

Description

Title of Invention:

DEVICE FOR DETERMINING TYPE OF ARRHYTHMIA,
METHOD FOR DETERMINING TYPE OF ARRHYTHMIA, AND
5 PROGRAM FOR DETERMINING TYPE OF ARRHYTHMIA

Technical Field

[0001]

10 The present invention relates to technology for
determining a type of arrhythmia.

Background Art

[0002]

15 There is a widely-used technology for acknowledging a
relation between the left and right sides of the heart and a
relation between the atriums from a moving image of a heart
obtained by ultrasonography. For example, Patent Literature 1
discloses an ultrasound diagnostic device that identifies a
group of boundary positions between a plurality of heart
20 chambers in a moving image obtained by ultrasonography and
obtains, on the basis of a result of tracking the group of the
boundary positions, the boundary positions between the
plurality of heart chambers over a period of at least one
heartbeat.

Citation List

Patent Literatures

[0003]

Patent Literature 1

5 Japanese Patent Application Publication, Tokukai, No.
2022-149097

Summary of Invention

Technical Problem

10 [0004]

Conventionally, electrocardiography has primarily been
used to diagnose arrhythmia. With electrocardiography,
however, it is sometimes difficult to determine a type of
arrhythmia having occurred. This leaves room for improvement
15 in terms of accuracy in determination.

[0005]

An aspect of the present invention has an object to
precisely determine a type of arrhythmia from an image
obtained by image-capturing of a heart.

20 Solution to Problem

[0006]

In order to attain the above object, an arrhythmia type
determination device in accordance with an aspect of the
present invention includes: an obtaining section which obtains
25 peak information about one or more higher-level peak

frequencies each having a high peak value, among peak frequencies in frequency spectra of signal waveforms indicative of time-series changes in an area of each of regions of a left atrium, a left ventricle, a right atrium, and a right ventricle included in an image obtained by image-capturing of a heart; and a determination section which determines a type of arrhythmia on a basis of the peak information.

[0007]

An arrhythmia type determination method in accordance with an aspect of the present invention is an arrhythmia type determination method which is executed by one or more information processing devices, the arrhythmia type determination method including: an obtaining step of obtaining peak information about one or more higher-level peak frequencies each having a high peak value, among peak frequencies in frequency spectra of signal waveforms indicative of time-series changes in an area of each of regions of a left atrium, a left ventricle, a right atrium, and a right ventricle included in an image obtained by image-capturing of a heart; and a determination step of determining a type of arrhythmia on a basis of the peak information.

[0008]

The arrhythmia type determination device in accordance with the foregoing aspects of the present invention may be realized by a computer. In such a case, the present invention

encompasses: a control program for the information processing device that causes a computer to operate as each of the sections (software elements) of the arrhythmia type determination device so that the arrhythmia type determination device can be realized by the computer; and a computer-readable storage medium storing the control program therein.

Advantageous Effects of Invention

[0009]

In accordance with an aspect of the present invention, it is possible to precisely determine a type of arrhythmia from an image of a heart.

Brief Description of Drawings

[0010]

Fig. 1 is a view illustrating an example of a configuration of an arrhythmia type determination system in accordance with an embodiment of the present invention.

Fig. 2 is a block diagram illustrating an example of a configuration of a main part of an arrhythmia type determination device in accordance with the embodiment of the present invention.

Fig. 3 is a block diagram illustrating an example of a configuration of a main part of an information processing device in accordance with the embodiment of the present invention.

Fig. 4 is a block diagram illustrating an example of a configuration of a main part of a learning device in accordance with the embodiment of the present invention.

5 Fig. 5 is a block diagram illustrating an example of a configuration of a main part of an arrhythmia detection device in accordance with the embodiment of the present invention.

Fig. 6 is a view illustrating an example of regions in an image obtained by image-capturing of a heart which regions are targets to be detected.

10 Fig. 7 is a view illustrating an example of a process carried out by the information processing device.

Fig. 8 is a view illustrating an example of signal waveforms indicative of time-series changes in areas of atriums and ventricles.

15 Fig. 9 is a view illustrating an example of peak information extracted from frequency spectra of the signal waveforms indicative of the time-series changes in the areas of the atriums and ventricles.

20 Fig. 10 is a view illustrating (i) an example of a data structure of time-frequency analysis data obtained by carrying out time-frequency analysis on a signal waveform indicative of time-series changes in the area of a respective one of the regions of the heart and (ii) an example of a heat map generated from the time-frequency analysis data.

25 Fig. 11 is a view illustrating an example of a method for

correcting a result of wavelet analysis on signal waveforms indicative of time-series changes in the areas of the atriums and ventricles.

Fig. 12 is a view illustrating a case where determination of premature contraction is made on the basis of the result of wavelet analysis carried out on the signal waveforms indicative of the time-series changes in the areas of the atriums and ventricles.

Fig. 13 is a sequence diagram illustrating an example of a process carried out by the arrhythmia type determination system.

Fig. 14 is a flowchart illustrating an example of a process carried out by an arrhythmia type determination device.

Fig. 15 is a view illustrating an example of criteria for classification of a type of arrhythmia which classification is carried out by the arrhythmia type determination device.

Fig. 16 is a view illustrating an example of a result of classification of a type of arrhythmia which classification is carried out by the arrhythmia type determination device.

Fig. 17 is a view illustrating an example of a result of determination of a type of arrhythmia which determination is made by the arrhythmia type determination device.

Description of Embodiments

[0011]

Embodiments

The following will describe details of an embodiment of the present invention.

[0012]

5 Overview of Arrhythmia Type Determination Device 1

An arrhythmia type determination device 1 in accordance with an embodiment of the present invention determines a type of arrhythmia on the basis of peak information obtained from frequency spectra of signal waveforms indicative of time-series
10 changes in an area of each of regions included in a heart, that is, a left atrium, a left ventricle, a right atrium, and a right ventricle. Here, the peak information is information about one or more higher-level peak frequencies each having a high peak value, among peak frequencies in the frequency spectra of the
15 signal waveforms indicative of the time-series changes in the area of each of the atriums and ventricles.

[0013]

The areas of the atriums and ventricles can be calculated on the basis of areas of regions corresponding to the atriums and ventricles included in an input image (e.g., an ultrasound
20 image such as an echo image for forming a tomographic image) which is obtained by image-capturing of a heart of a subject and which includes images of a plurality of frames. In the ultrasound image, the atriums and ventricles of the heart are
25 imaged as closed spaces. For each of the frames, the areas of

the regions corresponding to the atriums and ventricles can be calculated. That is, from the ultrasound image, the areas of the left atrium, left ventricle, right atrium, and right ventricle of the subject's heart are calculated, and the frequency spectra of the signal waveforms indicative of the time-series changes are analyzed. Consequently, it is possible to obtain the peak information. Hereinafter, the areas of the regions corresponding to the atriums and ventricles will be referred to as "the areas of the atriums and ventricles" or "the areas of the regions".

