unit generates a mark when the output information satisfies a mark display condition. The mark display condition includes a condition that requires that the lesion site probability identified from the output information exceeds a threshold value. The graph includes a display element that represents the threshold value. The graph generator unit changes the display element in accordance with a change in the threshold value. With this structure, the threshold value can be set with reference to a plurality of representative values.

(20) In an embodiment, the reference information generator unit includes a map generator unit and a graph generator unit. The map generator unit generates a two-dimensional map that represents spatial distribution of lesion site probabilities. The graph generator unit generates a graph that represents temporal change of lesion site probabilities. The reference information includes the two-dimensional map and the graph. With this structure, the inspector's probe operation and image observation can be assisted in a comprehensive manner or in multiple manners.

(21) An ultrasound image processing method according to an embodiment of the present disclosure includes a detection step, a mark generation step, a reference information generation step, and a display step. In the detection step, detection processing for detecting a lesion site in an ultrasound image is performed. In the mark generation step, a mark that provides notification of the lesion site is generated based on output information that represents a result of execution of the detection processing. In the reference information generation step, reference information that represents at least one of spatial distribution of lesion site probabilities and temporal change of lesion site probabilities is generated based on the output information as inspection assistance information that is different from the mark. In the display step, the ultrasound image, the mark, and the reference information are displayed in real time.

(22) The above-described ultrasound image processing method is implemented as software functions or as hardware functions. A program for performing the above-described ultrasound image processing method may be installed onto an information processing apparatus over a network or through a portable storage medium. The concept of the information processing apparatus encompasses an ultrasound diagnostic apparatus, a medical system, a computer, and others. The information processing apparatus includes a non-transitory storage medium.

(2) Details of Embodiments

(23) FIG. **1** illustrates an ultrasound diagnostic apparatus according to an embodiment of the present disclosure. The ultrasound diagnostic apparatus is a medical apparatus for performing ultrasound inspection on a subject (living body) in a healthcare facility or elsewhere. An ultrasound diagnostic apparatus according to an embodiment of the present disclosure has a CADe function, as will be described in detail later; that is, the function of automatically detecting a lesion site included in a tomographic image to provide notification of the lesion site using a mark.

(24) Referring to FIG. **1**, a probe **10** is a device for transmitting ultrasound waves to a living body and receiving reflected waves from the living body. More specifically, the probe **10** is composed of a probe head, a cable, and a connector. The probe head is held by an inspector. The probe head is the main component of the probe **10**, and in the following description, the probe head is simply referred to as the probe **10**.

(25) The probe **10** includes a transducer array that consists of a plurality of transducers. An ultrasound beam **11** is formed by the transducer array, and the ultrasound beam **11** is electronically scanned. Examples of known electronically scanning methods include an electronic linear scanning method and an electronic sector scanning method. A scanning plane **12** is formed by electronically scanning the ultrasound beam **11**. The scanning plane **12** is repeatedly formed by repeatedly electronically scanning the ultrasound beam **11**. The probe **10** may include a two-dimensional transducer array to obtain volume data from a living body.

(26) A transmitter receiver unit **13** supplies a plurality of transmission signals to the transducer array in parallel with each other during transmission. A transmission beam is formed in this manner. During reception, the transmitter receiver unit **13** performs processing of a plurality of reception signals that are output from the transducer array in parallel with each other. The processing performed here includes A/D conversion processing, phase alignment and summation (delay and summation), and others.

(27) As a result of the processing of the plurality of reception signals, reception beam data are generated. A plurality of sets of reception beam data which are successive in the electronic scanning direction constitute a set of reception frame data. A plurality of sets of reception frame data which are successive on a time axis constitute a reception frame data array. Each set of reception beam data is composed of a plurality of sets of echo data which are successive in the depth direction.

(28) An image former unit **14** is a module that generates a display frame data array based on the reception frame data array. The image former unit **14** has a coordinate conversion function, a pixel interpolation function, a frame rate adjustment function, and other functions. Specifically, the image former unit **14** is composed of a digital scan converter (DSC). Each set of display frame data corresponds to a tomographic image serving as a still-frame image, and the display frame data array corresponds to a tomographic image serving as a video image. An ultrasound image other than a tomographic image may be formed. In an embodiment, the display frame data array is transmitted to a display processor unit **18** and is transmitted to a lesion site detector unit **22**. As indicated by reference numeral **23**, the reception frame data array may be transmitted to the lesion site detector unit **22**.

