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MACHII

(54) **IMAGE PROCESSING APPARATUS, IMAGE PROCESSING METHOD, AND PROGRAM**

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(57) **ABSTRACT**

There is provided an image processing apparatus including: at least one processor, in which the processor is configured to execute: calcification candidate image detection processing of detecting a calcification candidate image estimated to be a calcification image from a series of a plurality of projection images obtained by tomosynthesis imaging of a breast or a plurality of tomographic images obtained from the plurality of projection images; calcification candidate image group generation processing of generating a calcification candidate image group by cutting out a region including the calcification candidate image detected by the calcification candidate image detection processing, from each of the plurality of projection images; and calcification determination processing of determining whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated by the calcification candidate image group generation processing.

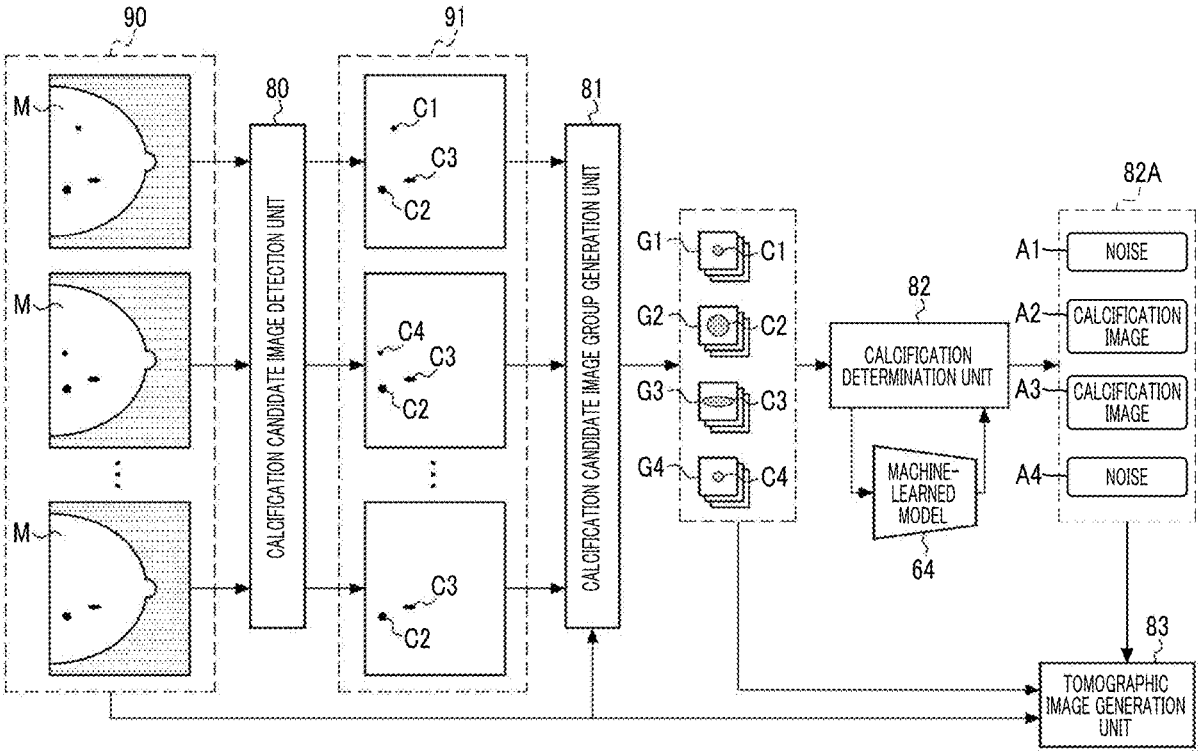

FIG. 1

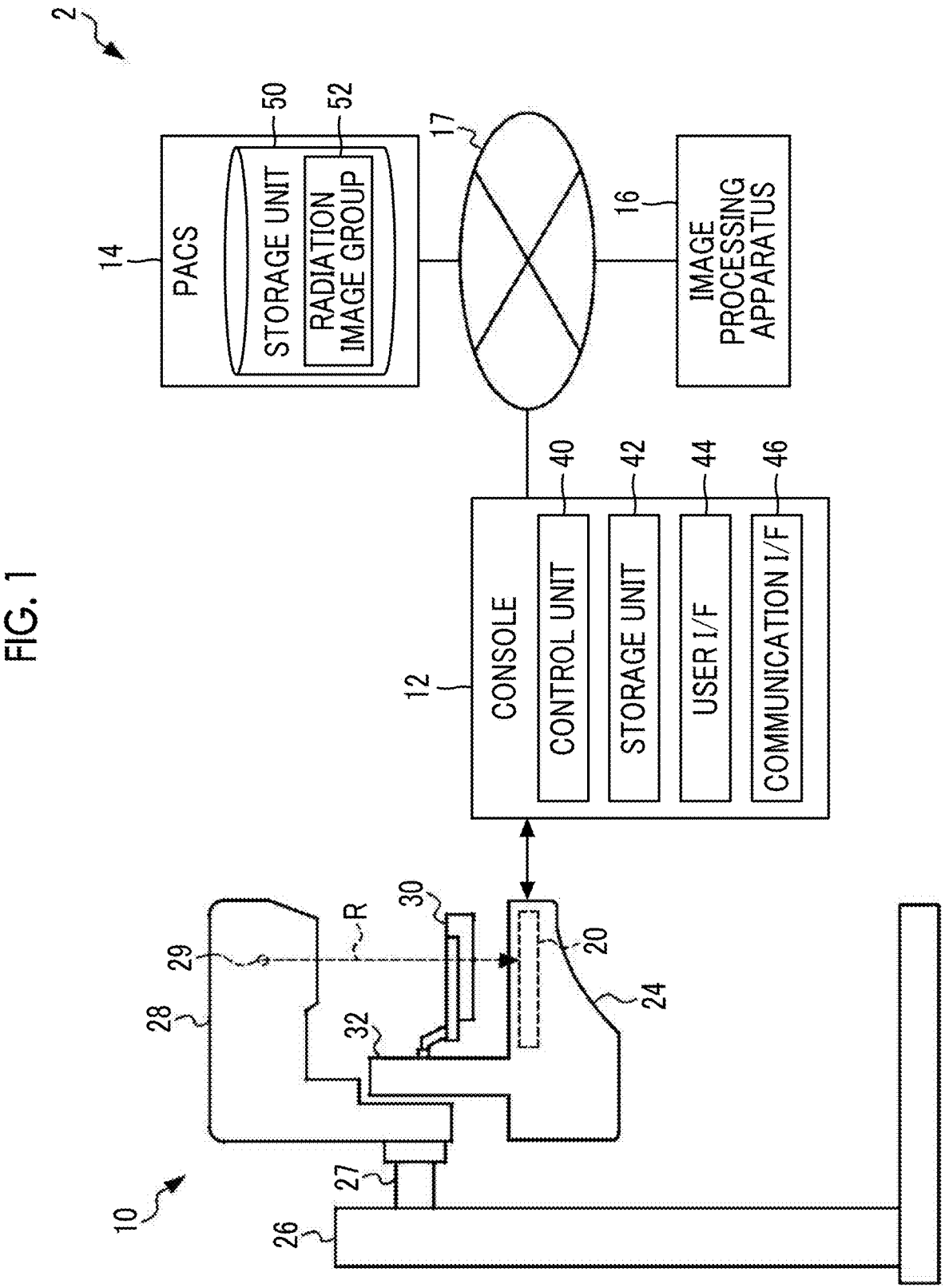
2
14
PACS
50
STORAGE UNIT
52
RADIATION IMAGE GROUP
17
16
IMAGE PROCESSING APPARATUS
12
CONSOLE
40
CONTROL UNIT
42
STORAGE UNIT
44
USER I/F
46
COMMUNICATION I/F
10
26
27
28
29
R
30
32
20
24

FIG. 2

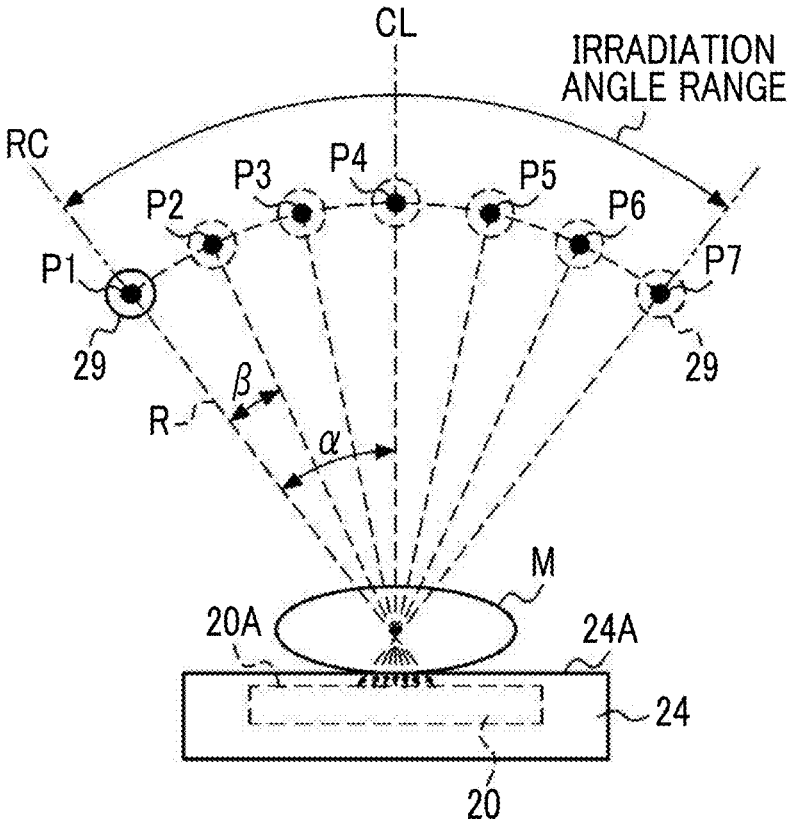
CL
IRRADIATION ANGLE RANGE
RC
P1
P2
P3
P4
P5
P6
P7
29
29
β
R
α
M
20A
24A
24
20

FIG. 3

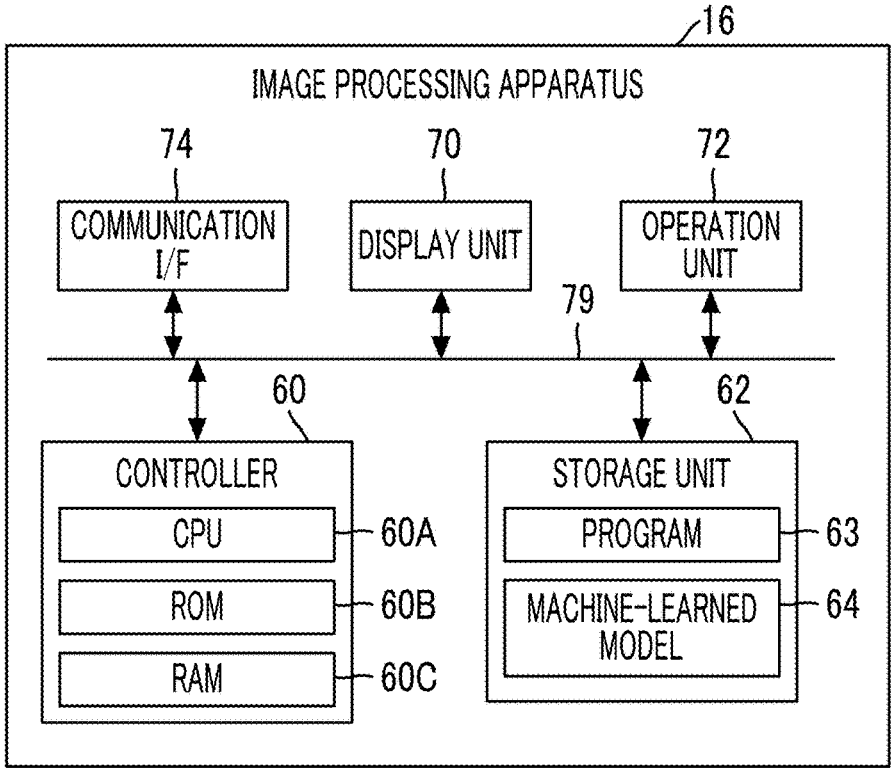
16
IMAGE PROCESSING APPARATUS
74
70
72
COMMUNICATION I/F
DISPLAY UNIT
OPERATION UNIT
79
60
62
CONTROLLER
CPU
60A
ROM
60B
RAM
60C
STORAGE UNIT
PROGRAM
63
MACHINE-LEARNED MODEL
64