[0014]

On the basis of the peak information, the arrhythmia type determination device 1 can determine (i) "normocardia", which indicates a heartbeat of a frequency in a reference frequency band (e.g., not less than 100 bpm and not more than 170 bpm) that is set as a normal range in advance, and (ii) six types of arrhythmia indicated below.

- "Premature atrial contraction (PAC)": Arrhythmia in which contraction out of contraction rhythm occurs in an atrium. -

"Premature ventricular contraction (PVC)": Arrhythmia in which contraction out of contraction rhythm occurs in a ventricle. - "Atrial flutter (AFL)": Arrhythmia in which fast movement at approximately 200 bpm to 350 bpm occurs in an atrium.

- "Supraventricular tachycardia (SVT)": Arrhythmia in which

movement of atriums and ventricles is faster than frequencies in the reference frequency band.

- "Sinus bradycardia": Arrhythmia in which movement of atriums and ventricles is slower than frequencies in the reference frequency band.

- "Complete atrioventricular block (CAVB)": Arrhythmia in which movement of atriums is normal but movement of ventricles is slow and thus the atriums and ventricles do not work in cooperation with each other.

[0015]

The areas of the atriums and ventricles may be generated on the basis of an ultrasound image including images of a plurality of frames obtained as a result of image-capturing of a fetus. The ultrasound image obtained by image-capturing of the fetus includes the fetus's heart. From the ultrasound image, the areas of the left atrium, left ventricle, right atrium, and right ventricle of the fetus's heart are calculated, and the frequency spectra of the signal waveforms indicative of the time-series changes are analyzed. In this manner, it is possible to obtain the peak information.

[0016]

The inventors of the present invention found that the peak information (e.g., a band of each peak frequency and a proportion of each peak value) varies depending on the type of arrhythmia. Employment of this determination method makes

it possible to precisely determine a type of arrhythmia having occurred in the heart from, for example, an ultrasound image obtained by image-capturing of a heart.

[0017]

5 Configuration of Arrhythmia Type Determination System
100

First, the following will describe, with reference to Fig. 1, a configuration of an arrhythmia type determination system 100 in accordance with an embodiment of the present invention. Fig. 1 is a view illustrating an example of the configuration of the arrhythmia type determination system 100. The arrhythmia type determination system 100 may include an image capturing device 2, an information processing device 3, a learning device 5, an arrhythmia detection device 4, an arrhythmia type determination device 1, and a display device 6.

[0018]

The image capturing device 2 may be an ultrasound image capturing device capable of capturing an image of an area inside a subject in a non-invasive manner. As shown in Fig. 1, the image capturing device 2 may be communicably connected with the information processing device 3. In this case, the information processing device 3 may directly obtain, from the image capturing device 2, an input image obtained by image-capturing carried out by the image capturing device 2.

25 [0019]

The information processing device 3 uses a learning model to detect regions corresponding to atriums and ventricles of a heart included in the input image. Further, the information processing device 3 calculates, for each frame, areas of the atriums and ventricles thus detected. The information processing device 3 may be provided in a facility (e.g., a medical facility) in which the image capturing device 2 is provided or may be provided in a remote place. In a case where the information processing device 3 is provided in a remote place, the information processing device 3 may obtain the input image through communication carried out over a communication network such as the Internet.

[0020]

The learning device 5 generates, from the image of the heart imaged by the image capturing device 2, a learning model used to detect the regions corresponding to the atriums and ventricles of the heart. The learning device 5 executes a program for causing a computer to function as a learning device. The function of the learning device 5 may be included in the information processing device 3. In this case, the learning device 5 is eliminated from the constituent elements of the arrhythmia type determination system 100.

[0021]

By using the calculation result from the information processing device 3, the arrhythmia detection device 4 analyzes

time-series changes in the areas of the atriums and ventricles. The arrhythmia detection device 4 may be capable of detecting arrhythmia by detecting fluctuations in cyclic increasing and decreasing patterns of the areas of the left atrium, right atrium, left ventricle, and right ventricle. The function of the arrhythmia detection device 4 may be included in the information processing device 3. In this case, the arrhythmia detection device 4 is eliminated from the constituent elements of the arrhythmia type determination system 100.

[0022]

By using the analysis result output from the arrhythmia detection device 4, the arrhythmia type determination device 1 determines a type of the arrhythmia. As shown in Fig. 1, the arrhythmia type determination device 1 may be communicably connected with the arrhythmia detection device 4. In this case, the arrhythmia type determination device 1 may directly obtain, from the arrhythmia detection device 4, the analysis result obtained by the analysis carried out by the arrhythmia detection device 4. Note that the analysis obtained by the analysis carried out by the arrhythmia detection device 4 may be stored in a portable storage medium, for example. In this case, the arrhythmia type determination device 1 may read the analysis result from the storage medium. Alternatively, the analysis result obtained by the analysis carried out by the arrhythmia detection device 4 may be stored in, e.g., a storage

device (not illustrated) such that the analysis result is associated with subject information (e.g., electronic medical record information) of each subject. In this case, the arrhythmia type determination device 1 may obtain the analysis result from the storage device.

[0023]

The arrhythmia type determination device 1 may be provided in a facility (e.g., a medical facility) in which the arrhythmia detection device 4 is provided or may be provided in a remote place. In a case where the arrhythmia type determination device 1 is provided in the remote place, the arrhythmia type determination device 1 may obtain, over communication carried out via a communication network such as the Internet, the analysis result obtained by the analysis carried out by the arrhythmia detection device 4.

[0024]

The display device 6 is a device which can display various kinds of information output from the arrhythmia type determination device 1. The display device 6 may display, in addition to the various kinds of information output from the arrhythmia type determination device 1, the detection result output from the arrhythmia detection device and the analysis result output from the arrhythmia detection device 4.

[0025]

Further, a part of the processes which are to be carried

out by the arrhythmia type determination device 1 may be carried out by another computer system. For example, the determination of the type of the arrhythmia can include a classification process and a determination process, each of which will be described later. However, at least one of the classification process and determination process may be carried out by another computer system. In this case, the arrhythmia type determination device 1 may transmit information necessary to carry out the classification process or determination process to another computer system through communication carried out via a communication network and may receive a process result transmitted from the another computer system.

[0026]

The arrhythmia type determination device 1 may include any one of or all of the function of the information processing device 3, the function of the arrhythmia detection device 4, and the function of the learning device 5. For example, in a case where the arrhythmia type determination device 1 has the function of the information processing device 3 and the function of the arrhythmia detection device 4, the information processing device 3 and the arrhythmia detection device 4 are eliminated from the constituent elements of the arrhythmia type determination system 100.