(29) The reception frame data array may be temporarily stored in a memory **16**. Similarly, the display frame data array may be temporarily stored in a memory **20**. Each of the memory **16** and the memory **20** serves as a cine memory with a ring buffer structure. In a freeze state (transmission and reception suspend state) after the real-time operation, the frame data arrays stored in the memory **16** and the memory **20** are read.

(30) The lesion site detector unit **22** is composed of a machine learning object detector. Specifically, the lesion site detector unit **22** includes an object detection network (object detection model) such as a CNN, and the object detection network has a plurality of layer sections that are provided in series. The plurality of layer sections perform a plurality of detection steps stepwise. Each of the layer sections includes one or a plurality of convolutional layers and optionally

includes one or a plurality of pooling layers. The plurality of detection steps constitute a series of detection processing. Examples of known object detection networks include R-CNN (Regional CNN), SSD (Single Shot MultiBox Detector), M2Det, and YOLO.

(31) In response to input of one tomographic image to the lesion site detector unit **22**, output information that is reflective of a feature amount of that tomographic image is generated. The output information represents a lesion site detection result. The output information is transmitted to a postprocessor unit **24** and a map generator unit **30**.

(32) The postprocessor unit **24** performs maximum value determination processing and threshold value processing for each display frame. The output information is information that represents spatial distribution of lesion site probabilities. That is, the output information includes a plurality of lesion site probabilities (lesion site scores) that are arrayed two-dimensionally. The maximum value determination processing determines a maximum value in the plurality of lesion site probabilities. The threshold value processing compares the determined maximum value with a threshold value. When the maximum value exceeds the threshold value, it is determined that a mark that indicates detection of a lesion site is to be displayed. When the maximum value does not exceed the threshold value, no mark is displayed.

(33) The postprocessor unit **24** may apply removal processing. For example, the removal processing may reject a falsely detected lesion site. The maximum value that is determined in the maximum value determination processing is transmitted to a graph generator unit **28**. The maximum value that has been subjected to the threshold value processing is transmitted to a mark generator unit **26**.

(34) When the mark display condition is satisfied (that is, when the maximum value exceeds the threshold value), the mark generator unit **26** generates, as a mark, a rectangular box enclosing the lesion site based on cell information corresponding to the maximum value. The mark is a graphic element. An image that represents the mark is transmitted to the display processor unit **18**. The mark may be always generated to allow the mark to be actually rendered upon determination that the lesion site is to be displayed. In either case, the mark appears on the screen when the mark display condition is satisfied.

(35) The map generator unit **30** generates, for each display frame, a two-dimensional map (two-dimensional color map) that represents spatial distribution of lesion site probabilities based on the output information. A plurality of two-dimensional maps corresponding to a plurality of display frames that are successive in chronological order constitute a two-dimensional map serving as a video image. Information that represents a two-dimensional map serving as a video image is transmitted to the display processor unit **18**. This two-dimensional map is a video image corresponding to a tomographic image serving as a video image, and serves as a first reference image that assists with ultrasound inspection.

(36) The graph generator unit **28** generates a graph based on a plurality of maximum values that are successive in chronological order. This graph is a video image representing temporal change of lesion site probabilities, and serves as a second reference image that assists with ultrasound inspection. The plurality of maximum values are a plurality of representative values that are representative of the plurality of two-dimensional maps. A plurality of representative values other than the plurality of maximum values may be used. For example, a plurality of average values may be used. Data that represents the generated graph are transmitted to the display processor unit **18**.

(37) The graph generated by the graph generator unit **28** includes a plurality of bars that represent the plurality of maximum values, and a line that represents a threshold value. Information that represents a currently set threshold value is transmitted to the postprocessor unit **24** and the graph generator unit **28** from a controller unit **34**, which will be described later.

(38) The display processor unit **18** has an image combiner function, a color calculator function, and other functions. The display processor unit **18** generates a display image that is to be displayed on the screen of a display **32**. The display image includes a tomographic image serving as an

ultrasound image, a mark that is to be superimposed upon the tomographic image, a two-dimensional map serving as the first reference image, and a graph serving as the second reference image. Each of the tomographic image, the mark, the two-dimensional map, and the graph corresponds to a video image that shows information regarding a current inspection target in real time. In the freeze state, the tomographic image, the mark, the two-dimensional map, and the graph may be displayed in the form of a video image or a still-frame image.