FIG. 4

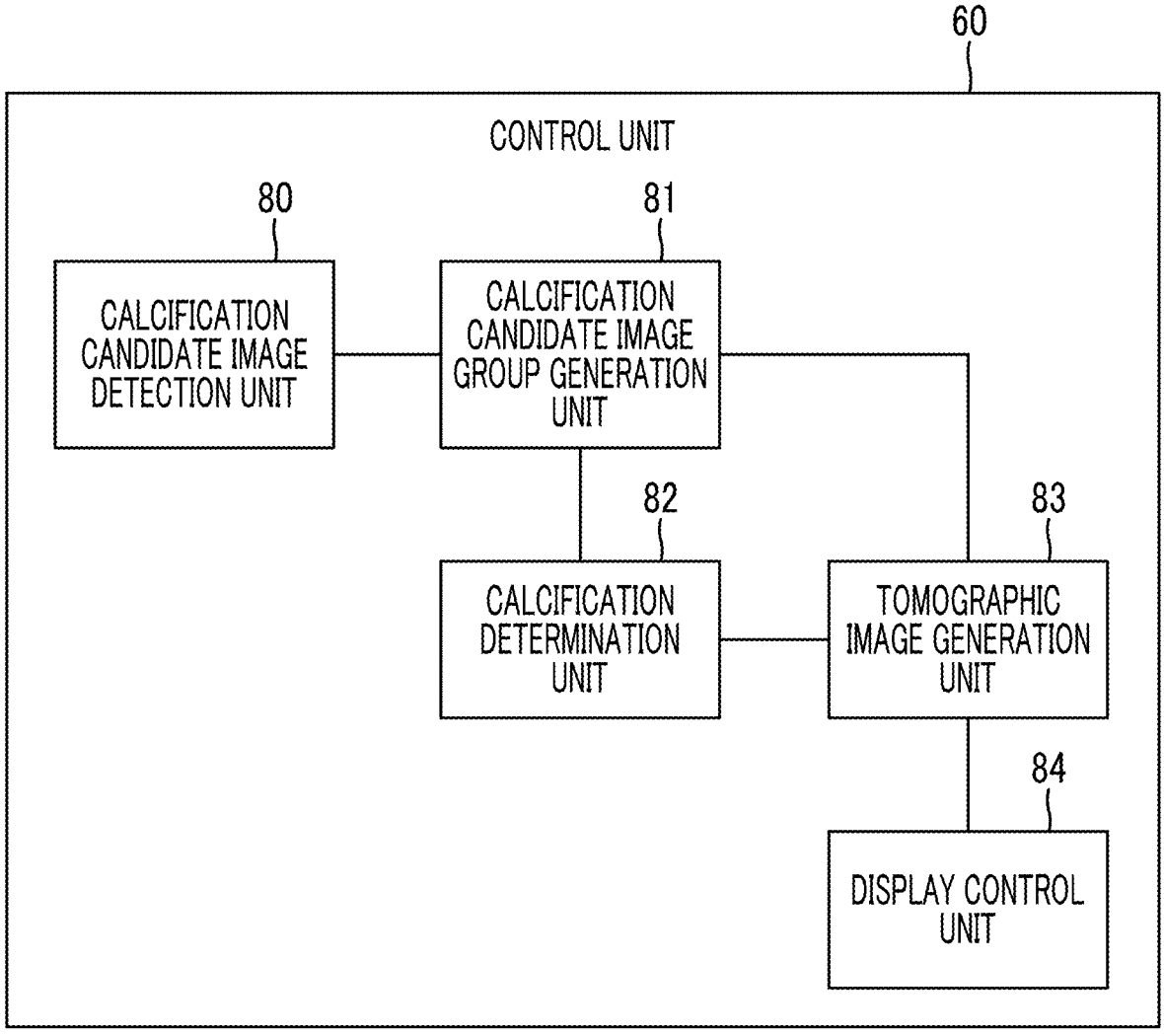
60
CONTROL UNIT
80
CALCIFICATION CANDIDATE IMAGE DETECTION UNIT
81
CALCIFICATION CANDIDATE IMAGE GROUP GENERATION UNIT
82
CALCIFICATION DETERMINATION UNIT
83
TOMOGRAPHIC IMAGE GENERATION UNIT
84
DISPLAY CONTROL UNIT

FIG. 5

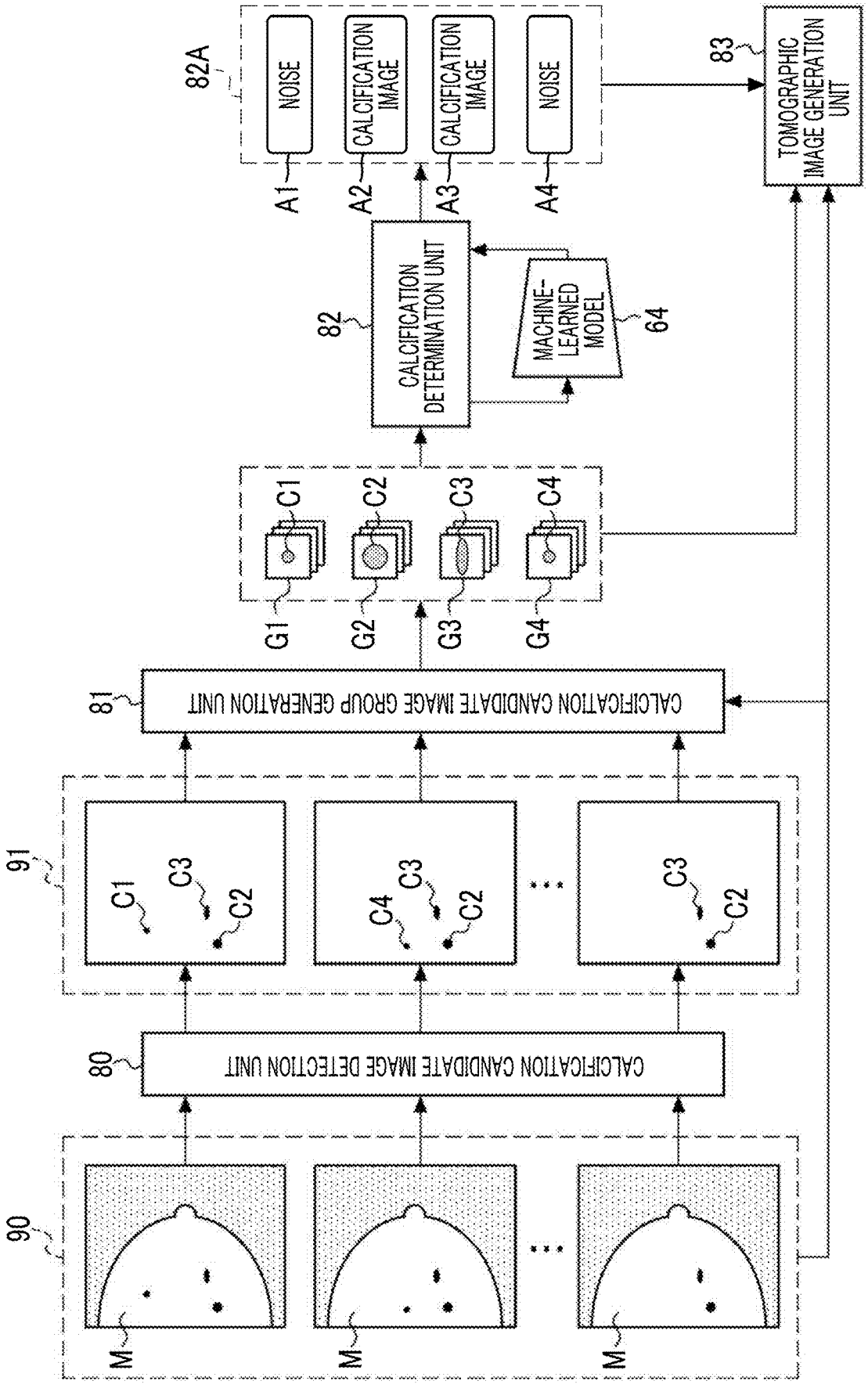
90
M
M
M
80
CALCIFICATION CANDIDATE IMAGE DETECTION UNIT
91
C1
C3
C2
C4
C3
C2
C3
C2
81
CALCIFICATION CANDIDATE IMAGE GROUP GENERATION UNIT
G1
G2
G3
G4
C1
C2
C3
C4
82
CALCIFICATION DETERMINATION UNIT
MACHINE-LEARNED MODEL
64
82A
A1
A2
A3
A4
NOISE
CALCIFICATION IMAGE
CALCIFICATION IMAGE
NOISE
83
TOMOGRAPHIC IMAGE GENERATION UNIT

FIG. 6

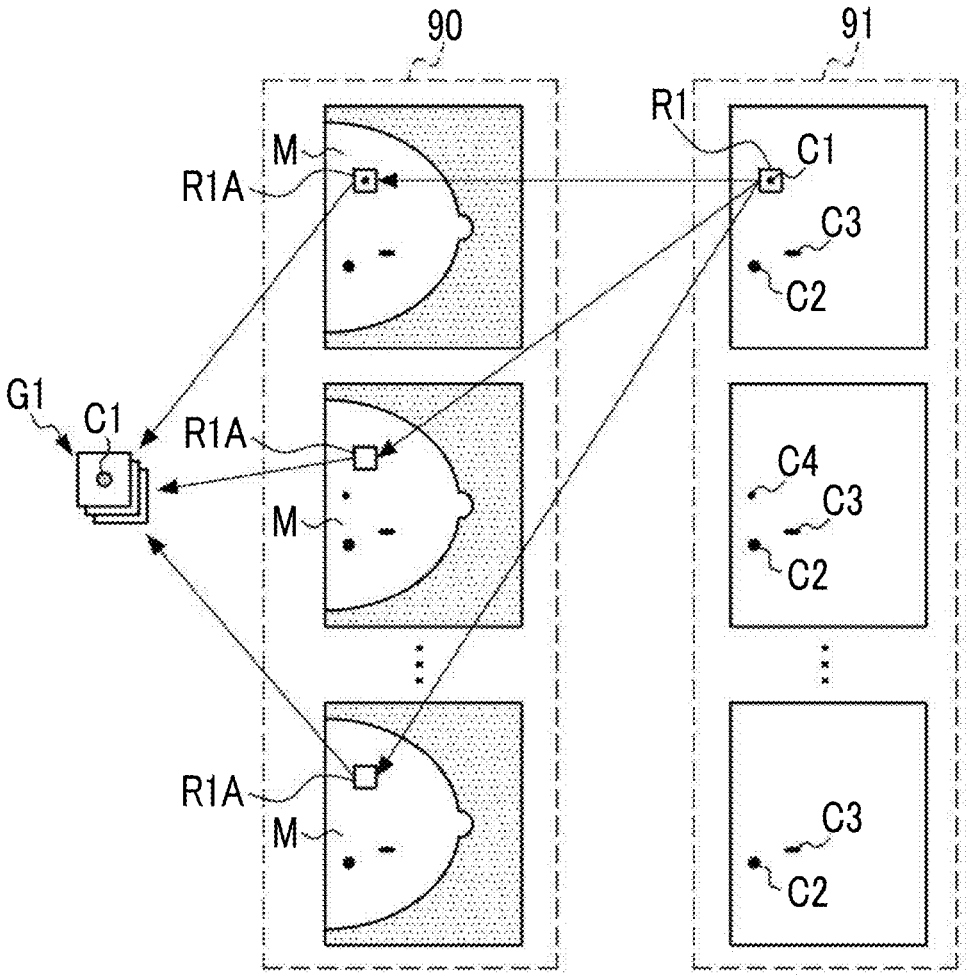

FIG. 7

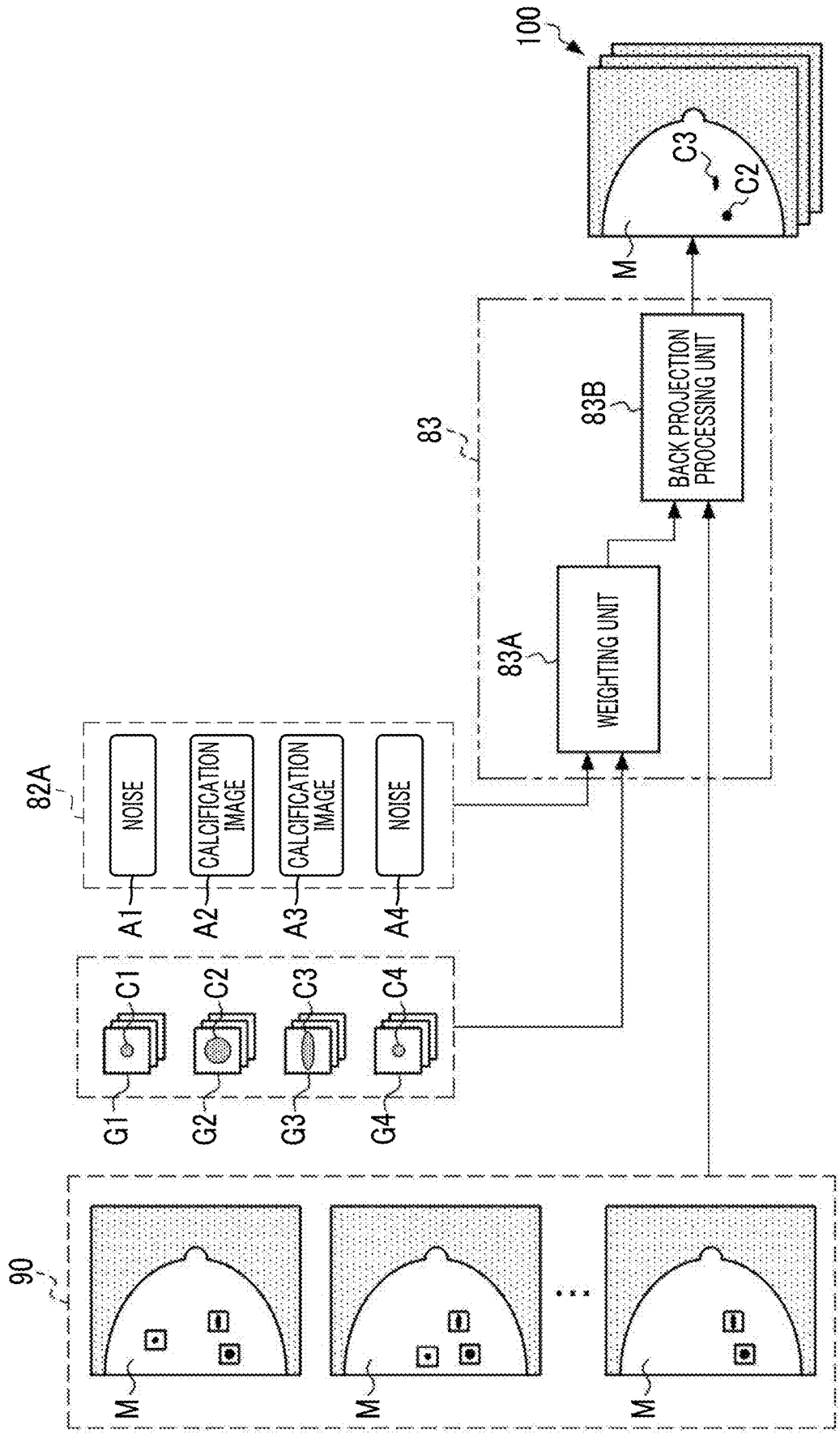
90
M
M
M
G1
G2
G3
G4
C1
C2
C3
C4
82A
A1
A2
A3
A4
NOISE
CALCIFICATION IMAGE
CALCIFICATION IMAGE
NOISE
83
83A
WEIGHTING UNIT
83B
BACK PROJECTION PROCESSING UNIT
100
M
C3
C2