[0027]

Configuration of Arrhythmia Type Determination Device

1

Next, the following will describe a configuration of the arrhythmia type determination device 1 with reference to Fig.

2. Fig. 2 is a block diagram illustrating an example of a
5 configuration of a main part of the arrhythmia type determination device 1. As shown in Fig. 2, the arrhythmia type determination device 1 includes a processor 10, a memory 11, and a storage device 12. The arrhythmia type determination
10 device 1 may be, for example, a personal computer, a server, or a work station. The processor 10 loads the information processing program stored in the storage device 12 into the memory 11 and executes the information processing program, so that the processor 10 functions as an obtaining section 101,
15 a determination section 102, an attenuating section 104, and an output control section 103.

[0028]

The processor 10 can be realized by a logical circuit (hardware) formed in an integrated circuit (IC chip) or the like
20 or can be realized by software. In a case where the processor 10 is realized by software, the processor 10 may be constituted by, for example, a Central Processing Unit (CPU), a Graphics Processing Unit (GPU), or a combination thereof. In this case, the software is stored in the storage device 12. Further, the
25 processor 10 loads the software into the memory 11 and

executes the software.

[0029]

Each of the memory 11 and the storage device 12 is a storage device in which various kinds of data used by the arrhythmia type determination device 1 is stored. The memory 11 is a storage device capable of writing and reading out data at higher speeds in comparison to the storage device 12. The storage device 12 has a larger data storage capacity in comparison to the memory 11. As the memory 11, a high-speed access memory such as a Synchronous Dynamic Random-Access Memory (SDRAM) can be employed, for example. As the storage device 12, a Hard Disk Drive (HDD), a Solid-State Drive (SSD), a Secure Digital (SD) card, an embedded Multi-Media Controller (eMMC), or the like can be employed, for example.

[0030]

The arrhythmia type determination device 1 includes, as an interface (IF) with an external device, an arrhythmia detection device interface section 13 and a display device interface section 14. As each of these interfaces, any interface is applicable. Examples of such an interface may include a Universal Serial Bus (USB) and a High-Definition Multimedia Interface (HDMI) (registered trademark).

[0031]

The arrhythmia detection device interface section 13 is an interface via which the arrhythmia detection device 4 and

the arrhythmia type determination device 1 are communicably connected with each other. The arrhythmia detection device interface section 13 may be an interface for wired communication or an interface for radio communication. For example, a USB, a Local-Area Network (LAN), a wireless LAN, or the like can be employed as each of these interface sections. Each of these interfaces is an interface for obtaining the above-described input image from the image capturing device 2. The display device interface section 14 is an interface for transmitting, to the display device 6, information output from the arrhythmia type determination device 1.

[0032]

The display device interface section 14 is an interface which is used by the arrhythmia type determination device 1 to display an image on the non-illustrated display device 6. For example, the arrhythmia type determination device 1 can also cause, via the display device interface section 14, the display device 6 to display the analysis result obtained by the analysis carried out by the arrhythmia detection device. Note that the arrhythmia type determination device 1 may include a display section which can function as the display device 6.

[0033]

The arrhythmia type determination device 1 may further include an interface via which the arrhythmia type determination device 1 communicates with various devices (e.g.,

the storage device) on a communication network such as the Internet, for example. Note that the arrhythmia type determination device 1 may include, in addition to the above-described interfaces, an interface and/or the like for access to, for example, an externally attached storage device (e.g., a hard disk).

[0034]

The processor 10 functions as each of the obtaining section 101, the determination section 102, the attenuating section 104, and the output control section 103 as discussed above. The following will describe each of the sections.

[0035]

The obtaining section 101 obtains an analysis result obtained by analysis on the time-series changes in the areas of the regions of the heart which analysis is carried out by the arrhythmia detection device 4. Specifically, the analysis result is peak information about one or more higher-level peak frequencies each having a high peak value, among the peak frequencies in the frequency spectra of the signal waveforms indicative of the time-series changes in the areas of the regions, that is, the left atrium, left ventricle, right atrium, and right ventricle of the heart included in the input image. There is no particular limitation on a method for obtaining the analysis result. For example, the obtaining section 101 may obtain a captured image from the image capturing device 2 via the

arrhythmia detection device interface section 13.

[0036]

On the basis of the peak information which is the analysis result obtained by the analysis on the time-series changes in the areas of the regions of the heart which analysis is carried out by the arrhythmia detection device 4, the determination section 102 determines the type of the arrhythmia occurring in the heart.

[0037]

Note that the peak information may include time-frequency analysis data obtained by carrying out time-frequency analysis on the signal waveform indicative of the time-series changes in the area of each of the regions. In this case, the determination section 102 may determine the type of the arrhythmia (e.g., premature contraction) on the basis of the time-series changes in a first peak frequency in the time-frequency analysis data. In this case, the arrhythmia type determination device 1 functions as a premature contraction determination device. In a case where a period in which a value of the first peak frequency has changed by a prescribed proportion (e.g., 10%) or more exists in the time-frequency analysis data, the determination section 102 may determine that the arrhythmia is premature contraction. In this case, the determination section 102 may specify, as the period in which the premature contraction has occurred, a period from (i) a time

point at which the value of the first peak frequency starts decreasing toward a value decreased by the prescribed proportion or more to (ii) a time point at which the value of the first peak frequency finishes increasing by the given proportion or more from the decreased value.

[0038]

The attenuating section 104 carries out attenuation such that, among frequency components in the time-frequency analysis data obtained by the time-frequency analysis on the signal waveforms indicative of the time-series changes in the areas of the regions, a frequency which is farther away from the first peak frequency is attenuated more (see Fig. 11). With this, the arrhythmia type determination device 1 can precisely determine the premature contraction.

[0039]

The output control section 103 controls outputting, to the display device 6, the classification result and the determination result given by the arrhythmia type determination device 1.

[0040]

With the above configuration, the arrhythmia type determination device 1 can precisely determine the type of the arrhythmia having occurred in the heart. The process in which the determination section 102 determines the type of the arrhythmia will be described later.

[0041]

Configuration of Information Processing Device 3

Next, the following will describe a configuration of the information processing device 3 with reference to Fig. 3. Fig. 3 is a block diagram illustrating an example of a configuration of a main part of the information processing device 3. As shown in Fig. 3, the information processing device 3 includes a processor 30, a memory 31, and a storage device 32. The information processing device 3 may be, for example, a personal computer, a server, or a work station. The processor 30 loads an information processing program stored in the storage device 32 into the memory 31 and executes the information processing program, so that the processor 30 functions as each of an image obtaining section 301 to an output control section 304 (which will be described later).

[0042]

The processor 30 can be realized by a logical circuit (hardware) formed in an integrated circuit (IC chip) or the like or can be realized by software. In a case where the processor 30 is realized by software, the processor 30 may be constituted by, for example, a CPU, a GPU, or a combination thereof. Further, in this case, the software is stored in the storage device 12. Further, the processor 30 loads the software into the memory 31 and executes the software.