(39) The controller unit **34** is composed of a processor (such as a CPU) that executes a program. The controller unit **34** controls the operation of the components illustrated in FIG. **1**. Each of the image former unit **14**, the display processor unit **18**, the lesion site detector unit **22**, the postprocessor unit **24**, the mark generator unit **26**, the graph generator unit **28**, and the map generator unit **30** may be composed of a processor or may be implemented as a function that is performed by, for example, a CPU.

(40) An operation panel **36** is an input device, which includes a plurality of switches, a plurality of knobs, a keyboard, a trackball, and others. The operation panel **36** is used to set the above-described threshold value. The display **32** is composed of, for example, a liquid crystal display or an organic EL display device.

(41) FIG. **2** illustrates an example of a display image. A display image **40** is displayed on the display screen and includes a tomographic image **42**, a two-dimensional map **44**, a graph **46**, and others.

(42) The tomographic image **42** is a black-and-white image, and a mark **48** that is in the form of a color graphic is superimposed upon the tomographic image **42**. In the illustrated example, the tomographic image **42** has a horizontal axis that corresponds to the electronic scanning direction and a vertical axis that corresponds to the depth direction. At the present time, the tomographic image **42** includes a lesion site (specifically, a cross-sectional image of a tumor) **50**, and the mark **48** encloses the lesion site **50**. Any shape may be used as the mark **48**, but the form and the size of the mark **48** are set so as not to hinder observation of the lesion site. The content of the tomographic image **42** changes significantly in accordance with change in the position and the orientation of the probe. A two-dimensional blood flow image may be combined and displayed on the tomographic image **42**.

(43) The two-dimensional map **44** represents lesion site probability distribution in a two-dimensional space. The two-dimensional map **44** has a coordinate system corresponding to the coordinate system of the tomographic image **42**. In the two-dimensional map **44**, the horizontal axis corresponds to the electronic scanning direction, and the vertical axis corresponds to the depth direction. The two-dimensional map **44** shows a scanning plane that is the same as the scanning plane shown by the tomographic image **42**. The two-dimensional map **44** is smaller in size than the tomographic image **42**, and the two-dimensional map **44** corresponds to a scaled-down image of the tomographic image **42**. The two-dimensional map **44** expresses spatial change of lesion site probabilities by the change of hue. Reference numeral **51** denotes a hue-changed portion that corresponds to the lesion site **50** in the tomographic image **42**. The two-dimensional map **44** is a video image, and its content changes dynamically in accordance with change in the position and the orientation of the probe.

(44) The tomographic image **42** has depth tick marks **56** along the vertical axis. Correspondingly, the two-dimensional map **44** also has depth tick marks **58** along the vertical axis.

(45) In the illustrated example, the two-dimensional map **44** is displayed on the right side of the tomographic image **42**, but it may be displayed on the left side of the tomographic image, above the tomographic image, or below the tomographic image. For convenience in simultaneous observation of the tomographic image **42** and the two-dimensional map **44**, they are preferably displayed on the same screen to present the two-dimensional map in the vicinity of the tomographic image **42** so as not to overlap the tomographic image **42**.

(46) A color bar **52** is displayed in the vicinity of the two-dimensional map **44**. The color bar **52** is a

color sample that represents change of hue corresponding to change of lesion site probabilities. In the illustrated example, the color bar **52** is displayed in a manner to have the longitudinal direction of the color bar **52** oriented to be parallel to the horizontal direction. The left end of the color bar **52** corresponds to a lesion site probability of 0.0, and the right end of the color bar **52** corresponds to a lesion site probability of 1.0 (refer to reference numeral **54**). A line **55** that represents a currently set threshold value is displayed on the color bar **52**. The color bar **52** may also be displayed in a manner in which the longitudinal direction of the color bar **52** is oriented parallel to the vertical direction. In FIG. **2**, as the threshold value is changed, the line **55** moves accordingly in the horizontal direction.