FIG. 8

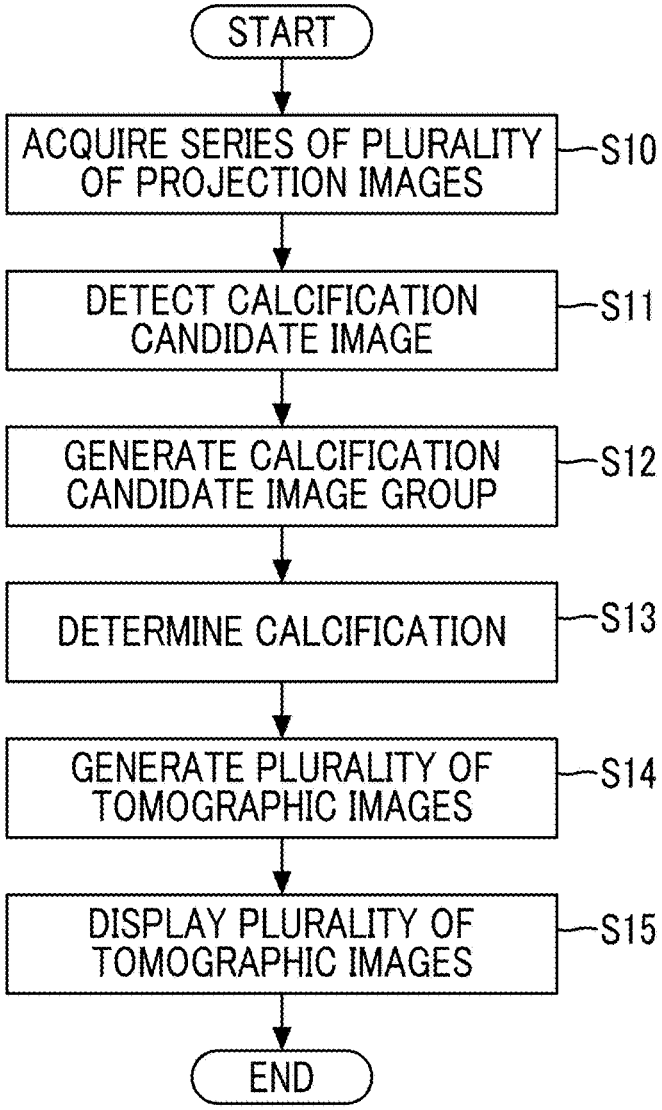
START
ACQUIRE SERIES OF PLURALITY OF PROJECTION IMAGES
S10
DETECT CALCIFICATION CANDIDATE IMAGE
S11
GENERATE CALCIFICATION CANDIDATE IMAGE GROUP
S12
DETERMINE CALCIFICATION
S13
GENERATE PLURALITY OF TOMOGRAPHIC IMAGES
S14
DISPLAY PLURALITY OF TOMOGRAPHIC IMAGES
S15
END

FIG. 9

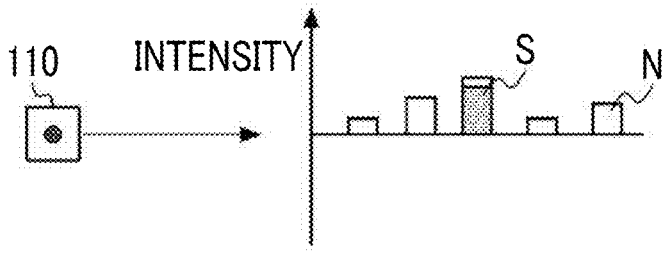
110
INTENSITY
S
N

FIG. 10

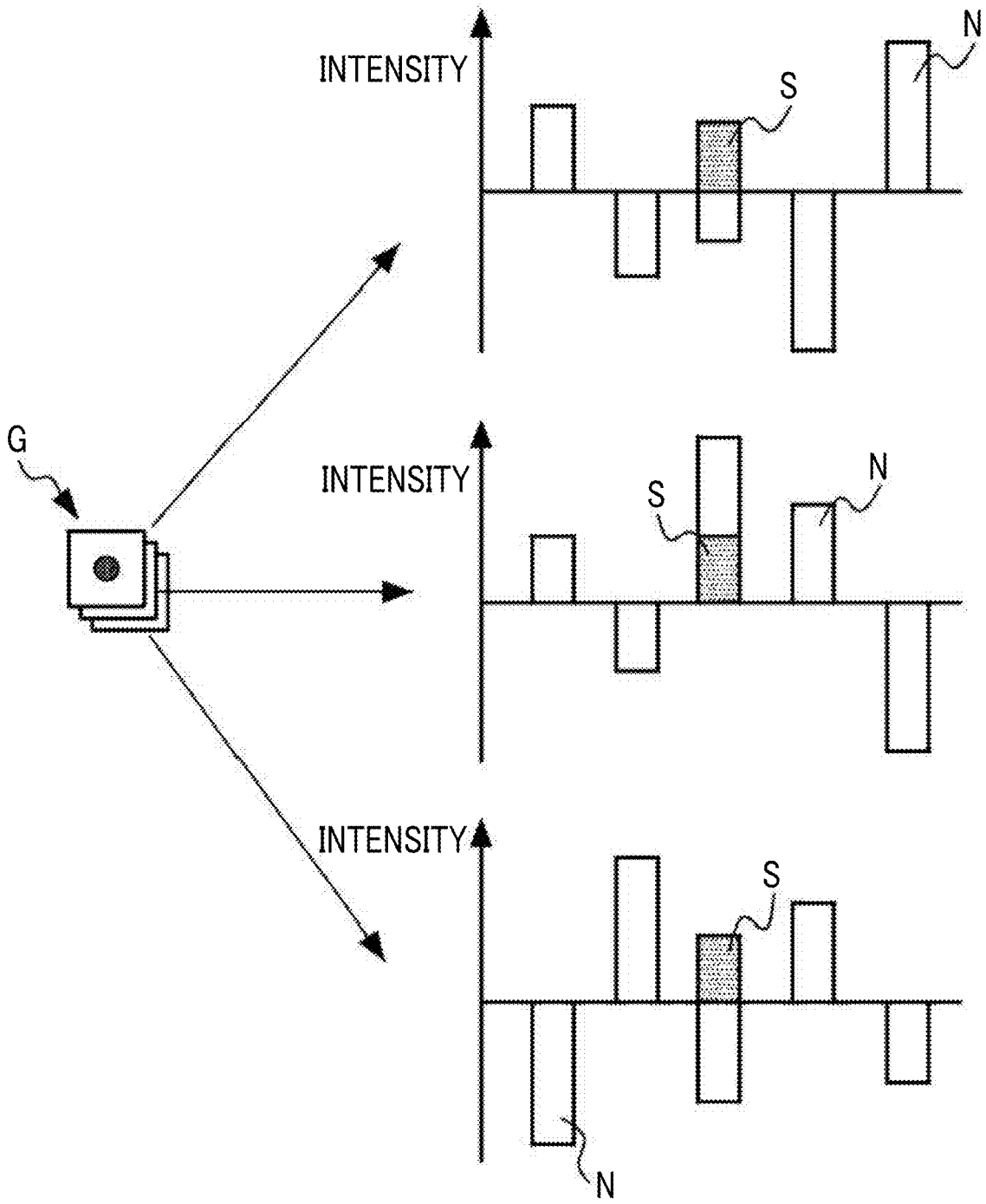

FIG. 11

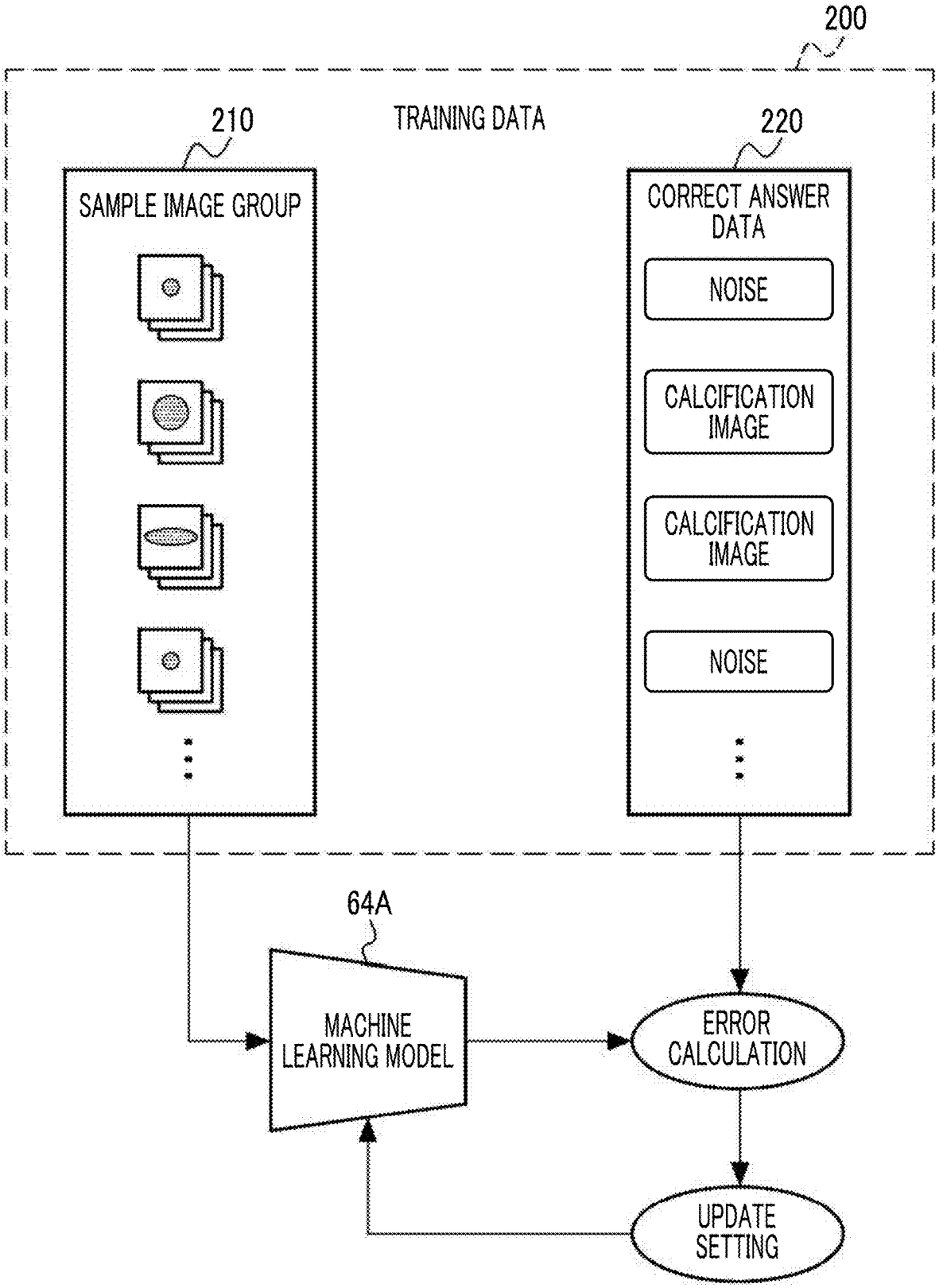
200
TRAINING DATA
210
SAMPLE IMAGE GROUP
220
CORRECT ANSWER DATA
NOISE
CALCIFICATION IMAGE
CALCIFICATION IMAGE
NOISE
64A
MACHINE LEARNING MODEL
ERROR CALCULATION
UPDATE SETTING