[0043]

Each of the memory 31 and the storage device 32 is a storage device in which various kinds of data used by the information processing device 3 is stored. The memory 31 is a storage device allowing writing and reading of data at higher speeds in comparison to the storage device 32. The storage device 32 has a larger data storage capacity in comparison to the memory 31. As the memory 31, a high-speed access memory such as a SDRAM can be employed, for example. As the storage device 32, a HDD, a SSD, a SD card, an eMMC, or the like can be employed, for example.

[0044]

Further, the information processing device 3 includes, as an interface (IF) with an external device, an image capturing device interface section 33, an arrhythmia detection device interface section 35, and a display device interface section 34. As each of these interfaces, any interface is applicable. Examples of such an interface may include a USB and a HDMI (registered trademark).

[0045]

The image capturing device interface section 33 is an interface via which the image capturing device 2 and the information processing device 3 are communicably connected with each other. The image capturing device interface section 33 may be an interface for wired communication or an interface for radio communication. For example, a USB, a LAN, a wireless

LAN, or the like can be employed as each of these interface sections. Each of these interfaces is an interface for obtaining the above-described input image from the image capturing device 2. The arrhythmia detection device interface section 35 is an interface via which information output from the information processing device 3 is transmitted to the arrhythmia detection device 4. The display device interface section 34 is an interface via which information output from the information processing device 3 is transmitted to the display device 6.

[0046]

The information processing device 3 may further include an interface via which the information processing device 3 communicates with various devices (e.g., the storage device) on a communication network such as the Internet, for example. The information processing device 3 may include, in addition to the above-described interfaces, an interface and/or the like for access to, for example, an externally attached storage device (e.g., a hard disk).

[0047]

The processor 30 functions as each of the image obtaining section 301, a detection section 302, an analysis section 303, and the output control section 304 as discussed above. The following will describe each of the sections.

[0048]

The image obtaining section 301 obtains an input image obtained by image-capturing of the heart which image-capturing is carried out by the image capturing device 2. There is no particular limitation on a method for obtaining the input
5 image. For example, the image obtaining section 301 may obtain a captured image from the image capturing device 2 via the image capturing device interface section 33.

[0049]

By using a learning model generated by machine learning,
10 the detection section 302 detects, from an image of each of frames included in the input image obtained by image-capturing of the heart, the regions corresponding to the atriums and ventricles which regions are targets to be detected. The machine learning for generating the learning model will be
15 described later.

[0050]

The analysis section 303 calculates, for each of the frames, areas of the atriums and ventricles having been detected. Here, each of the areas of the regions may be
20 indicated by the number of pixels included in a respective one of the regions corresponding to the left atrium, right atrium, left ventricle, and right ventricle in the image of each of the frames. Alternatively, each of the areas of the regions may be indicated by an area (mm²) obtained by conversion carried out
25 on the basis of actual sizes of the left atrium, right atrium, left

ventricle, and right ventricle.

[0051]

The detection section 302 may have a function of (a) generating a binarized image by binarizing the input image having been used to detect the regions corresponding to the atriums and ventricles and (b) detecting, from an image of each of the frames included in the binarized image, regions corresponding to internal spaces of the atriums and ventricles. A reference value for binarization in the binarization process can be set so that (a) a pixel value for the regions corresponding to the internal spaces of the atriums and ventricles and (b) a pixel value for a region corresponding to a tissue (e.g., a myocardium or an atrioventricular valve) differ from each other. For example, in the binarized image, a pixel value for the regions corresponding to the internal spaces of the atriums and ventricles is "0", and a pixel value for a region corresponding to a tissue (e.g., a myocardium) of the heart is "1".

[0052]

By using (a) the regions corresponding to the atriums and ventricles having been detected from the input image and (b) the binarized image generated from the input image, the detection section 302 detects the regions corresponding to the internal spaces of the atriums and ventricles. For example, assume a case of a binarized image in which a pixel value for the regions and/or the like corresponding to the internal

spaces of the atriums and ventricles is "0". In this case, the detection section 302 detects, as the regions corresponding to the internal spaces of the atriums and ventricles, regions which are included in the regions corresponding to the atriums and ventricles in the input image and which have a pixel value "0" in the binarized image. Meanwhile, for example, assume a case of a binarized image in which a pixel value for the regions and/or the like corresponding to the internal spaces of the atriums and ventricles is "1". In this case, the detection section 302 may detect, as the regions corresponding to the internal spaces of the atriums and ventricles, regions which are included in the regions corresponding to the atriums and ventricles in the input image and which have a pixel value "1" in the binarized image.

[0053]

Note that, by using the learning model generated by machine learning using the binarized image, the detection section 302 may detect, from an image of each of the frames included in the binarized image, the regions corresponding to the internal spaces of the atriums and ventricles. In this case, the analysis section 303 calculates, for each of the frames, areas of the internal spaces of the atriums and ventricles having been detected.

[0054]

The output control section 304 controls outputting of the

analysis result from the information processing device 3.

[0055]

Configuration of Learning Device 5

Next, the following will describe, with reference to Fig. 4,
5 a configuration of the learning device 5 which generates the
learning model. Fig. 4 is a block diagram illustrating an
example of a configuration of a main part of the learning device
5. As shown in Fig. 4, the learning device 5 includes a processor
50, a memory 51, and a storage device 52. Similarly to the
10 information processing device 3, the learning device 5 may be
a personal computer, a server, or a work station. The processor
50 loads a learning program stored in the storage device 52
into the memory 51 and executes the learning program, so that
the processor 50 functions as each of an image obtaining
15 section 501 to a learning section 504 (which will be described
later).

[0056]

The processor 50 can be realized by a logical circuit
(hardware) formed in an integrated circuit (IC chip) or the like
20 or can be realized by software. In a case where the processor
50 is realized by software, the processor 50 may be constituted
by, for example, a CPU, a GPU, or a combination thereof.
Further, in this case, the software is stored in the storage
device 52. Furthermore, the processor 50 loads the software
25 into the memory 51 and executes the software.

[0057]

Each of the memory 51 and the storage device 52 is a storage device in which various kinds of data used by the learning device 5 is stored. The memory 51 is a storage device capable of writing and reading out data at higher speeds in comparison to the storage device 52. The storage device 52 has a larger data storage capacity in comparison to the memory 51. As the memory 51, a high-speed access memory such as a SDRAM can be employed, for example. As the storage device 52, a HDD, a SSD, a SD card, an eMMC, or the like can be employed, for example.