(47) The graph **46** represents temporal change of lesion site probabilities. In the graph **46**, the horizontal axis corresponds to the time axis, and the vertical axis represents the lesion site probability. The graph **46** is composed of bars **60** that are generated for each display frame, the heights of the bars **60** representing lesion site probabilities. Specifically, the height of each bar **60** represents a maximum value of lesion site probabilities in the display frame. Bars may be displayed at certain time intervals, or maximum values smoothed in the time axis direction may be expressed in the form of a curve. An indicator **62** represents the present time. Although the indicator **62** is displayed at a fixed position, it may be displayed at a position that scans in the horizontal direction.

(48) In addition to a plurality of bars **60**, the graph **46** includes a threshold value line **64**. The threshold value line **64** represents threshold values that are set at respective times. An indicator **66** represents a current threshold value. When the threshold value is changed using the operation panel, the indicator **66** moves accordingly in the vertical direction. The indicator **66** itself can also be operated, and the threshold value may be changed by moving the indicator **66** in the vertical direction.

(49) In the illustrated display example, a body mark **68** is displayed below the two-dimensional map **44**, and a probe mark **70** is also displayed. In an embodiment, diagnosis target organs are breasts, and the body mark **68** schematically illustrates a breast.

(50) Displaying the two-dimensional map **44** and the graph **46** in real time together with a tomographic image including the mark **48** allows the inspector to evaluate a lesion site in a comprehensive manner or in multiple manners. For example, the observation of the two-dimensional map **44** enables recognition of detailed probability distribution regarding a lesion site for which the mark **48** provides notification, or enables recognition of the presence of another lesion site that does not satisfy the mark display condition. The observation of the graph **46** enables recognition of a lesion site detection frequency, which can be used to aid in the probe operation. It is also easy to recognize the occurrence of a lesion site for which notification is not provided.

(51) FIG. **3** schematically illustrates lesion site detection processing and some associated steps of processing. The lesion site detector unit **22** performs detection processing that consists of a plurality of detection steps. Referring to FIG. **3**, the plurality of detection steps are performed in a plurality of layer sections that are successive in chronological order. The plurality of layer sections correspond to a learned network.

(52) Specifically, FIG. **3** illustrates a plurality of layer sections including layer sections L**1** to L**5**. Each layer section includes one or a plurality of convolution layers and optionally includes one or a plurality of pooling layers.

(53) The layer section L**1** is an input layer section, to which a tomographic image **76** serving as an input image is input. In the illustrated example structure, the plurality of layer sections includes a number M of output layer sections. A number M of output maps **78-1** to **78**-M are output from the number M of output layer sections. M is an integer of 1 or greater, and M may be, for example, 2 or 3. The number M of output maps **78-1** to **78**-M constitute output information **77**. The output maps **78-1** to **78**-M exhibit responses that are different from each other depending on the lesion site size. The output map **78-1** gives a large response to a lesion site having a large size, and therefore tends to show a result of detection of a lesion site having a large size. The output map **78**-M gives a large

response to a lesion site having a small size, and therefore tends to show a result of detection of a lesion site having a small size. Each of the output maps **78-1** to **78**-M is composed of a plurality of cells **79-1** to **79**-M that are arrayed two-dimensionally. Each of the cells **79-1** to **79**-M has cell information that is associated with specific coordinates.

(54) An example of cell information is given in the upper right of FIG. **3**. The illustrated cell information **80** includes, for example, an X coordinate **82** and a Y coordinate **84** that identify center coordinates of a detected lesion site, information **86** that represents a horizontal width W of the detected lesion site, information **88** that represents a height (vertical width) H of the detected lesion site, an object score (OS) **90** that represents a probability that the lesion site falls under a specific class, and others. A number n of sets of cell information corresponding to a number n of classes may be generated for each cell.

(55) The postprocessor unit **24** includes a maximum value determination unit **72** and a threshold value processing unit **74**. The maximum value determination unit **72** identifies, for each display frame, a maximum object score in the output information **77** (that is, the plurality of output maps **78-1** to **78**-M) as a maximum value. The threshold value processing unit **74** compares the identified maximum value with a threshold value. When the maximum value exceeds the threshold value, the mark generator unit **26** generates a mark. When the maximum value does not exceed the threshold value, no mark is generated. Instead of the maximum value determination, processing to determine a number K of highest object scores may be performed. In that case, a maximum number K of marks are generated simultaneously based on the number K of highest object scores. K is an integer of 2 or greater. Note that a graph is generated by referring to maximum values.