FIG. 12

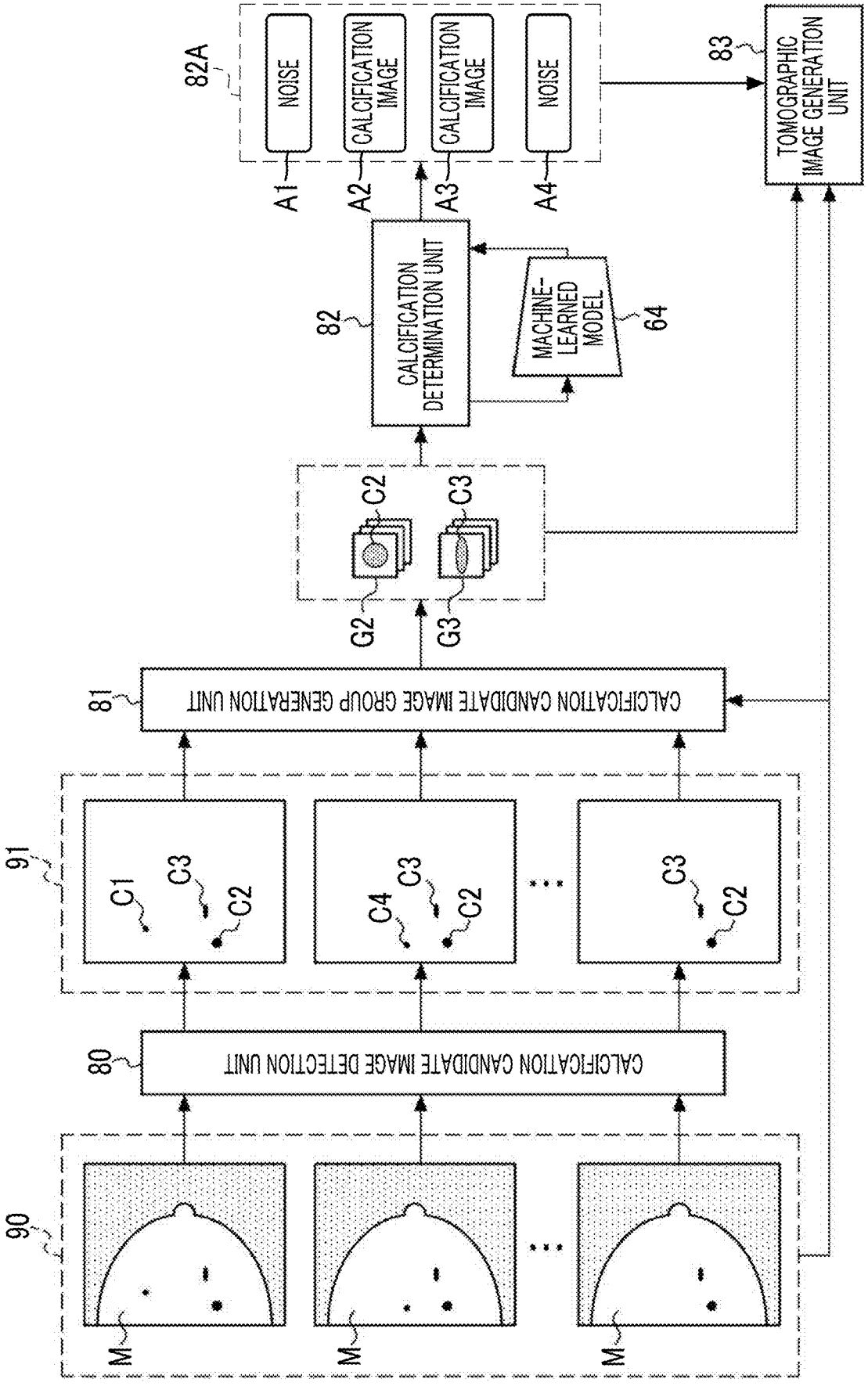
90
M
M
M
80
CALCIFICATION CANDIDATE IMAGE DETECTION UNIT
91
C1
C3
C2
C4
C3
C2
C3
C2
81
CALCIFICATION CANDIDATE IMAGE GROUP GENERATION UNIT
G2
G3
C2
C3
82
CALCIFICATION DETERMINATION UNIT
MACHINE-LEARNED MODEL
64
82A
A1
A2
A3
A4
NOISE
CALCIFICATION IMAGE
CALCIFICATION IMAGE
NOISE
83
TOMOGRAPHIC IMAGE GENERATION UNIT

FIG. 13

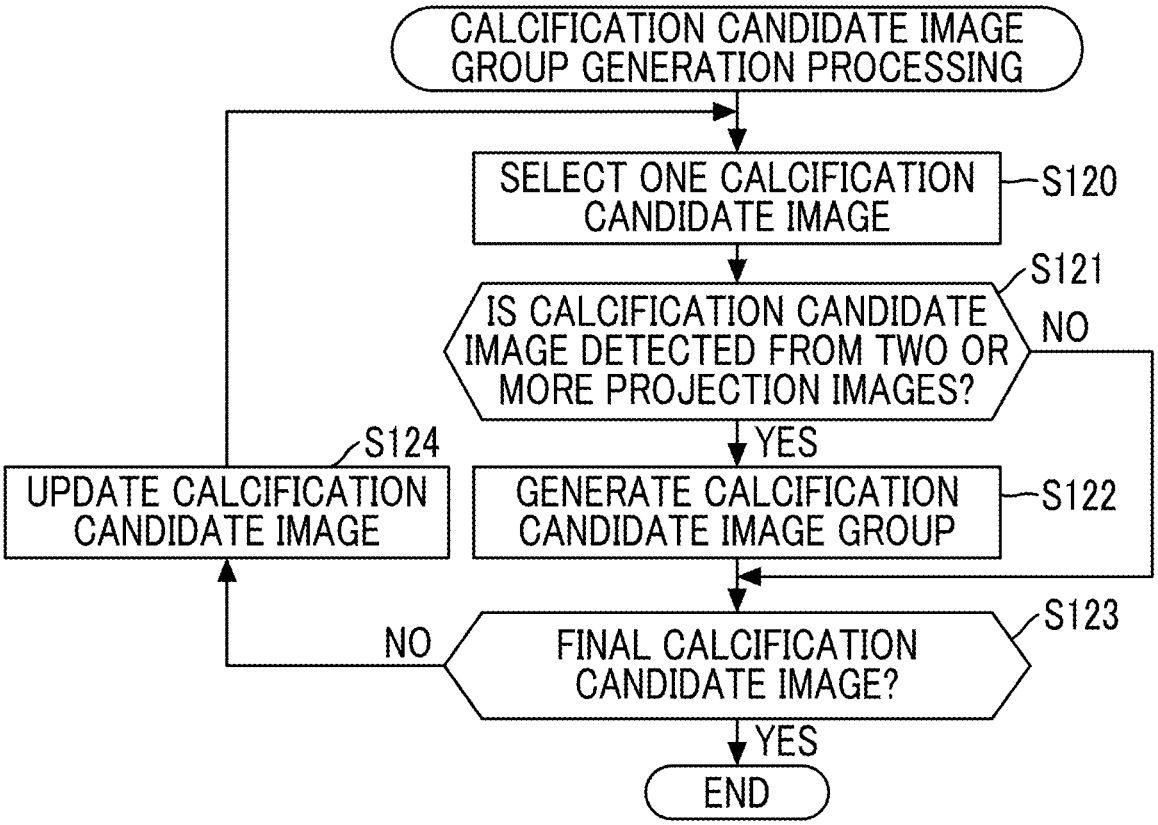
CALCIFICATION CANDIDATE IMAGE GROUP GENERATION PROCESSING
SELECT ONE CALCIFICATION CANDIDATE IMAGE
S120
S121
IS CALCIFICATION CANDIDATE IMAGE DETECTED FROM TWO OR MORE PROJECTION IMAGES?
NO
YES
S124
UPDATE CALCIFICATION CANDIDATE IMAGE
GENERATE CALCIFICATION CANDIDATE IMAGE GROUP
S122
S123
NO
FINAL CALCIFICATION CANDIDATE IMAGE?
YES
END

FIG. 14

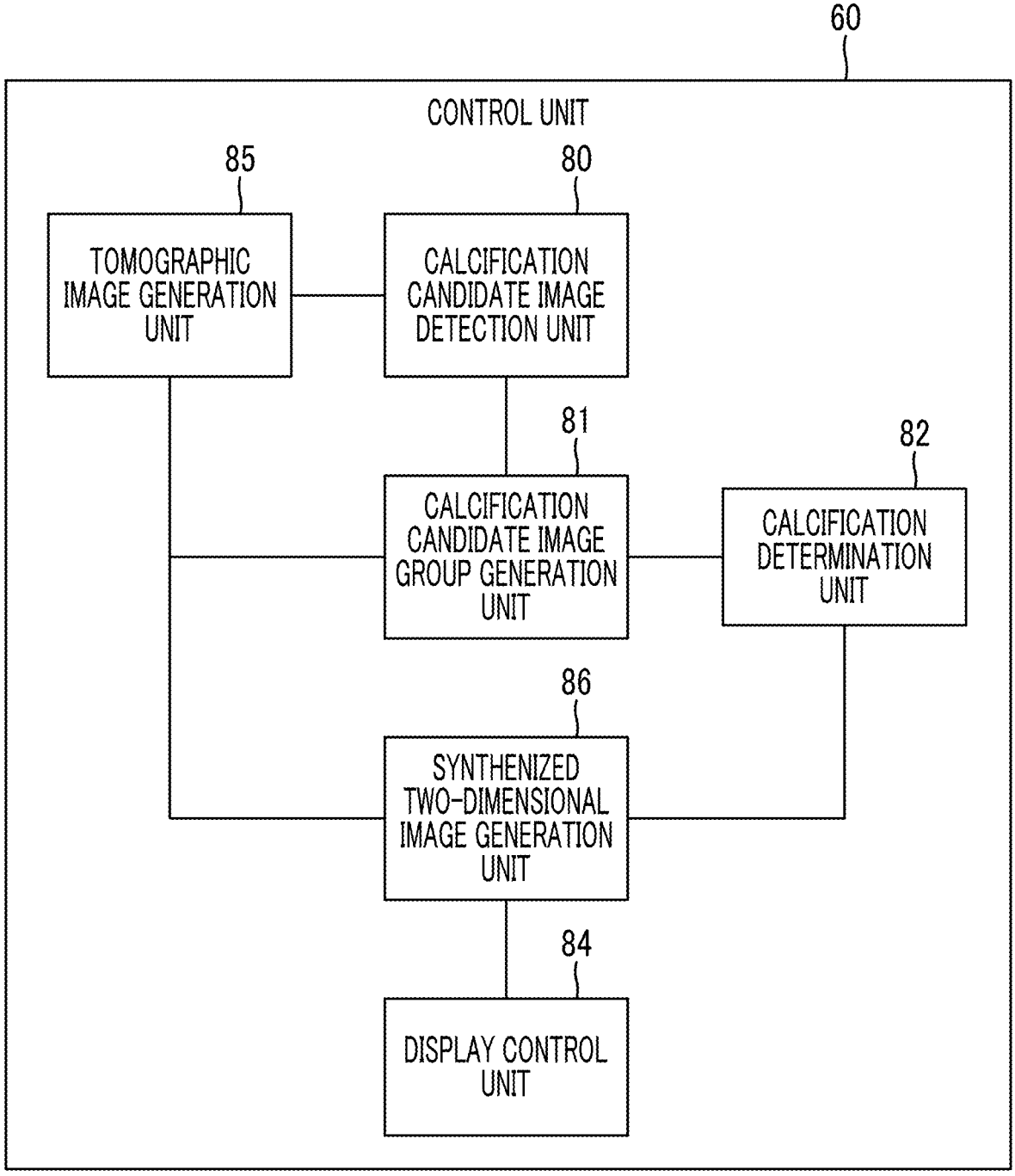
60
CONTROL UNIT
85
TOMOGRAPHIC IMAGE GENERATION UNIT
80
CALCIFICATION CANDIDATE IMAGE DETECTION UNIT
81
CALCIFICATION CANDIDATE IMAGE GROUP GENERATION UNIT
82
CALCIFICATION DETERMINATION UNIT
86
SYNTHENIZED TWO-DIMENSIONAL IMAGE GENERATION UNIT
84
DISPLAY CONTROL UNIT

FIG. 15

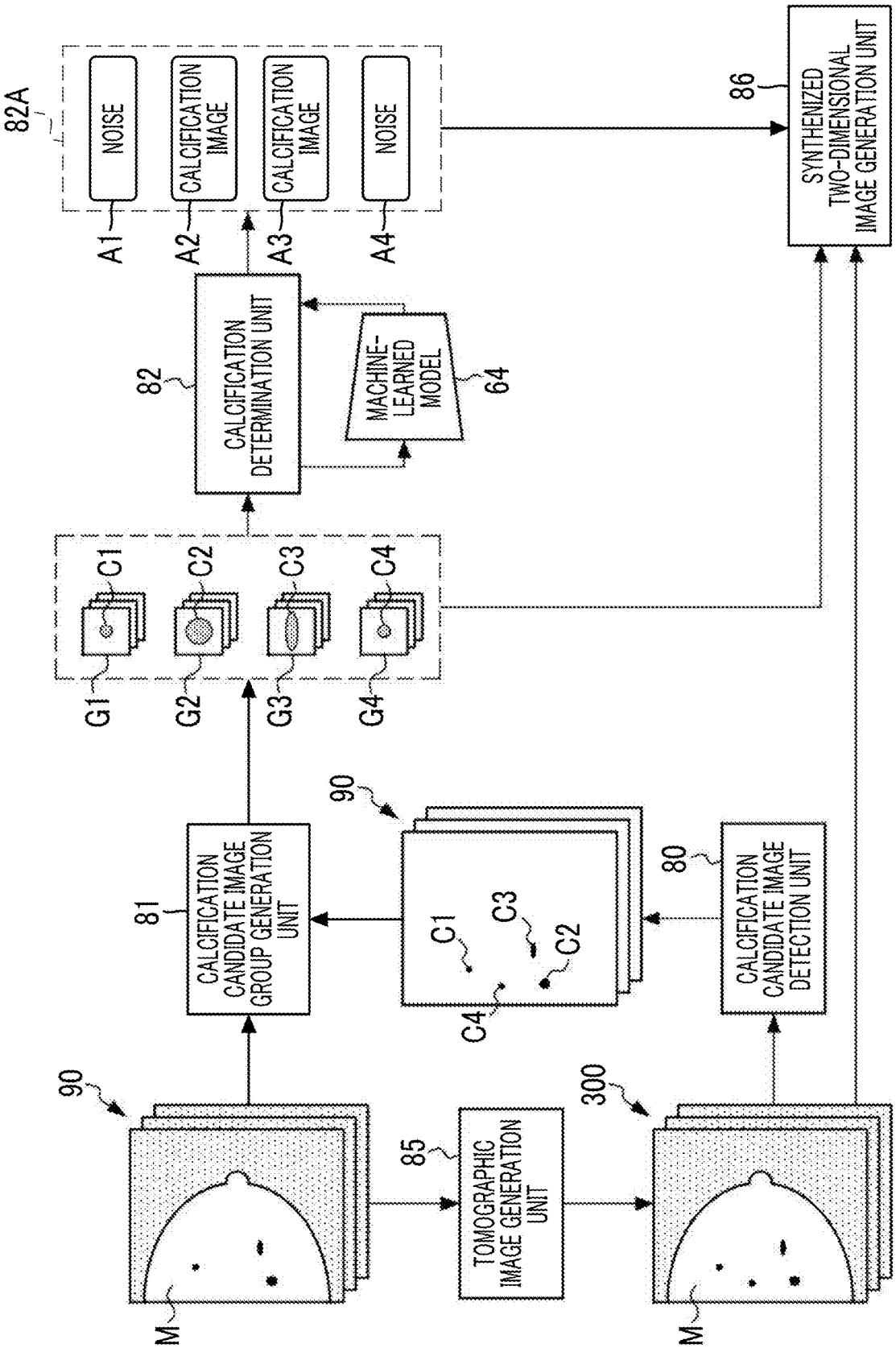
82A
NOISE
CALCIFICATION IMAGE
CALCIFICATION IMAGE
NOISE
A1
A2
A3
A4
86
SYNTHENIZED TWO-DIMENSIONAL IMAGE GENERATION UNIT
82
CALCIFICATION DETERMINATION UNIT
MACHINE-LEARNED MODEL
64
C1
C2
C3
C4
G1
G2
G3
G4
90
81
CALCIFICATION CANDIDATE IMAGE GROUP GENERATION UNIT
80
CALCIFICATION CANDIDATE IMAGE DETECTION UNIT
85
TOMOGRAPHIC IMAGE GENERATION UNIT
300
M