[0058]

Further, the learning device 5 includes, as an interface (IF) with an external device, an image capturing device interface section 53, an input device interface section 55, and a display device interface section 54. The input device interface section 55 is an interface which accepts an input signal from an input device such as a keyboard or a mouse. The input device interface section 55 may be an interface such as a USB, for example. Among the interfaces included in the learning device 5, an interface having the same name as that included in the information processing device 3 shown in Fig. 2 has the same function as that included in the information processing device 3. Therefore, description of such an interface will be omitted.

[0059]

The processor 50 functions as each of the image obtaining section 501, an annotation obtaining section 502, a training data generating section 503, and a learning section 504 as discussed above. The following will describe each of the sections.

[0060]

The image obtaining section 501 obtains an image for training (i.e., a training image) obtained by image-capturing carried out by the image capturing device 2. There is no particular limitation on a method for obtaining the training image. For example, the image obtaining section 501 may obtain the above-described training image from the image capturing device 2 via the image capturing device interface section 53. For example, by communication with the information processing device 3, the image obtaining section 501 may obtain the training image stored in the storage device 12 of the information processing device 3. For another example, in a case where the training image is stored in a storage device external to the information processing device 3, the image obtaining section 301 may access the storage device to obtain the captured image.

[0061]

The annotation obtaining section 502 obtains different classifications for regions of the heart included in the training

image, the regions being targets to be detected. The classification can be input via the input device by a medical worker who has checked the training image.

[0062]

5 Regions (Target Regions) R1 to R4 which are Targets to be Detected

10 The description here will discuss, with reference to Fig. 6, target regions and a collected region including the target regions in an image obtained by image-capturing of a heart T and a plurality of target regions. Fig. 6 is a view illustrating an example of target regions R1 to R4 which are targets to be detected, the regions being of the image obtained by image-capturing of the heart T. The heart T includes four anatomic regions (that is, two ventricles and two atriums). Therefore, for
15 the heart T, a target region R1 corresponding to the right ventricle, a target region R2 corresponding to the left ventricle, a target region R3 corresponding to the left atrium, and a target region R4 corresponding to the right atrium can be set as regions which are targets to be detected (as shown in Fig. 6).

20 [0063]

25 In the ultrasound image obtained by image-capturing of the heart T, the target regions R1 to R4 can be associated with different classifications, respectively. For example, classifications of "right ventricle", "left ventricle", "left atrium", and "right atrium" can be assigned to the target regions R1 to

R4 as annotations, respectively. Further, classifications of "ventricle" and "atrium" can be assigned to a collected region including the target regions R1 and R2 and a collected region including the target regions R3 and R4 as annotations, respectively.

[0064]

The training data generating section 503 respectively generates, for the target regions R1 to R4, training images to which different classifications are assigned as annotations. The training image is training data used by the learning section 504 to carry out machine learning of the learning model. Note that the learning model is a model used by the detection section 302 of the information processing device 3 to detect the target regions and the collected regions.

[0065]

The learning section 504 generates the learning model by machine learning. As discussed above, generation of the learning model is carried out by using a training image generated by the training data generating section 503.

[0066]

Note that the learning device 5 can generate a learning model used to detect regions in a binarized image which regions correspond to the internal spaces of the atriums and ventricles of the heart (for example, regions having a pixel value "0"). By inputting the binarized image into such a learning model, the

information processing device 3 can detect, from an image of each of the frames included in the binarized image, the regions corresponding to the internal spaces of the atriums and ventricles.

5 [0067]

Configuration of Arrhythmia Detection Device 4

Next, the following will describe a configuration of the arrhythmia detection device 4 with reference to Fig. 5. Fig. 5 is a block diagram illustrating an example of a configuration of a main part of the arrhythmia detection device 4. As shown in Fig. 5, the arrhythmia detection device 4 includes a processor 40, a memory 41, and a storage device 42. The arrhythmia detection device 4 may be, for example, a personal computer, a server, or a work station. The processor 40 loads an information processing program stored in the storage device 42 into the memory 41 and executes the information processing program, so that the processor 40 functions as an analysis result obtaining section 401, a time-series analysis section 402, and a detection section 403 (which will be described later).

20 [0068]

The processor 40 can be realized by a logical circuit (hardware) formed in an integrated circuit (IC chip) or the like or can be realized by software. In a case where the processor 40 is realized by software, the processor 40 may be constituted by, for example, a CPU, a GPU, or a combination thereof.

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Further, in this case, the software is stored in the storage device 42. Further, the processor 40 loads the software into the memory 41 and executes the software.

[0069]

5 Each of the memory 41 and the storage device 42 is a storage device in which various kinds of data used by the arrhythmia detection device 4 is stored. The memory 41 is a storage device capable of writing and reading out data at higher speeds in comparison to the storage device 42. The storage
10 device 42 has a larger data storage capacity in comparison to the memory 41. As the memory 41, a high-speed access memory such as a SDRAM can be employed, for example. As the storage device 42, a HDD, a SSD, a SD card, an eMMC, or the like can be employed, for example.

15 [0070]

 The arrhythmia detection device 4 includes, as an interface (IF) with an external device, an information processing device interface section 43 and an arrhythmia type determination device interface section 44. As each of these
20 interfaces, any interface is applicable. Examples of such an interface may include a USB and a HDMI (registered trademark).

[0071]

 The information processing device interface section 43 is an interface via which the information processing device 3 and
25 the arrhythmia detection device 4 are connected with each

other. The information processing device interface section 43 may be an interface for wired communication or an interface for radio communication. For example, a USB, a LAN, a wireless LAN, and/or the like can be employed as each of these interface sections. Each of these interface sections is an interface for obtaining the above-described input image from the image capturing device 2. The arrhythmia type determination device interface section 44 is an interface for transmitting, to the arrhythmia type determination device 1, information output from the arrhythmia detection device 4.

[0072]

The arrhythmia detection device 4 may further include an interface via which the arrhythmia detection device 4 communicates with various devices (e.g., the storage device) on a communication network such as the Internet, for example. The arrhythmia detection device 4 may include, in addition to the above-described interfaces, an interface and/or the like for access to, for example, an externally attached storage device (e.g., a hard disk).

[0073]

The processor 40 functions as the analysis result obtaining section 401, the time-series analysis section 402, and the detection section 403 as discussed above. The following will describe each of the sections.

[0074]

The analysis result obtaining section 401 obtains the analysis result output from the information processing device 3. The analysis result is, for example, the areas of the regions, that is, the left atrium, left ventricle, right atrium, and right ventricle in an image of each of the frames included in the input image.

[0075]

The time-series analysis section 402 generates signal waveforms indicative of time-series changes in the areas of the regions of the heart, and outputs an analysis result including peak information obtained from frequency spectra of the signal waveforms. The peak information is information about one or more higher-level peak frequencies each having a high peak value, among peak frequencies in the frequency spectrum. The peak information may include at least one first peak information. For example, the peak information may include (1) and (2) indicated below (see Fig. 9).