(56) The graph generator unit **28** renders a maximum value for each display frame in the form of a bar and does this repeatedly, thereby generating a graph. Instead of a graph that shows a plurality of maximum values in chronological order, a graph that shows a plurality of average values in chronological order may be generated. A graph that shows maximum values may be subjected to moving average processing and other processing. The generated graph may also include a bar that represents a maximum value that does not satisfy the mark display condition.

(57) In the example shown in FIG. **3**, the output information **77** (that is, the plurality of output maps **78-1** to **78**-M) is transmitted to the map generator unit **30** without being processed. In an embodiment, the map generator unit **30** generates a two-dimensional map based on the output information **77**. Specifically, an object score; that is, a lesion site probability retrieved from each cell, is converted to a color. Colors obtained by the conversion are mapped in a two-dimensional space. The plurality of output maps **78-1** to **78**-M have sizes that are different from each other, but they have a common coordinate system. The colors are mapped to the common coordinate system. Part of the output information **77** may serve as a target to be mapped.

(58) When the output information **77** includes information (first information) that satisfies the mark display condition and information (second information) that does not satisfy the mark display condition, the mark generator unit **26** generates a mark based only on the information (first information) that satisfies the mark display condition (a maximum value condition and a threshold value condition). In that case, however, the map generator unit **30** generates a two-dimensional map based on both the information (first information) that satisfies the mark display condition and the information (second information) that does not satisfy the mark display condition. The graph generator unit **28** generates a graph based only on information that satisfies the maximum value condition.

(59) Note that the plurality of output maps **78-1** to **78**-M may be generated using feature maps **92** and **94** that are retrieved from some points during the detection processing.

(60) FIG. **4** illustrates a first generation example of the two-dimensional map. Referring to intermediate information **100**, in the illustrated example, a lesion site is detected at each of two coordinate points **102** and **104**. In practical cases, lesion sites are detected at, for example, tens or hundreds of coordinate points in one display frame.

(61) The lesion site probability at the coordinate point **102** is (0.8), and the lesion site probability at the coordinate point **104** is (0.4). The size of the lesion site detected at the coordinate point **102** is indicated by reference numeral **102**A, and the size of the lesion site detected at the coordinate point **104** is indicated by reference numeral **104**A.

(62) In the first generation example, lesion site probabilities are converted to color codes. For example, the lesion site probability (0.8) at the coordinate point **102** is converted to a color code (**204**), and the lesion site probability (0.4) at the coordinate point **104** is converted to a color code (**120**). Reference numeral **106** denotes information obtained after the conversion. A two-dimensional map **108** is generated by mapping a color (an R value, a G value, and a B value) corresponding to each color code in a two-dimensional space. Scale-down processing and scale-up processing may be performed in the process of generating the two-dimensional map **108**. Interpolation processing or smoothing processing may be applied after the color mapping.

(63) FIG. **5** illustrates a second generation example of the two-dimensional map. The intermediate information **100**, which is already described, is processed as follows. A local area **102**B having certain dimensions is defined based on the size **102**A that is identified at the coordinate point **102**, and similarly, a local area **104**B having certain dimensions is defined based on the size **104**A that is identified at the coordinate point **104**. The local areas **102**B and **104**B may be generated by, for example, scaling down the sizes **102**A and **104**A.

(64) The lesion site probability (0.8) at the coordinate point **102** is converted to a color code (**204**), and the color code is assigned to the entire local area **102**B. Similarly, the lesion site probability (0.4) at the coordinate point **104** is converted to a color code (**120**), and the color code is assigned to the entire local area **104**B. Based on information **110** configured as described above, a two-dimensional map **112** is generated by mapping a color (an R value, a G value, and a B value) corresponding to each color code in a two-dimensional space.

(65) In the second generation example, the sizes **102**A and **104**A may be used as the local areas **102**B and **104**B without being processed.