FIG. 16

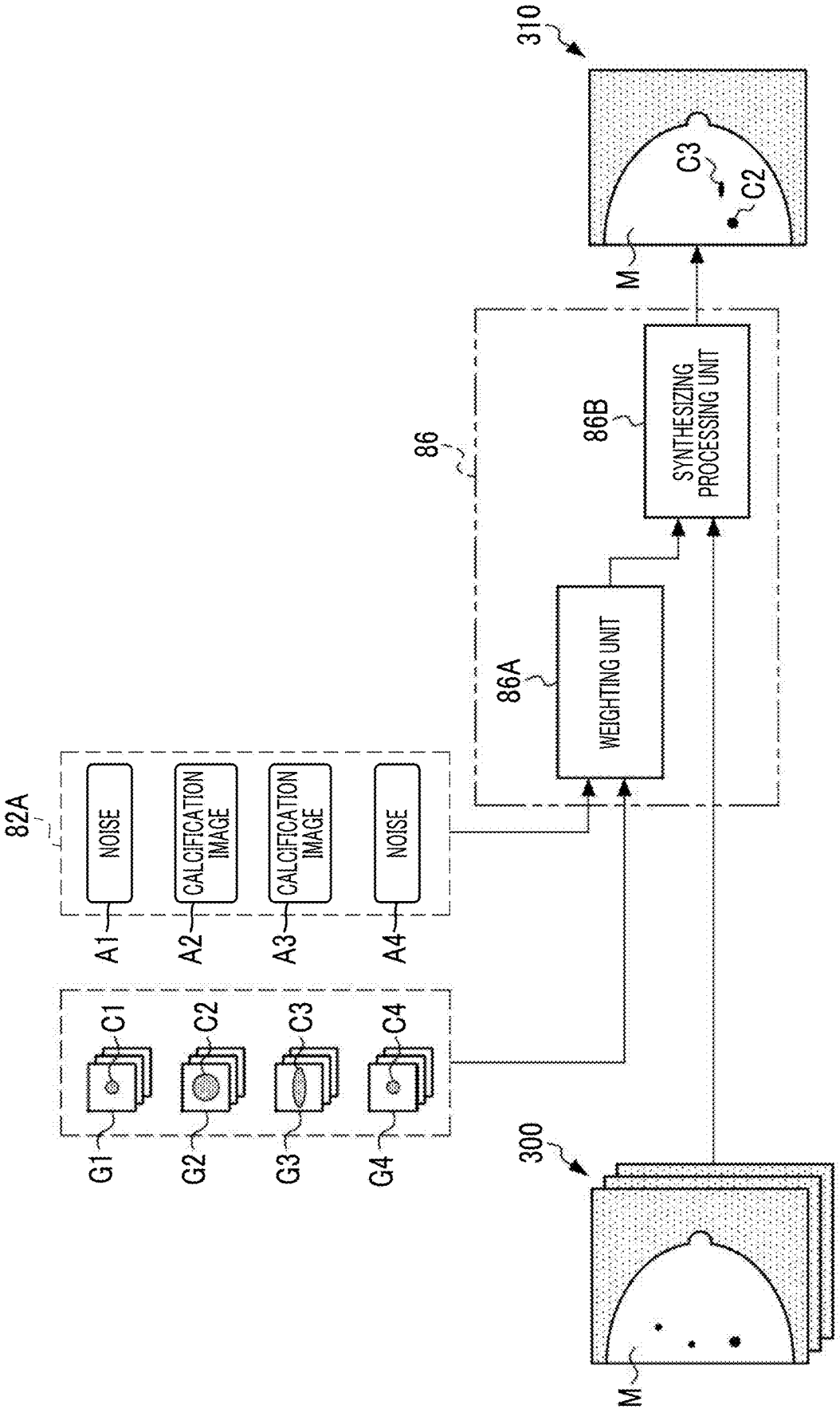
310
C3
C2
M
86
86B
SYNTHESIZING PROCESSING UNIT
86A
WEIGHTING UNIT
82A
NOISE
CALCIFICATION IMAGE
CALCIFICATION IMAGE
NOISE
A1
A2
A3
A4
C1
C2
C3
C4
G1
G2
G3
G4
300
M

FIG. 17

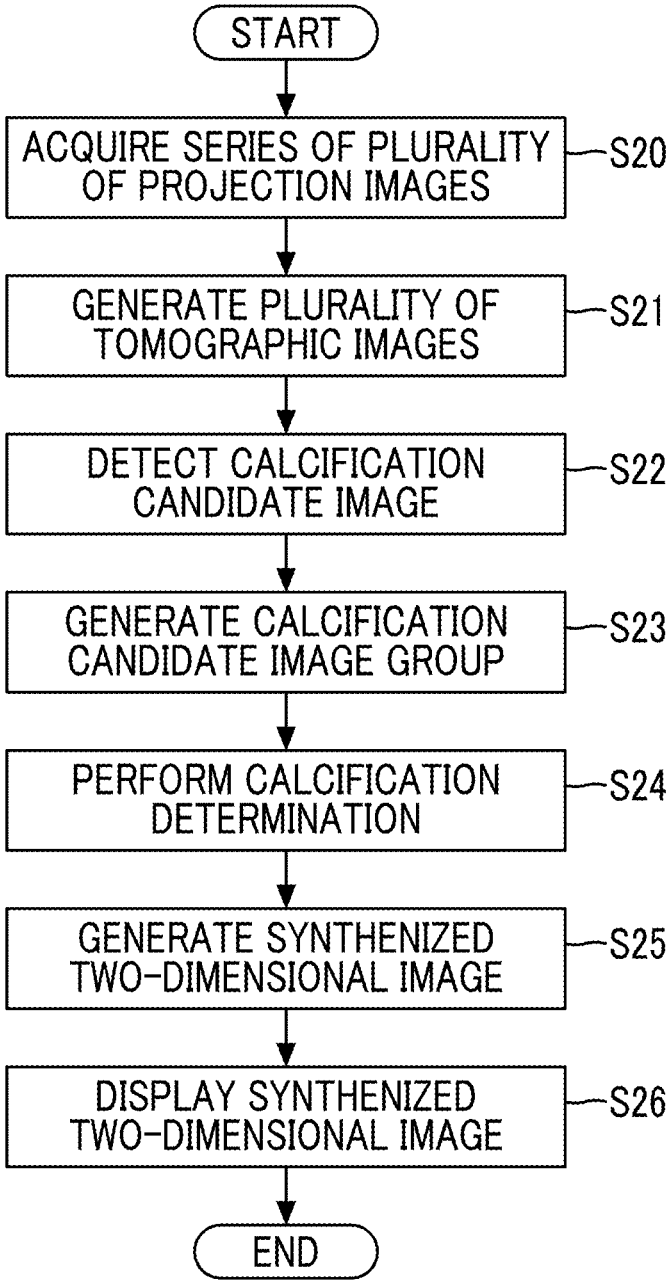
START
ACQUIRE SERIES OF PLURALITY OF PROJECTION IMAGES
S20
GENERATE PLURALITY OF TOMOGRAPHIC IMAGES
S21
DETECT CALCIFICATION CANDIDATE IMAGE
S22
GENERATE CALCIFICATION CANDIDATE IMAGE GROUP
S23
PERFORM CALCIFICATION DETERMINATION
S24
GENERATE SYNTHENIZED TWO-DIMENSIONAL IMAGE
S25
DISPLAY SYNTHENIZED TWO-DIMENSIONAL IMAGE
S26
END

IMAGE PROCESSING APPARATUS, IMAGE PROCESSING METHOD, AND PROGRAM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation application of International Application No. PCT/JP2022/045733, filed Dec. 12, 2022, the disclosure of which is incorporated herein by reference in its entirety. Further, this application claims priority from Japanese Patent Application No. 2022-006669, filed on Jan. 19, 2022, the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND

1. Technical Field

[0002] The present disclosure relates to an image processing apparatus, an image processing method, and a program.

2. Description of the Related Art

[0003] A technique for recognizing a tissue of a breast in which calcification may occur by using a radiation image obtained by irradiating the breast with radiations is known. In addition, tomosynthesis imaging in which a series of a plurality of projection images is acquired by irradiating a breast with radiations having a plurality of angles is known. By reconfiguring the plurality of projection images obtained by tomosynthesis imaging, a plurality of tomographic images in which an overlap of mammary glands is reduced are obtained. Further, a technique of generating one synthesized two-dimensional image in which an overlap of mammary glands is reduced by synthesizing a plurality of tomographic images is known.

[0004] JP2020-096752A discloses a technique of detecting a position of a lesion, such as calcification of a breast, in a plurality of tomographic images generated by reconstructing a plurality of projection images obtained by tomosynthesis imaging, increasing a weight such that the detected lesion is emphasized, and generating a synthesized two-dimensional image.

SUMMARY

[0005] In the tomographic image, noise that is indistinguishable from a small calcification image is present. It is difficult for a person to visually distinguish a small calcification image and noise on a tomographic image, and it is also difficult to mechanically separate a small calcification image and noise on a tomographic image. In addition, in a case where a synthesized two-dimensional image is generated based on the plurality of tomographic images, noise is drawn on the synthesized two-dimensional image as a pseudo calcification image. As a result, this may lead to misdiagnosis.

[0006] JP2020-096752A discloses a method of increasing a weight such that a lesion such as calcification is emphasized in a plurality of tomographic images and generating a synthesized two-dimensional image. However, JP2020-096752A does not disclose a method of distinguishing a calcification image and noise.

[0007] An object of the technology of the present disclosure is to provide an image processing apparatus, an image processing method, and a program that can accurately distinguish between a calcification image and noise.

[0008] In order to achieve the above object, according to the present disclosure, there is provided an image processing apparatus including: at least one processor, in which the processor is configured to execute: calcification candidate image detection processing of detecting a calcification candidate image estimated to be a calcification image from a series of a plurality of projection images obtained by tomosynthesis imaging of a breast or a plurality of tomographic images obtained from the plurality of projection images; calcification candidate image group generation processing of generating a calcification candidate image group by cutting out a region including the calcification candidate image detected by the calcification candidate image detection processing, from each of the plurality of projection images; and calcification determination processing of determining whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated by the calcification candidate image group generation processing.

[0009] Preferably, the processor is configured to: individually generate the calcification candidate image group for each of a plurality of the calcification candidate images in the calcification candidate image group generation processing, in a case where a plurality of the calcification candidate images are detected in the calcification candidate image detection processing.

[0010] Preferably, the processor is configured to: detect only the calcification candidate image of which a signal value is equal to or smaller than a certain value in the calcification candidate image detection processing.

[0011] Preferably, the processor is configured to: detect the calcification candidate image estimated to be a calcification image from the plurality of projection images in the calcification candidate image group generation processing; and generate the calcification candidate image group in the calcification candidate image group generation processing, in a case where a corresponding calcification candidate image is detected from a certain number or more of the projection images among the series of the plurality of projection images in the calcification candidate image detection processing.

[0012] Preferably, the processor is configured to: detect the calcification candidate image estimated to be a calcification image from the plurality of projection images in the calcification candidate image group generation processing; and perform weighting on the calcification candidate image based on a determination result of the calcification determination processing, and generate the plurality of tomographic images by a back projection method.

[0013] Preferably, the processor is configured to: detect the calcification candidate image estimated to be a calcification image from the plurality of tomographic images in the calcification candidate image group generation processing; and perform weighting on the calcification candidate image based on a determination result of the calcification determination processing, and generate a synthesized two-dimensional image by synthesizing the plurality of tomographic images.

[0014] Preferably, the processor is configured to: execute the calcification determination processing by inputting the calcification candidate image group into a machine-learned model obtained by performing machine learning of a rela-

tionship between the calcification candidate image group and whether or not the calcification candidate image is a calcification image.