[0076]

(1) A first peak frequency, which is a peak frequency having a highest peak value in a respective one of the frequency spectra corresponding to the regions, that is, the left atrium, left ventricle, right atrium, and right ventricle, and a peak value of the first peak frequency.

[0077]

(2) An N-th peak frequency, which is a peak frequency

having an n-th highest peak value in a respective one of the frequency spectra corresponding to the regions, that is, the left atrium, left ventricle, right atrium, and right ventricle, and a peak values of the n-th peak frequency (n is equal to or more than 2).

[0078]

The time-series analysis section 402 may be capable of generating time-frequency analysis data which can be obtained by carrying out time-frequency analysis on the signal waveforms indicative of the time-series changes in the areas of the regions of the heart. The time-frequency analysis can be wavelet analysis, for example. The time-series analysis section 402 may be capable of outputting the peak information including information about the first peak frequency in the time-frequency analysis data. That is, the peak information may include information about the first peak frequency in the time-frequency analysis data (see Figs. 11 and 12). The information about the first peak frequency in the time-frequency analysis data can be used for a case where the arrhythmia type determination device 1 determines "premature contraction", which is one type of arrhythmia. A method in which the arrhythmia type determination device 1 determines premature contraction by using the time-frequency analysis data will be described later.

[0079]

The detection section 403 detects arrhythmia occurring in the heart included in the input image. The detection result may be output together with the analysis result from the time-series analysis section 402.

5 [0080]

Process Executed by Information Processing Device 3

Next, the following will describe, with reference to Fig. 7, a process executed by the information processing device 3. Fig. 7 is a view illustrating an example of the process carried out by the information processing device.

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[0081]

The uppermost row in Fig. 7 shows images respectively corresponding to frames 0, 1, 2, 3, ... of the input image obtained by image-capturing of the fetus's heart. The middle row in Fig. 7 shows regions respectively indicating the left atrium, right atrium, left ventricle, and right ventricle which have been detected by the information processing device 3 in an image of each of the frames and which are interposed on the respective images. As shown in the lowermost row in Fig. 7, the information processing device 3 calculates, for each of the frames, areas of the regions having been detected.

15

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[0082]

Process Executed by Arrhythmia Detection Device 4

Next, the following will describe, with reference to Fig. 8, a process in which the detection section 403 of the arrhythmia

25

detection device 4 detects arrhythmia. Fig. 8 is a view illustrating an example of signal waveforms indicative of time-series changes in areas of the atriums and ventricles. The signal waveforms shown in Fig. 8 are represented by graphs showing, in time series, the areas (sizes) of the left atrium, right atrium, left ventricle, and right ventricle having been detected by the information processing device 3. A unit of the area may be mm^2 , for example. Alternatively the unit of the area may be the number of pixels included in a respective one of the regions corresponding to the left atrium, right atrium, left ventricle, and right ventricle.

[0083]

In a case where arrhythmia does not occur, cyclic increasing and decreasing patterns of the areas (sizes) of the left atrium, right atrium, left ventricle, and right ventricle are repeated. In contrast to this, in a case where arrhythmia occurs, the cyclic increasing and decreasing patterns are disordered, as observed in the frames indicated by the quadrangle frame shown in Fig. 8. The arrhythmia detection device 4 can detect arrhythmia by detecting disorders in the cyclic increasing and decreasing patterns of the areas (sizes) of the left atrium, right atrium, left ventricle, and right ventricle.

[0084]

Peak Information

The arrhythmia type determination device 1 uses the

peak information obtained by analyzing the frequency spectra of the signal waveforms indicative of the time-series changes in the areas of the right atrium, left atrium, right ventricle, and left ventricle. The description here will discuss, with reference to Fig. 9, the peak information used by the arrhythmia type determination device 1. Fig. 9 is a view illustrating an example of peak information extracted from the frequency spectra of the signal waveforms indicative of the time-series changes in the areas of the atriums and ventricles. For simplification of explanation, Fig. 9 only illustrates a frequency spectrum of a signal waveform indicative of time-series changes in an area of the right atrium.

[0085]

By carrying out frequency analysis on the signal waveform, data of a frequency spectrum can be obtained. The data of the frequency spectrum is a spectrum indicative of amounts ("amplitudes" in Fig. 9) of frequency components of the signal waveforms. An upper left part of Fig. 9 illustrates a frequency spectrum obtained by plotting data extracted from a designated range (for example, 50 bpm to 500 bpm).

[0086]

The time-series analysis section 402 extracts a first peak frequency and a peak value thereof, a second peak frequency and a peak value thereof, and the like, the first peak frequency being a peak frequency having a highest peak value in the

frequency spectrum, the second peak frequency being a peak frequency having a second highest peak value in the frequency spectrum. An upper right part of Fig. 9 illustrates a state in which a peak A (first peak) having a highest peak value to a peak E (fifth peak) having a fifth highest peak value were detected from the frequency spectrum. Note that the "peaks" which are targets to be detected include (i) a peak protruding upward, i.e., a peak having a highest value in the frequency spectrum and (ii) a peak protruding downward, i.e., a peak having a lowest value in the frequency spectrum. In the example shown in Fig. 9, the peaks A to D are peaks protruding upward, whereas the peak E is a peak protruding downward.

[0087]

A lower part of Fig. 9 illustrates an example of peak information obtained from the frequency spectrum indicated in the upper part of Fig. 9.

- "fft_value" is peak information including, as its elements, the peak values of the first peak to the fifth peak.

- "fft_freq" is peak information including, as its elements, frequencies of the first peak to the fifth peak (at their peak positions).

- "fft_ratio" is peak information including, as its elements, relative values of the peak values of the first peak to the fifth peak.

- "fft_q" is peak information indicating whether each of the first

peak to the fifth peak is a peak protruding upward or a peak protruding downward. In Fig. 9, a peak protruding upward has "1" assigned thereto, whereas a peak protruding downward has "0" assigned thereto.

5 [0088]

Next, the following will describe, with reference to Fig. 10, peak information used by the arrhythmia type determination device 1 to determine premature contraction. Fig. 10 is a view illustrating (i) an example of a data structure of time-frequency analysis data obtained by carrying out time-frequency analysis on a signal waveform indicative of time-series changes in the area of a respective one of the regions of a heart and (ii) an example of a heat map generated from the time-frequency analysis data.

15 [0089]

The time-frequency analysis data (i.e., a wavelet analysis result) obtained by carrying out time-frequency analysis on the signal waveform indicative of the time-series changes in the area of a respective one of the regions of the heart is represented as a matrix of "the number of frames (i) $\times$ frequency (j)" as shown in an upper part of Fig. 10. By using a time interval at which the images of the frames were captured, a heat map such as the one illustrated in a lower part of Fig. 10 is generated from the time-frequency analysis data. In the heat map shown in the lower part of Fig. 10, the vertical axis

indicates a frequency (bpm), whereas the horizontal axis indicates time (second). In the heat map shown in the lower part of Fig. 10, different colors are assigned to different amounts of frequency components, and a belt-shaped part corresponding to the first peak frequency (f_{FFT}) can be observed at the position indicated by the arrow. For example, in the example shown in the lower part of Fig. 10, it can be observed that a period in which the first peak frequency changed exists in the part indicated by a frame with broken lines.