(66) FIG. **6** illustrates an example of color conversion. Reference numeral **114** denotes a color conversion function set. Specifically, the color conversion function set **114** is composed of a B conversion function **118**B, a G conversion function **118**G, and an R conversion function **118**R. The horizontal axis represents the color index, which corresponds to the lesion site score. The vertical axis represents the relative luminance. FIG. **6** illustrates a color bar **116** that expresses colors defined by respective color indices. The color conversion function set **114** illustrated in FIG. **6** is given merely by way of example, and various types of color conversion function sets; that is, various types of color bars, may be used. The lesion site score can also be expressed by grayscale.

(67) FIG. **7** illustrates a modification example of a graph. A graph **120** is composed of a plurality of bars that represent lesion site probabilities. An index **122** represents the current time. There is a step in a threshold value line **126**. The step represents a change in threshold value. A portion **126**B, which is temporally older than the step, indicates a relatively high threshold value, and a portion **126**A, which is temporally newer than the step, indicates a relatively low threshold value. An index **124** may be moved vertically to change the current threshold value. A change in threshold value changes the form of the threshold value line **126**.

(68) A tomographic image, a two-dimensional map, and a graph may be generated based on, for example, a frame data array that is stored in a cine memory, and they may be displayed. In that case, these images may be displayed in the form of a still-frame image associated with a past specific time, rather than in the form of a video image. In that case, the past specific time may be specified by an element **128**. The element **128** is a mark that moves along the horizontal axis of the graph **120**. For example, the past specific point in time at which a lesion site is detected may be specified by the element **128**.

(69) FIG. **8** illustrates an alternative example of a display image. A display image **40**A includes a tomographic image **42**, a two-dimensional map **44**A, graphs **46**A and **46**B, and others. The

tomographic image **42** includes a lesion site **50**, and a mark **48** that provides notification thereof is superimposed. In this alternative example, two types of lesion sites (for example, a tumor site and a non-tumor site) are to be detected, and a lesion site probability; that is, a lesion site score, is calculated for each lesion site.

(70) In the two-dimensional map **44**A, for example, a first lesion site probability is expressed by the luminance of a blue-based hue, and a second lesion site probability is expressed by the luminance of a red-based hue. A relationship between the first lesion site probability and the luminance of the blue-based hue is expressed by a first color bar **52**A, and a relationship between the second lesion site probability and the luminance of the red-based hue is expressed by a second color bar **52**B. Lines **55**A and **55**B each representing a threshold value are indicated on the respective color bars **52**A and **52**B.

(71) A first two-dimensional map representing distribution of first lesion site probabilities and a second two-dimensional map representing distribution of second lesion site probabilities may be separately generated and displayed. Although a first lesion site and a second lesion site are identified on the tomographic image **42** using the same mark **48** without being distinguished from each other, different markers may be displayed depending on the types of the lesion sites.

(72) The first graph **46**A represents temporal change of the first lesion site probabilities (maximum values). The second graph **46**B represents temporal change of the second lesion site probabilities (maximum values). The first graph **46**A includes a line **64**A serving as a display element that represents a threshold value, and the second graph **46**B includes a line **64**B serving as a display element that represents a threshold value.

(73) With the above-described embodiments, as inspection assistance information, a two-dimensional map and a graph are displayed in addition to a mark. The two-dimensional map and the graph are displayed regardless of whether or not the mark is displayed. As such, the inspector can obtain more detailed information regarding a current inspection target through the observation of these items of information that are displayed. This enables assistance in careful examination of a lesion site for which notification is provided through mark display, or enables verification of adequacy of mark display. Also, the current inspection target can be evaluated under circumstances where no mark is displayed.

Claims

1. An ultrasound diagnostic apparatus comprising: a detector unit configured to perform detection processing for detecting a lesion site in an ultrasound image; a mark generator unit configured to generate a mark based on output information from the detector unit, the mark providing notification of the lesion site; a reference information generator unit configured to generate reference information based on the output information as inspection assistance information that is different from the mark, the reference information representing at least one of spatial distribution of lesion site probabilities and temporal change of lesion site probabilities; and a display configured to display the ultrasound image, the mark, and the reference information in real time, wherein the reference information generator unit includes a graph generator unit configured to generate, as the reference information, a graph that represents the temporal change of lesion site probabilities, wherein the graph generator unit identifies, for each frame, a representative value of lesion site probabilities in the frame, and wherein the graph generator unit generates the graph based on a plurality of representative values identified from a plurality of frames.

2. The ultrasound diagnostic apparatus according to claim 1, wherein the representative value for each of the frames is a maximum value.