[0015] Preferably, the processor is configured to: determine whether or not the calcification candidate image is a calcification image based on a pattern of signals included in each of the calcification candidate images included in the calcification candidate image group in the calcification determination processing.

[0016] According to the present disclosure, there is provided an image processing method including: a calcification candidate image detection step of detecting a calcification candidate image estimated to be a calcification image from a series of a plurality of projection images obtained by tomosynthesis imaging of a breast or a plurality of tomographic images obtained from the plurality of projection images; a calcification candidate image group generation step of generating a calcification candidate image group by cutting out a region including the calcification candidate image detected by the calcification candidate image detection step, from each of the plurality of projection images; and a calcification determination step of determining whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated by the calcification candidate image group generation step.

[0017] According to the present disclosure, there is provided a program causing a computer to execute: calcification candidate image detection processing of detecting a calcification candidate image estimated to be a calcification image from a series of a plurality of projection images obtained by tomosynthesis imaging of a breast or a plurality of tomographic images obtained from the plurality of projection images; calcification candidate image group generation processing of generating a calcification candidate image group by cutting out a region including the calcification candidate image detected by the calcification candidate image detection processing, from each of the plurality of projection images; and calcification determination processing of determining whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated by the calcification candidate image group generation processing.

[0018] According to the technology of the present disclosure, it is possible to provide an image processing apparatus, an image processing method, and a program that can accurately distinguish between a calcification image and noise.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Exemplary embodiments according to the technique of the present disclosure will be described in detail based on the following figures, wherein:

[0020] FIG. **1** is a diagram illustrating an example of an entire configuration of a radiography system,

[0021] FIG. **2** is a diagram illustrating an example of tomosynthesis imaging,

[0022] FIG. **3** is a block diagram illustrating an example of a configuration of an image processing apparatus,

[0023] FIG. **4** is a block diagram illustrating an example of a function realized by a control unit of the image processing apparatus,

[0024] FIG. **5** is a diagram schematically illustrating a flow of processing by the image processing apparatus,

[0025] FIG. **6** is a diagram conceptually illustrating an example of processing of generating one calcification candidate image group,

[0026] FIG. **7** is a diagram conceptually illustrating an example of tomographic image generating processing,

[0027] FIG. **8** is a flowchart illustrating a flow of a series of processing by the image processing apparatus,

[0028] FIG. **9** is a diagram conceptually illustrating intensities of signals included in a tomographic image,

[0029] FIG. **10** is a diagram conceptually illustrating intensities of signals included in each of calcification candidate images included in a calcification candidate image group,

[0030] FIG. **11** is a diagram conceptually illustrating an example of learning processing of a machine learning model,

[0031] FIG. **12** is a diagram schematically illustrating a flow of processing by the image processing apparatus according to a first modification example,

[0032] FIG. **13** is a flowchart illustrating a flow of calcification candidate image group generation processing according to the first modification example,

[0033] FIG. **14** is a block diagram illustrating a function realized by a control unit of the image processing apparatus according to a second modification example,

[0034] FIG. **15** is a diagram schematically illustrating a flow of processing by the image processing apparatus according to the second modification example,

[0035] FIG. **16** is a diagram conceptually illustrating an example of synthesized two-dimensional image generation processing, and

[0036] FIG. **17** is a flowchart illustrating a flow of a series of processing by the image processing apparatus according to the second modification example.

DETAILED DESCRIPTION

[0037] Hereinafter, an embodiment of the present disclosure will be described in detail with reference to the drawings.

[0038] FIG. **1** illustrates an example of an entire configuration of a radiography system **2** according to the present embodiment. The radiography system **2** includes a mammography apparatus **10**, a console **12**, a picture archiving and communication systems (PACS) **14**, and an image processing apparatus **16**. The console **12**, the PACS **14**, and the image processing apparatus **16** are connected to each other via a network **17** by wired communication or wireless communication.

[0039] FIG. **1** illustrates an example of an appearance of the mammography apparatus **10**. FIG. **1** illustrates an example of an appearance in a case where the mammography apparatus **10** is viewed from a left side of a subject.

[0040] The mammography apparatus **10** operates according to a control of the console **12**, and is a radiography apparatus that acquires a radiation image of a breast M by irradiating the breast M of the subject as a target with radiations R (for example, X rays) from a radiation source **29**.

[0041] The mammography apparatus **10** has a function of performing normal imaging in which imaging is performed in a state where the radiation source **29** is positioned at an irradiation position along a normal direction of a detection surface **20**A of a radiation detector **20** and a function of performing tomosynthesis imaging in which imaging is

performed in a state where the radiation source **29** is moved to each of a plurality of irradiation positions.

[0042] As illustrated in FIG. **1**, the mammography apparatus **10** includes an imaging table **24**, a base **26**, an arm portion **28**, and a compression unit **32**. A radiation detector **20** is disposed inside the imaging table **24**. As illustrated in FIG. **2**, in the mammography apparatus **10**, in a case of performing imaging, the breast M of the subject is positioned on an imaging surface **24**A of the imaging table **24** by a user.

[0043] The radiation detector **20** detects radiations R passing through the breast M as a target. Specifically, the radiation detector **20** detects the radiations R that pass through the breast M of the subject, enter into the imaging table **24**, and reach a detection surface **20**A of the radiation detector **20**, and generates a radiation image based on the detected radiations R. The radiation detector **20** outputs image data representing the generated radiation image. In the following, a series of operations of irradiating the breast with radiations R from the radiation source **29** and generating a radiation image by the radiation detector **20** may be referred to as "imaging". The radiation detector **20** may be an indirect-conversion-type radiation detector that converts the radiations R into light beams and converts the converted light beams into charges, or may be a direct-conversion-type radiation detector that directly converts the radiations R into charges.

[0044] A compression plate **30** that is used for compressing the breast M when performing imaging is attached to the compression unit **32**. The compression plate **30** is moved in a direction toward or away from the imaging table **24** (hereinafter, referred to as a "vertical direction") by a compression plate driving unit (not illustrated) provided in the compression unit **32**. The compression plate **30** compresses the breast M between the compression plate **30** and the imaging table **24** by moving in the vertical direction.

[0045] The arm portion **28** can be rotated with respect to the base **26** by a shaft portion **27**. The shaft portion **27** is fixed to the base **26**, and the shaft portion **27** and the arm portion **28** are rotated as one body. Gears are provided in each of the shaft portion **27** and the compression unit **32** of the imaging table **24**. By switching the gears between an engaged state and a non-engaged state, the compression unit **32** of the imaging table **24** and the shaft portion **27** can be switched between a state where the compression unit **32** and the shaft portion **27** are connected to each other and are rotated as one body and a state where the shaft portion **27** is separated from the imaging table **24** and idles. Elements for switching between transmission and non-transmission of power of the shaft portion **27** are not limited to the gears, and various mechanical elements can be used. The arm portion **28** and the imaging table **24** can be separately rotated with respect to the base **26** with the shaft portion **27** as a rotation axis.

[0046] In a case of performing tomosynthesis imaging in the mammography apparatus **10**, the radiation source **29** is sequentially moved to each of a plurality of irradiation positions having different irradiation angles by rotation of the arm portion **28**. The radiation source **29** includes a radiation tube (not illustrated) that generates the radiations R, and the radiation tube is moved to each of the plurality of irradiation positions in accordance with the movement of the radiation source **29**.

[0047] FIG. **2** illustrates an example of tomosynthesis imaging. In FIG. **2**, the compression plate **30** is not illustrated. In the present embodiment, the radiation source **29** is moved to irradiation positions Pk (k=1, 2, . . . , 7) at which irradiation angles are different by a certain angle β. That is, the radiation source **29** is sequentially moved to a plurality of positions at which the irradiation angles of the radiations R with respect to the detection surface **20**A of the radiation detector **20** are different. In FIG. **2**, the number of the irradiation positions Pk is set to 7. On the other hand, the number of the irradiation positions Pk is not limited and can be changed as appropriate.

[0048] At each irradiation position Pk, the radiation R is emitted from the radiation source **29** toward the breast M, and the radiation detector **20** generates a radiation image by detecting the radiation R passing through the breast M. In the radiography system **2**, in a case where the radiation source **29** is moved to each of the irradiation positions Pk and tomosynthesis imaging for generating a radiation image at each irradiation position Pk is performed, in the example of FIG. **2**, seven radiation images are obtained.

[0049] In the following, in the tomosynthesis imaging, the radiation image obtained by performing imaging at each irradiation position Pk is referred to as a "projection image" in a case of distinguishing and describing the radiation image from a tomographic image, and a plurality of projection images obtained by performing tomosynthesis imaging once are referred to as a "series of the plurality of projection images". Further, in a case where the projection image is referred to without distinguishing the projection image from the tomographic image, the projection image is simply referred to as a "radiation image".

[0050] In addition, as illustrated in FIG. **2**, the irradiation angle of the radiation R means an angle α formed by a normal line CL of the detection surface **20**A of the radiation detector **20** and a radiation axis RC. The radiation axis RC means an axis connecting a focus of the radiation source **29** at each irradiation position Pk and a preset position. Further, the detection surface **20**A of the radiation detector **20** is a surface substantially parallel to the imaging surface **24**A. The radiation R emitted from the radiation source **29** is a cone beam having a focus as the apex and the radiation axis RC as a central axis.

[0051] On the other hand, in a case of performing normal imaging in the mammography apparatus **10**, the position of the radiation source **29** is fixed to the irradiation position P**4** at which the irradiation angle α is 0 degree. The radiation R is emitted from the radiation source **29** according to an instruction of the console **12**, and the radiation detector **20** generates a radiation image by detecting the radiation R passing through the breast M.

[0052] The mammography apparatus **10** and the console **12** are connected to each other by wired communication or wireless communication. The radiation image generated by the radiation detector **20** in the mammography apparatus **10** is output to the console **12** by wired communication or wireless communication via a communication interface (I/F) (not illustrated).

[0053] The console **12** includes a control unit **40**, a storage unit **42**, a user I/F **44**, and a communication I/F **46**. As described above, the control unit **40** has a function of performing control related to radiography by the mammography apparatus **10**. The control unit **40** is configured with,

for example, a computer system including a central processing unit (CPU), a read only memory (ROM), and a random access memory (RAM).

[0054] The storage unit **42** stores information related to radiography, the radiation image acquired from the mammography apparatus **10**, and the like. The storage unit **42** is a non-volatile storage such as a hard disk drive (HDD) or a solid state drive (SSD).

[0055] The user I/F **44** includes an input device including various buttons and switches, which are related to imaging of the radiation image and are operated by a user such as a technician, and a display device such as a lamp or a display that displays information related to imaging, the radiation image obtained by imaging, and the like.

[0056] The communication I/F **46** performs communication of various types of data such as the information related to radiography, the radiation image, and the like between the console **12** and the mammography apparatus **10** by wired communication or wireless communication. Further, the communication I/F **46** performs communication of various types of data such as the radiation image between the PACS **14** and the image processing apparatus **16** via the network **17** by wired communication or wireless communication.

[0057] In addition, the PACS **14** includes a storage unit **50** (refer to FIG. **1**) that stores a radiation image group **52**. The radiation image group **52** includes a projection image acquired from the console **12** via the network **17**.

[0058] The image processing apparatus **16** has a function of supporting diagnosis by a doctor by performing determination related to diagnosis of a lesion in a case where a doctor or the like (hereinafter, simply referred to as a "doctor") performs diagnosis related to a lesion of the breast M using the radiation image.

[0059] FIG. **3** illustrates an example of a configuration of the image processing apparatus **16**. The image processing apparatus **16** includes a control unit **60**, a storage unit **62**, a display unit **70**, an operation unit **72**, and a communication I/F **74**. The control unit **60**, the storage unit **62**, the display unit **70**, the operation unit **72**, and the communication I/F **74** are connected to each other via a bus **79** such as a system bus or a control bus such that various types of information can be exchanged.

[0060] The control unit **60** controls overall operations of the image processing apparatus **16**. The control unit **60** is configured with a computer system including a CPU **60**A, a ROM **60**B, and a RAM **60**C. Various programs, data, and the like for performing control by the CPU **60**A are stored in advance in the ROM **60**B. The RAM **60**C temporarily stores various types of data.

[0061] The storage unit **62** is a non-volatile storage such as an HDD or an SSD. The storage unit **62** stores a program **63** for causing the control unit **60** to execute various types of processing, a machine-learned model **64** for performing calcification determination processing to be described later, and the like.

[0062] The display unit **70** is a display that displays a radiation image, various types of information, and the like. The operation unit **72** is used to allow a doctor to input an instruction for diagnosing a lesion of a breast using a radiation image, various types of information, and the like. The operation unit **72** includes, for example, various switches, a touch panel, a touch pen, a mouse, and the like.

[0063] The communication I/F **74** performs communication of various types of information between the console **12** and the PACS **14** via the network **17** by wireless communication or wired communication.

[0064] FIG. **4** illustrates an example of a function realized by the control unit **60** of the image processing apparatus **16**. The CPU **60**A of the control unit **60** realizes various functions by executing processing based on the program **63** stored in the storage unit **62**. The control unit **60** functions as a calcification candidate image detection unit **80**, a calcification candidate image group generation unit **81**, a calcification determination unit **82**, a tomographic image generation unit **83**, and a display control unit **84**.

[0065] FIG. **5** schematically illustrates a flow of processing by the image processing apparatus **16**. Processing by the calcification candidate image detection unit **80**, the calcification candidate image group generation unit **81**, the calcification determination unit **82**, and the tomographic image generation unit **83** will be described with reference to FIG. **5**.