[0090]

During the period in which premature contraction occurs, a value of the first peak frequency decreases by a prescribed proportion or more. In a case where a period in which the value of the first peak frequency has changed by the prescribed proportion (e.g., 10%) or more exists in the time-frequency analysis data, the arrhythmia type determination device 1 determines that arrhythmia is premature contraction. With the above configuration, it is possible to appropriately identify the period in which premature contraction has occurred and to precisely determine that the arrhythmia is premature contraction.

[0091]

The time-frequency analysis data may be corrected so that the belt-shaped part which is included in the heat map generated from the time-frequency analysis data and which

corresponds to the first peak frequency (f_{FFT}) is made clearer. Fig. 11 is a view illustrating an example of a method for correcting a result of wavelet analysis on signal waveforms indicative of time-series changes in the areas of the atriums and ventricles. This correction can be carried out by the attenuating section 104 of the arrhythmia type determination device 1. In Fig. 11, " α " indicative of an adjustment parameter for a collection level may be changed in accordance with a frequency f_i which is a target to be corrected. For example, in a case where f_i is less than 100 bpm, α may be set at "1". In a case where f_i is equal to or more than 170 bpm, α may be set at "0.1". In a case where f_i is 100 bpm to 170 bpm, α may be set at 150. Changing α in this manner enables the following. In the time-frequency analysis data ($w'_{i,j}$) having been corrected, an amount of a frequency component which is lower than 100 bpm and is closer to a low-frequency side can be attenuated more as the amount of the frequency component gets farther away from 100 bpm, and an amount of a frequency component which is higher than 170 bpm and is closer to a high-frequency side can be attenuated more as the amount of the frequency component gets farther away from 170 bpm. Meanwhile, an amount of a frequency component within a range of 100 bpm to 170 bpm is hardly affected by this correction. As a result, in the heat map generated from the time-frequency analysis data, the belt-shaped part corresponding to the first peak frequency

(f_{FFT}) can be emphasized. Consequently, in the heat map generated from the time-frequency analysis data, a detection sensitivity in the period in which the first peak frequency has changed can be improved.

[0092]

Fig. 12 is a view illustrating a process for determining premature contraction on the basis of the result of wavelet analysis on the signal waveforms indicative of the time-series changes in the areas of the atriums and ventricles. The arrhythmia type determination device 1 (e.g., the determination section 102) may determine, as a period in which premature contraction occurs, a period from (i) a time point at which the value of the first peak frequency starts decreasing toward a value decreased by the prescribed proportion or more to (ii) a time point at which the value of the first peak frequency finishes increasing by the given prescribed or more from the decreased value. In the example shown in Fig. 12, a decrease in the first peak frequency is observed in each of a period P1 in the right atrium, a period P2 in the left atrium, a period P3 in the right ventricle, and a period P4 in the left ventricle. Then, the arrhythmia type determination device 1 (e.g., the determination section 102) determines that the type of the arrhythmia occurring in these periods is premature contraction.

[0093]

Process Executed by Arrhythmia Type Determination

System 100

Next, the following will describe, with reference to Fig. 13, a process carried out by the arrhythmia type determination system 100. Fig. 13 is a sequence diagram illustrating an example of the process carried out by the arrhythmia type determination system 100.

[0094]

First, the information processing device 3 obtains an input image (step S1), and detects regions, that is, a left atrium, a left ventricle, a right atrium, and a right ventricle from an image of each of frames included in the input image (step S2). Then, the information processing device 3 calculates, for each of the frames, areas of the regions having been detected (step S3). The number of information processing devices 3 may be one or two or more.

[0095]

Subsequently, the arrhythmia detection device 4 analyzes signal waveforms indicative of time-series changes in the areas of the regions (step S11), and analyzes frequency spectra of the signal waveforms indicative of the time-series changes in the areas of the regions (step S12). The number of arrhythmia detection devices 4 may be one or two or more.

[0096]

Next, the arrhythmia type determination device 11 obtains an analysis result (peak information) on the regions of

the heart (step S21: obtaining step), and determines the type of the arrhythmia (step S22: determination step). The number of arrhythmia type determination devices 1 may be one or two or more.

5 [0097]

Determination Step S22: Rough Classifications of Types of Arrhythmia

The following will describe, with reference to Fig. 14, the determination step carried out by the arrhythmia type determination device 1 (step S22 in Fig. 13). Fig. 14 is a flowchart illustrating an example of the process carried out by the arrhythmia type determination device 1.

[0098]

In step S221, the arrhythmia type determination device 1 determines a first number, which is the number of frequency spectra in each of which a first peak frequency exists in the reference frequency band. In step S222, the arrhythmia type determination device 1 determines a second number, which is the number of frequency spectra in each of which a first peak frequency exists in a frequency band that is higher in value than the reference frequency band. In step S223, the arrhythmia type determination device 1 determines a third number, which is the number of frequency spectra in each of which a first peak frequency exists in a frequency band that is lower in value than the reference frequency band. Then, in step

S224, the arrhythmia type determination device 1 classifies the type of the arrhythmia on the basis of a magnitude relation between the first number, second number, and third number. Note that the order of processing steps S221 to S223 is not limited to this. For example, steps S221 to S223 may be processed in parallel.

[0099]

The first number can be any number from 0 to 4. The expression "the first number is 0" means that a first peak frequency does not exist in the reference frequency band in each of the frequency spectra of the signal waveforms indicative of the time-series changes in all of the areas of the regions, that is, the right atrium, right ventricle, left atrium, and left ventricle. Meanwhile, the expression "the first number is 4" means that a first peak frequency exists in the reference frequency band in each of the frequency spectra of the signal waveforms indicative of the time-series changes in all of the areas of the regions, that is, the right atrium, right ventricle, left atrium, and left ventricle.

[0100]

The second number can be any number from 0 to 4. The expression "the second number is 0" means that a first peak frequency does not exist in a frequency band higher in value than the reference frequency band in each of the frequency spectra of the signal waveforms indicative of the time-series

changes in all of the areas of the regions, that is, the right atrium, right ventricle, left atrium, and left ventricle. Meanwhile, the expression "the second number is 4" means that a first peak frequency exists in a frequency band higher in value than the reference frequency band in each of the frequency spectra of the signal waveforms indicative of the time-series changes in all of the areas of the regions, that is, the right atrium, right ventricle, left atrium, and left ventricle.