3. The ultrasound diagnostic apparatus according to claim 1, wherein the reference information generator unit comprises a map generator unit configured to generate a two-dimensional map that represents the spatial distribution of lesion site probabilities, and wherein the reference information

includes the two-dimensional map and the graph.

4. The ultrasound diagnostic apparatus according to claim 1, wherein the mark is displayed on the ultrasound image, and wherein the reference information is displayed in the vicinity of the ultrasound image.

5. The ultrasound diagnostic apparatus according to claim 1, wherein the reference information generator unit includes a map generator unit configured to generate, as the reference information, a two-dimensional map that represents the spatial distribution of lesion site probabilities.

6. The ultrasound diagnostic apparatus according to claim 5, wherein when the output information includes first information that satisfies a mark display condition and second information that does not satisfy the mark display condition, the mark generator unit generates the mark based on the first information, and the map generator unit generates the two-dimensional map based on the first information and the second information.

7. An ultrasound image processing method comprising: performing detection processing for detecting a lesion site in an ultrasound image; generating a mark based on output information that represents a result of execution of the detection processing, the mark providing notification of the lesion site; generating reference information based on the output information as inspection assistance information that is different from the mark, the reference information representing at least one of spatial distribution of lesion site probabilities and temporal change of lesion site probabilities; and displaying the ultrasound image, the mark, and the reference information in real time, the reference information being generated as a graph that represents the temporal change of lesion site probabilities, the mark being generated when the output information satisfies a mark display condition, the mark display condition including a condition that requires that a lesion site probability identified from the output information exceeds a threshold value, and the graph including a display element that represents the threshold value.

8. The ultrasound image processing method according to claim 7, further comprising changing the display element in accordance with a change in the threshold value.

9. The ultrasound image processing method according to claim 7, wherein the mark is displayed on the ultrasound image, and the reference information is displayed in the vicinity of the ultrasound image.

10. The ultrasound image processing method according to claim 7, wherein a two-dimensional map that represents the spatial distribution of lesion site probabilities is generated as the reference information.

11. The ultrasound image processing method according to claim 10, wherein when the output information includes first information that satisfies a mark display condition and second information that does not satisfy the mark display condition, the mark is generated based on the first information, and the two-dimensional map is generated based on the first information and the second information.

12. The ultrasound image processing method according to claim 7, wherein the representative value for each of the frames is a maximum value.

13. The ultrasound image processing method according to claim 7, further comprising: generating a two-dimensional map that represents the spatial distribution of lesion site probabilities; and generating the graph that represents the temporal change of lesion site probabilities, wherein the reference information includes the two-dimensional map and the graph.

14. A non-transitory storage medium storing a program executable by an information processing apparatus, the program comprising: a function of performing detection processing for detecting a lesion site in an ultrasound image; a function of generating a mark based on output information that represents a result of execution of the detection processing, the mark providing notification of the lesion site; a function of generating reference information based on the output information as inspection assistance information that is different from the mark, the reference information representing at least one of spatial distribution of lesion site probabilities and temporal change of

lesion site probabilities, the reference information being generated as a graph that represents the temporal change of lesion site probabilities; and a function of displaying the ultrasound image, the mark, and the reference information in real time; and a function of identifying, for each frame, a representative value of lesion site probabilities in the frame, the graph being generated based on a plurality of representative values identified from a plurality of frames.

15. The non-transitory storage medium according to claim 14, wherein the mark is displayed on the ultrasound image, and the reference information is displayed in the vicinity of the ultrasound image.

16. The non-transitory storage medium according to claim 14, wherein a two-dimensional map that represents the spatial distribution of lesion site probabilities is generated as the reference information.

17. The non-transitory storage medium according to claim 16, wherein when the output information includes first information that satisfies a mark display condition and second information that does not satisfy the mark display condition, the mark is generated based on the first information, and the two-dimensional map is generated based on the first information and the second information.

18. The non-transitory storage medium according to claim 14, wherein the representative value for each of the frames is a maximum value.

19. The non-transitory storage medium according to claim 14, further comprising: a function of generating a two-dimensional map that represents the spatial distribution of lesion site probabilities; and a function of generating the graph that represents the temporal change of lesion site probabilities, wherein the reference information includes the two-dimensional map and the graph.