[0066] The calcification candidate image detection unit **80** acquires a series of a plurality of projection images **90** from the console **12** of the mammography apparatus **10** or the PACS **14**. The calcification candidate image detection unit **80** performs calcification candidate image detection processing of detecting, as a calcification candidate image, a region in the breast M that is estimated as an image of a tissue in which an occurrence of calcification is expected (hereinafter, referred to as a calcification image), from the series of the plurality of acquired projection images **90**. Specifically, the calcification candidate image detection unit **80** detects a calcification candidate image from each of the series of the plurality of projection images **90**.

[0067] As the calcification candidate image detection unit **80**, a detector using a known computer-aided diagnosis (CAD) algorithm can be used. In the CAD algorithm, a probability (likelihood) indicating that a pixel in the projection image **90** is a calcification image is derived, and a pixel of which the probability is equal to or higher than a predetermined threshold value is detected as the calcification candidate image.

[0068] The calcification candidate image detection unit **80** is not limited to the detector using the CAD algorithm, and may be configured by a machine-learned model obtained by performing machine learning.

[0069] The detection result of the calcification candidate image by the calcification candidate image detection unit **80** is output as, for example, a mask image **91** representing a position of the calcification image. The mask image **91** is a binary image in which a pixel included in the calcification image is represented by "1" and the other pixels are represented by "0". The calcification candidate image detection unit **80** outputs one mask image **91** for each of the plurality of projection images **90**. In the example illustrated in FIG. **5**, four calcification candidate images C**1** to C**4** are detected by the calcification candidate image detection unit **80**. Here, the calcification candidate images C**1** and C**4** are detected from only one projection image **90** among the plurality of projection images **90**. The calcification candidate images C**2** and C**3** are detected from all of the projection images **90**.

[0070] The calcification candidate image group generation unit **81** performs calcification candidate image group generation processing of generating a calcification candidate image group by cutting out regions respectively corresponding to the region including the calcification candidate image

detected by the calcification candidate image detection processing, from each of the plurality of projection images **90**.

[0071] The calcification candidate image group generation unit **81** generates a calcification candidate image group including a plurality of calcification candidate images by cutting out a region corresponding to the same calcification candidate image, from each of the series of the plurality of projection images **90**, based on the mask image **91**. In addition, in a case where a plurality of calcification candidate images are detected in the calcification candidate image detection processing, the calcification candidate image group generation unit **81** individually generates a calcification candidate image group for each of the calcification candidate images.

[0072] The calcification candidate image group generation unit **81** individually generates a calcification candidate image group for each of the four calcification candidate images C**1** to C**4**. Thereby, a calcification candidate image group G**1** including the calcification candidate image C**1**, a calcification candidate image group G**2** including the calcification candidate image C**2**, a calcification candidate image group G**3** including the calcification candidate image C**3**, and a calcification candidate image group G**4** including the calcification candidate image C**4** are generated.

[0073] FIG. **6** conceptually illustrates an example of processing of generating the calcification candidate image group G**1**. The calcification candidate image group generation unit **81** specifies a region RI in the mask image **91** that includes the calcification candidate image C**1**. In addition, the calcification candidate image group generation unit **81** specifies regions RIA respectively corresponding to the region RI including the calcification candidate image C**1** based on positional information of a radiation tube when each of the series of the plurality of projection images **90** is captured, and generates a calcification candidate image group G**1** by cutting out the regions RIA from each of the plurality of projection images **90**.

[0074] The calcification determination unit **82** performs calcification determination processing of determining whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated by the calcification candidate image group generation processing. In the present embodiment, the calcification determination unit **82** inputs the calcification candidate image group to the machine-learned model **64** obtained by performing machine learning on a relationship between the calcification candidate image and whether or not the calcification candidate image is a calcification image, and acquires a determination result (hereinafter, referred to as a calcification determination result) **82**A output from the machine-learned model **64**.

[0075] The machine-learned model **64** is, for example, a convolutional neural network (CNN) obtained by performing machine learning by deep learning. The machine-learned model **64** may perform two-dimensional convolution processing, pooling processing, and the like by treating the plurality of calcification candidate images included in the calcification candidate image group, as channels. In addition, the machine-learned model **64** may perform three-dimensional convolution processing, pooling processing, and the like by using the calcification candidate image group as voxel data.

[0076] In the example illustrated in FIG. **5**, the calcification determination unit **82** individually inputs each of the four calcification candidate image groups G**1** to G**4** to the machine-learned model **64**. From the machine-learned model **64**, the calcification determination result **82**A representing whether or not the calcification candidate image is a calcification image is output for each of the four calcification candidate image groups G**1** to G**4**. The calcification determination result **82**A includes determination results A**1** to A**4**. The determination result A**1** represents that the calcification candidate image C**1** included in the calcification candidate image group G**1** is not a calcification image but noise. The determination result A**2** represents that the calcification candidate image C**2** included in the calcification candidate image group G**2** is a calcification image. The determination result A**3** represents that the calcification candidate image C**3** included in the calcification candidate image group G**3** is a calcification image. The determination result A**4** represents that the calcification candidate image C**4** included in the calcification candidate image group G**4** is not a calcification image but noise.

[0077] The tomographic image generation unit **83** performs tomographic image generation processing of performing weighting on the calcification candidate image based on the calcification determination result **82**A by the calcification determination processing and then generating a plurality of tomographic images by a back projection method.

[0078] FIG. **7** conceptually illustrates an example of tomographic image generation processing by the tomographic image generation unit **83**. As illustrated in FIG. **7**, the tomographic image generation unit **83** includes a weighting unit **83**A and a back projection processing unit **83**B. The weighting unit **83**A performs weighting on the calcification candidate image based on the calcification determination result **82**A. Specifically, the weighting unit **83**A increases a weight of a pixel included in the calcification candidate image determined to be a calcification image, and decreases a weight of a pixel included in the calcification candidate image determined to be noise.

[0079] In a state where the weighting unit **83**A performs weighting on pixels of the series of the plurality of projection images **90** acquired by the calcification candidate image detection unit **80**, the back projection processing unit **83**B generates a plurality of tomographic images **100** having different heights from the imaging surface **24**A by back projection. As the back projection method, a filter back projection (FBP) method, a successive approximation reconfiguration method, or the like can be used. The back projection processing unit **83**B outputs the plurality of generated tomographic images **100** to the display control unit **84**.

[0080] The display control unit **84** performs display processing of displaying the plurality of tomographic images **100** generated by the tomographic image generation processing on the display unit **70**. The display control unit **84** may perform highlight display by coloring or the like the calcification candidate image determined to be a calcification image by the calcification determination processing.

[0081] Next, a series of processing by the image processing apparatus **16** will be described with reference to FIG. **8**. First, in step S**10**, the calcification candidate image detection unit **80** acquires a series of a plurality of projection images **90** from the console **12** of the mammography apparatus **10** or the PACS **14**.

[0082] In step S**11**, the calcification candidate image detection unit **80** detects, as a calcification candidate image,

a region estimated to be a calcification image from the series of the plurality of projection images **90** acquired in step S**10**.

[0083] In step S**12**, the calcification candidate image group generation unit **81** generates a calcification candidate image group by cutting out regions respectively corresponding to the region including the calcification candidate image detected in step S**11**, from each of the plurality of projection images **90**.

[0084] In step S**13**, the calcification determination unit **82** determines whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated in step S**12**. Specifically, the calcification determination unit **82** inputs the calcification candidate image group to the machine-learned model **64**, and acquires a calcification determination result **82**A from the machine-learned model **64**.

[0085] In step S**14**, the tomographic image generation unit **83** performs weighting on the calcification candidate image based on the calcification determination result **82**A acquired in step S**13**, and then generates a plurality of tomographic images **100** by a back projection method.

[0086] In step S**15**, the display control unit **84** displays the plurality of tomographic images **100** generated in step S**14** on the display unit **70**.

[0087] As described above, according to the technology of the present disclosure, based on the calcification candidate image group generated by cutting out the regions respectively corresponding to the region including the calcification candidate image, from each of the plurality of projection images **90**, it is determined whether or not the calcification candidate image is a calcification image, and thus, it is possible to accurately distinguish a calcification image and noise.

[0088] FIG. **9** conceptually illustrates intensities of signals included in one tomographic image **110** generated from the series of the plurality of projection images **90**. As illustrated in FIG. **9**, in the tomographic image **110**, a calcification image signal S representing a calcification image is buried in a noise signal N. For this reason, in a case where the tomographic image **110** is used, it is difficult to accurately distinguish the calcification image and noise.

[0089] FIG. **10** conceptually illustrates intensities of signals included in each of the calcification candidate images included in the calcification candidate image group G. As illustrated in FIG. **10**, the noise signal N is randomly generated in each of the calcification candidate images, whereas the calcification image signal S is generated with a common intensity in each of the calcification candidate images. As described above, according to the technology of the present disclosure, the calcification candidate image group is used, and thus, the calcification image and the noise can be accurately distinguished based on a pattern of the signals between the calcification candidate images.

[0090] In the embodiment, the calcification candidate image detection unit **80** detects the calcification candidate image from the plurality of projection images **90**. The calcification candidate image detection unit **80** may detect only a calcification candidate image (so-called pale calcification candidate image) of which a signal value is equal to or smaller than a certain value. This is because a shape of the pale calcification candidate image is not accurately represented and it is difficult to determine whether or not the tomographic image **100** as a clinical image that is displayed on the display unit **70** is a calcification image.

[0091] FIG. **11** conceptually illustrates an example of learning processing of a machine learning model **64**A. As illustrated in FIG. **11**, the machine-learned model **64** is generated by performing machine learning on the machine learning model **64**A using training data **200** in a learning phase. The training data **200** includes a set of a plurality of sample image groups **210** and a plurality of pieces of correct answer data **220**. The sample image group **210** is images corresponding to the calcification candidate image group. The correct answer data **220** is information representing a correct answer as to whether or not the calcification candidate image included in the sample image group **210** is a calcification image.

[0092] The machine learning is performed on the machine learning model **64**A using, for example, an error back propagation method. In the learning phase, error calculation between the determination result obtained by inputting the sample image group **210** to the machine learning model **64**A and the correct answer data **220** and update setting of weights and biases are repeatedly performed. The machine learning model **64**A on which machine learning is performed in the learning phase is stored in the storage unit **62**, as a machine-learned model **64**. The machine learning of the machine learning model **64**A may be performed in the image processing apparatus **16** or in an external apparatus.

[0093] Hereinafter, various modification examples of the embodiment will be described.

First Modification Example

[0094] The first modification example is different from the embodiment only in calcification candidate image group generation processing by the calcification candidate image group generation unit **81**. In the present modification example, the calcification candidate image group generation unit **81** generates a calcification candidate image group in a case where a corresponding calcification candidate image is detected from two or more projection images **90** among the series of the plurality of projection images **90** in the calcification candidate image detection processing.

[0095] FIG. **12** schematically illustrates a flow of processing by the image processing apparatus **16** according to the first modification example. In the example illustrated in FIG. **12**, the calcification candidate images C**1** and C**4** are detected from only one projection image **90**, and the calcification candidate images C**2** and C**3** are detected from two or more projection images **90**. Therefore, in the present example, the calcification candidate image group generation unit **81** generates only calcification candidate image groups G**2** and G**3** respectively including the calcification candidate images C**2** and C**3** among the calcification candidate images C**1** to C**4**.

[0096] FIG. **13** illustrates a flow of calcification candidate image group generation processing according to the first modification example. First, in step S**120**, the calcification candidate image group generation unit **81** selects one calcification candidate image from among the plurality of calcification candidate images detected in the calcification candidate image detection processing.

[0097] In step S**121**, the calcification candidate image group generation unit **81** determines whether or not the calcification candidate image selected in step S**120** is detected from two or more projection images **90**. In a case where the calcification candidate image is detected from two or more projection images **90**, a determination result is Yes,

and the processing proceeds to step S122. In a case where the calcification candidate image is not detected from two or more projection images 90, a determination result is No, and the processing proceeds to step S123.

[0098] In step S122, the calcification candidate image group generation unit 81 generates a calcification candidate image group including the calcification candidate image detected from two or more projection images 90.

[0099] In step S123, the calcification candidate image group generation unit 81 determines whether or not the calcification candidate image selected in step S120 is a final calcification candidate image. That is, in step S123, the calcification candidate image group generation unit 81 determines whether or not the determination in step S121 is performed for all the calcification candidate images. In a case where the calcification candidate image is a final calcification candidate image, a determination result is Yes, and the processing is ended. In a case where the calcification candidate image is not a final calcification candidate image, a determination result is No, and the processing proceeds to step S124.

[0100] In step S124, the calcification candidate image group generation unit 81 changes the calcification candidate image to another calcification candidate image that is not selected in step S120. After step S124, the processing returns to step S120. Pieces of processing of step S120 to step S124 are repeatedly performed until the determination result in step S123 is Yes.

[0101] In the present modification example, the calcification candidate image detected from only one projection image 90 among the series of the plurality of projection images 90 is likely to be noise, and thus, the calcification candidate image group is not generated. In this way, the calcification candidate image detected from only one projection image 90 is excluded in advance from targets for generation of the calcification candidate image group, and thus the processing speed by the image processing apparatus 16 can be increased.

[0102] In step S121, the calcification candidate image group generation unit 81 determines whether or not the calcification candidate image selected in step S120 is detected from two or more projection images 90. On the other hand, the number of images as a determination criterion is not limited to two. That is, the calcification candidate image group generation unit 81 may determine whether or not the calcification candidate image is detected from a predetermined number or more of projection images 90.

Second Modification Example

[0103] FIG. 14 illustrates a function realized by the control unit 60 of the image processing apparatus 16 according to a second modification example. In the present modification example, the control unit 60 functions as a tomographic image generation unit 85, a calcification candidate image detection unit 80, a calcification candidate image group generation unit 81, a calcification determination unit 82, a synthesized two-dimensional image generation unit 86, and a display control unit 84.

[0104] FIG. 15 schematically illustrates a flow of processing by the image processing apparatus 16 according to the second modification example. The tomographic image generation unit 85 acquires a series of a plurality of projection images 90 from the console 12 of the mammography apparatus 10 or the PACS 14. The tomographic image generation unit 85 generates a plurality of tomographic images 300 having different heights from the imaging surface 24A by a back projection method based on the series of the plurality of acquired projection images 90.

[0105] In the present modification example, the calcification candidate image detection unit 80 performs calcification candidate image detection processing of detecting, as a calcification candidate image, a region estimated to be a calcification image from the plurality of tomographic images 300. In the present modification example, the calcification candidate image detection unit 80 outputs a plurality of mask images 91 corresponding to each of the plurality of tomographic images 300. In the example illustrated in FIG. 15, four calcification candidate images C1 to C4 are detected by the calcification candidate image detection unit 80.

[0106] The calcification candidate image group generation unit 81 generates a calcification candidate image group including a plurality of calcification candidate images by cutting out a region corresponding to the same calcification candidate image, from each of the series of the plurality of projection images 90, based on the plurality of mask images 91 and the positional information of the radiation tube when each of the series of the plurality of projection images 90 is captured. In addition, in a case where a plurality of calcification candidate images are detected in the calcification candidate image detection processing, the calcification candidate image group generation unit 81 individually generates a calcification candidate image group for each of the calcification candidate images. In the example illustrated in FIG. 15, the calcification candidate image group generation unit 81 individually generates a calcification candidate image group for each of the four calcification candidate images C1 to C4.

[0107] The calcification determination unit 82 performs calcification determination processing of determining whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated by the calcification candidate image group generation processing, as in the above embodiment.

[0108] The synthesized two-dimensional image generation unit 86 performs weighting on the calcification candidate image based on the calcification determination result 82A obtained by the calcification determination processing, and then performs synthesized two-dimensional image generation processing of generating a synthesized two-dimensional image by synthesizing the plurality of tomographic images 300.

[0109] FIG. 16 conceptually illustrates an example of synthesized two-dimensional image generation processing by the synthesized two-dimensional image generation unit 86. As illustrated in FIG. 16, the synthesized two-dimensional image generation unit 86 includes a weighting unit 86A and a synthesizing processing unit 86B. The weighting unit 86A performs weighting on the calcification candidate image based on the calcification determination result 82A. Specifically, the weighting unit 86A increases a weight of a pixel included in the calcification candidate image determined to be a calcification image, and decreases a weight of a pixel included in the calcification candidate image determined to be noise.

[0110] The synthesizing processing unit 86B performs weighting on pixels of the plurality of tomographic images 300, which are generated by the tomographic image generation unit 85, by the weighting unit 86A, and then gener-

ates a synthesized two-dimensional image **310** by synthesizing the plurality of tomographic images **300**. As a method of synthesizing the plurality of tomographic images **300**, for example, an addition method, an average method, a maximum value projection method, a minimum value projection method, or the like can be used. The synthesizing processing unit **86**B outputs the synthesized two-dimensional image **310** that is generated to the display control unit **84**.

[0111] In the present modification example, the display control unit **84** performs display processing of displaying the synthesized two-dimensional image **310** generated by the synthesized two-dimensional image generation processing on the display unit **70**. The display control unit **84** may perform highlight display in the synthesized two-dimensional image **310** by coloring or the like the calcification candidate image determined to be a calcification image by the calcification determination processing.

[0112] Next, a series of processing by the image processing apparatus **16** according to the second modification example will be described with reference to FIG. **17**. First, in step S**20**, the tomographic image generation unit **85** acquires a series of a plurality of projection images **90** from the console **12** of the mammography apparatus **10** or the PACS **14**.

[0113] In step S**21**, the tomographic image generation unit **85** generates a plurality of tomographic images **300** based on the plurality of projection images **90** acquired in step S**20**.

[0114] In step S**22**, the calcification candidate image detection unit **80** detects, as a calcification candidate image, a region estimated to be a calcification image from the plurality of tomographic images **300** generated in step S**21**.

[0115] In step S**23**, the calcification candidate image group generation unit **81** generates a calcification candidate image group by cutting out regions respectively corresponding to the region including the calcification candidate image detected in step S**22**, from each of the plurality of projection images **90**.

[0116] In step S**24**, the calcification determination unit **82** determines whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated in step S**23**. Specifically, the calcification determination unit **82** inputs the calcification candidate image group to the machine-learned model **64**, and acquires a calcification determination result **82**A from the machine-learned model **64**.

[0117] In step S**25**, the synthesized two-dimensional image generation unit **86** performs weighting on the calcification candidate image based on the calcification determination result **82**A acquired in step S**24**, and then generates a synthesized two-dimensional image **310** by synthesizing the plurality of projection images **90**.

[0118] In step S**26**, the display control unit **84** displays the synthesized two-dimensional image **310** generated in step S**25** on the display unit **70**.

[0119] Even in the present modification example, based on the calcification candidate image group generated by cutting out the regions respectively corresponding to the region including the calcification candidate image, from each of the plurality of projection images **90**, it is determined whether or not the calcification candidate image is a calcification image, and thus, it is possible to accurately distinguish a calcification image and noise.

Other Modification Examples

[0120] In the embodiment and each modification example, the calcification determination unit **82** performs the calcification determination processing using the machine-learned model **64**. On the other hand, the calcification determination processing may be performed by a method such as image analysis, without using the machine-learned model **64**. For example, the calcification determination unit **82** determines whether or not the calcification candidate image is a calcification image by analyzing a pattern of signals included in each of the calcification candidate images included in the calcification candidate image group. For example, as illustrated in FIG. **10**, in a case where a common signal S is included in each of the calcification candidate images, the calcification determination unit **82** determines that the calcification candidate image corresponding to the signal S is a calcification image.

[0121] As described above, the calcification determination unit **82** may determine whether or not the calcification candidate image is a calcification image based on a pattern of signals included in each of the calcification candidate images included in the calcification candidate image group. The pattern of the signals that is to be analyzed by the calcification determination unit **82** may be a distribution of intensities of signals (for example, a variance value). In addition, the calcification determination unit **82** may determine whether or not the calcification candidate image is a calcification image based on a pattern of signals included in a small region of the calcification candidate image without being limited to the entire calcification candidate image.

[0122] The embodiment and the modification examples can be appropriately combined as long as there is no contradiction.

[0123] In addition, in the embodiment and the first modification example, as the hardware structure of a processing unit that executes various types of processing, such as the calcification candidate image detection unit **80**, the calcification candidate image group generation unit **81**, the calcification determination unit **82**, the tomographic image generation unit **83**, and the display control unit **84**, the following various processors can be used. Further, in the second modification example, as the hardware structure of a processing unit that executes various types of processing, such as the tomographic image generation unit **85**, the calcification candidate image detection unit **80**, the calcification candidate image group generation unit **81**, the calcification determination unit **82**, the synthesized two-dimensional image generation unit **86**, and the display control unit **84**, the following various processors can be used.

[0124] The various processors include a graphics processing unit (GPU) in addition to a CPU. In addition, the various processors are not limited to a general-purpose processor such as a CPU that functions as various processing units by executing software (program), and include a dedicated electric circuit, which is a processor having a circuit configuration specifically designed to execute specific processing, such as a programmable logic device (PLD) or an application specific integrated circuit (ASIC) that is a processor of which the circuit configuration may be changed after manufacturing such as a field programmable gate array (FPGA).

[0125] One processing unit may be configured by one of the various processors, or may be configured by a combination of the same or different kinds of two or more processors (for example, a combination of a plurality of

FPGAs or a combination of the CPU and the FPGA). In addition, a plurality of processing units may be configured by one processor.

[0126] As an example in which the plurality of processing units are configured by one processor, firstly, as represented by a computer such as a client and a server, a form in which one processor is configured by a combination of one or more CPUs and software and the processor functions as the plurality of processing units may be adopted. Secondly, as represented by a system on chip (SoC) or the like, a form in which a processor that realizes the function of the entire system including the plurality of processing units by one integrated circuit (IC) chip is used may be adopted. As described above, the various processing units are configured by using one or more various processors as a hardware structure.

[0127] Furthermore, as the hardware structure of the various processors, more specifically, an electrical circuit (circuitry) in which circuit elements such as semiconductor elements are combined can be used.

[0128] In addition, in the embodiment and the modification examples, a form in which the program **63** is stored in the storage unit **62** in advance has been described. On the other hand, the present disclosure is not limited thereto. The program **63** may be provided by being recorded in a non-transitory recording medium such as a compact disc read only memory (CD-ROM), a digital versatile disc read only memory (DVD-ROM), or a Universal Serial Bus (USB) memory. Further, the program **63** may be downloaded from an external apparatus via a network.

[0129] The described contents and the illustrated contents are the detailed description of the parts according to the technology of the present disclosure, and are merely examples of the technology of the present disclosure. For example, the descriptions related to the configuration, the function, the operation, and the effect are descriptions related to examples of a configuration, a function, an operation, and an effect of a part according to the technology of the present disclosure. Therefore, it goes without saying that, in the described contents and illustrated contents, unnecessary parts may be deleted, new components may be added, or replacements may be made without departing from the spirit of the technology of the present disclosure. Further, in order to avoid complications and facilitate understanding of the part according to the technology of the present disclosure, in the described contents and illustrated contents, descriptions of technical knowledge and the like that do not require particular explanations to enable implementation of the technology of the present disclosure are omitted.

[0130] All documents, patent applications, and technical standards mentioned in this specification are incorporated herein by reference to the same extent as in a case where each document, each patent application, and each technical standard are specifically and individually described by being incorporated by reference.

What is claimed is:

1. An image processing apparatus comprising:

at least one processor,

wherein the processor is configured to execute:

calcification candidate image detection processing of detecting a calcification candidate image estimated to be a calcification image from a series of a plurality of projection images obtained by tomosynthesis imaging of a breast or a plurality of tomographic images obtained from the plurality of projection images;

calcification candidate image group generation processing of generating a calcification candidate image group by cutting out a region including the calcification candidate image detected by the calcification candidate image detection processing, from each of the plurality of projection images; and

calcification determination processing of determining whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated by the calcification candidate image group generation processing,

wherein the processor is configured to:

in a case where a plurality of the calcification candidate images are detected in the calcification candidate image detection processing, individually generate the calcification candidate image group for each of the plurality of calcification candidate images in the calcification candidate image group generation processing.

2. The image processing apparatus according to claim **1**,

wherein the processor is configured to:

detect only the calcification candidate image of which a signal value is equal to or smaller than a certain value in the calcification candidate image detection processing.

3. The image processing apparatus according to claim **1**,

wherein the processor is configured to:

detect the calcification candidate image estimated to be a calcification image from the plurality of projection images in the calcification candidate image group generation processing; and

generate the calcification candidate image group in the calcification candidate image group generation processing, in a case where a corresponding calcification candidate image is detected from a certain number or more of the projection images among the series of the plurality of projection images in the calcification candidate image detection processing.

4. The image processing apparatus according to claim **1**,

wherein the processor is configured to:

detect the calcification candidate image estimated to be a calcification image from the plurality of projection images in the calcification candidate image group generation processing; and

perform weighting on the calcification candidate image based on a determination result of the calcification determination processing, and generate the plurality of tomographic images by a back projection method.

5. The image processing apparatus according to claim **1**,

wherein the processor is configured to:

detect the calcification candidate image estimated to be a calcification image from the plurality of tomographic images in the calcification candidate image group generation processing; and

perform weighting on the calcification candidate image based on a determination result of the calcification determination processing, and generate a synthesized two-dimensional image by synthesizing the plurality of tomographic images.

6. The image processing apparatus according to claim **1**,

wherein the processor is configured to:

execute the calcification determination processing by inputting the calcification candidate image group into a

machine-learned model obtained by performing machine learning of a relationship between the calcification candidate image group and whether or not the calcification candidate image is a calcification image.

7. The image processing apparatus according to claim **1**, wherein the processor is configured to:

determine whether or not the calcification candidate image is a calcification image based on a pattern of signals included in each of the calcification candidate images included in the calcification candidate image group in the calcification determination processing.

8. An image processing method comprising:

a calcification candidate image detection step of detecting a calcification candidate image estimated to be a calcification image from a series of a plurality of projection images obtained by tomosynthesis imaging of a breast or a plurality of tomographic images obtained from the plurality of projection images;

a calcification candidate image group generation step of generating a calcification candidate image group by cutting out a region including the calcification candidate image detected by the calcification candidate image detection step, from each of the plurality of projection images; and

a calcification determination step of determining whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated by the calcification candidate image group generation step,

wherein in a case where a plurality of the calcification candidate images are detected in the calcification candidate image detection step, the calcification candidate image group for each of the plurality of calcification candidate images is individually generated in the calcification candidate image group generation step.

9. A non-transitory computer-readable storage medium storing a program causing a computer to execute:

calcification candidate image detection processing of detecting a calcification candidate image estimated to be a calcification image from a series of a plurality of projection images obtained by tomosynthesis imaging of a breast or a plurality of tomographic images obtained from the plurality of projection images;

calcification candidate image group generation processing of generating a calcification candidate image group by cutting out a region including the calcification candidate image detected by the calcification candidate image detection processing, from each of the plurality of projection images; and

calcification determination processing of determining whether or not the calcification candidate image is a calcification image based on the calcification candidate image group generated by the calcification candidate image group generation processing,

wherein the program causes the computer to:

in a case where a plurality of the calcification candidate images are detected in the calcification candidate image detection processing, individually generate the calcification candidate image group for each of the plurality of calcification candidate images in the calcification candidate image group generation processing.

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