[0101]

The third number can be any number from 0 to 4. The expression "the third number is 0" means that a first peak frequency does not exist in a frequency band lower in value than the reference frequency band in each of the frequency spectra of the signal waveforms indicative of the time-series changes in all of the areas of the regions, that is, the right atrium, right ventricle, left atrium, and left ventricle. Meanwhile, the expression "the third number is 4" means that a first peak frequency exists in a frequency band lower in value than the reference frequency band in each of the frequency spectra of the signal waveforms indicative of the time-series changes in all of the areas of the regions, that is, the right atrium, right ventricle, left atrium, and left ventricle.

[0102]

With the above configuration, the arrhythmia type determination device 1 can roughly classify, by a simple

method, the type of the arrhythmia having occurred.

[0103]

With reference to Fig. 15, the following will explain that a type of arrhythmia can be classified into three groups on the basis of a magnitude relation between the first number, second number, and third number. Fig. 15 is a view illustrating an example of criteria for classification of the type of arrhythmia which classification is carried out by the arrhythmia type determination device 1. The rows shown in Fig. 15 indicate "second number", "first number", "third number", and "type of arrhythmia" sequentially from the leftmost row.

[0104]

The arrhythmia type determination device 1 classifies the type of arrhythmia in the following manner.

[0105]

- A case where the second number $>$ the third number is classified into a group (the type "1" of arrhythmia in Fig. 15) including atrial flutter (AFL) and supraventricular tachycardia (SVT).

[0106]

- A case where the third number $>$ the second number and the third number $\geq$ the first number is classified into a group (the type "2" of arrhythmia in Fig. 15) including sinus bradycardia and complete atrioventricular block (CAVB).

[0107]

- A case where the first number $\geq$ the second number and the first number $\geq$ the third number is classified into a group (the type "3" of arrhythmia in Fig. 15) including normocardia, complete atrioventricular block (CAVB), premature atrial contraction (PAC), and premature ventricular contraction (PVC).
[0108]

With the above configuration, it is possible to roughly classify whether a subject case may correspond to any one of atrial flutter, supraventricular tachycardia, complete atrioventricular block, sinus bradycardia, premature contraction, and normocardia.
[0109]

The arrhythmia type determination device 1 may carry out the below-indicated determinations 1 to 5 in place of the process shown in Fig. 15.
[0110]

Determination 1: Determination of Atrial Flutter

In at least one of the following cases (i) to (iii), the arrhythmia type determination device 1 may determine that there is a possibility of atrial flutter.
[0111]

(i) A first peak frequency is a prescribed number (e.g., two) or more time a highest frequency (e.g., 170 bpm) in the reference frequency band in at least one of the frequency spectra of the left atrium and right atrium.

[0112]

(ii) A prescribed relation is satisfied by a highest peak value in a first frequency band higher in value than the reference frequency band and a highest peak value in a second frequency band higher in value than the first frequency band in at least one of the frequency spectra of the left atrium and right atrium. Here, the first frequency band may be a frequency band of 170 bpm to 340 bpm, for example. The second frequency band may be a frequency band of 340 bpm to 500 bpm, for example.

[0113]

(iii) (a) Peaks respectively exist in the first frequency band and the second frequency band in each of the frequency spectra of the left atrium and right atrium and (b) a peak does not exist in at least one of the first frequency band and the second frequency band in each of the frequency spectra of the left ventricle and right ventricle.

[0114]

The "prescribed relation" in (ii) above may be a relation which can serve as a determination criterion based on which the possibility of atrial flutter can be determined. For example, the "prescribed relation" can be set on the basis of a comparison between (i) a highest peak value in the first frequency band for an atrium and (ii) a highest peak value in the second frequency band for the atrium. In this case, the

"prescribed relation" may be, for example, such a relation that "the highest peak value in the first frequency band of the atrium $\times 0.7 <$ the highest peak value in the second frequency band of the atrium".

5 [0115]

Alternatively, the "prescribed relation" in (ii) described above may be set on the basis of a comparison result obtained by a comparison between (a) and (b) below.

[0116]

10 (a) A proportion (hereinafter, a "first proportion") of the highest peak value in the second frequency band of the atrium with respect to the highest peak value in the first frequency band of the atrium.

[0117]

15 (b) A proportion (hereinafter, a "second proportion") of the highest peak value in the second frequency band of the ventricle with respect to the highest peak value in the first frequency band of the ventricle. In this case, the "prescribed relation" may be, for example, "the first proportion $\times 0.7 >$ the
20 second proportion".

[0118]

Alternatively, the "prescribed relation" in (ii) described above may be set on the basis of a comparison result obtained by a comparison between (c) and (d) below.

25 [0119]

(c) Comparison criteria individually set for the atriums and ventricles on the basis of average frequencies (Ave) and standard deviations (SD) in the frequency spectra of the atriums and ventricles.

5 [0120]

(d) A highest peak value in the second frequency band. In this case, the "prescribed relation" may be, for example, such a relation that "the highest peak value in the second frequency band of the atrium > [Ave of the atrium + (n × SD of the atrium)] and the highest peak value in the second frequency band of the ventricle < [Ave of the ventricle + (n × SD of the ventricle)]". In one example, n may be 2.

10

[0121]

With the above configuration, the arrhythmia type determination device 1 can precisely determine that the arrhythmia having occurred is atrial flutter.

15

[0122]

Determination 2: Determination of Supraventricular Tachycardia

20 In at least one of the following cases (iv) and (v), the arrhythmia type determination device 1 may determine that there is a possibility of supraventricular tachycardia.

[0123]

(iv) A prescribed relation is satisfied by (a) a proportion of a highest peak value in the second frequency band with

25

respect to a highest peak value in the first frequency band in the frequency spectrum of the right atrium and (b) a proportion of a highest peak value in the second frequency band with respect to a highest peak value in the first frequency band in the frequency spectrum of the right ventricle.

[0124]

(v) A prescribed relation is satisfied by (a) a proportion of a highest peak value in the second frequency band with respect to a highest peak value in the first frequency band in the frequency spectrum of the left atrium and (b) a proportion of a highest peak value in the second frequency band with respect to a highest peak value in the first frequency band in the frequency spectrum of the left ventricle.

[0125]

The "prescribed relation" in (iv) and (v) above may be a relation which can serve as a determination criterion based on which the possibility of supraventricular tachycardia can be determined. For example, the "prescribed relation" in (iv) described above may be set on the basis of a comparison result obtained by a comparison between (e) and (f) below.

[0126]

(e) A proportion (hereinafter, a "third proportion") of a highest peak value in the second frequency band of the right atrium with respect to a highest peak value in the first frequency band of the right atrium.

[0127]

(f) A proportion (hereinafter, a "fourth proportion") of a highest peak value in the second frequency band of the right ventricle with respect to a highest peak value in the first frequency band of the right ventricle.

In this case, the "prescribed relation" may be, for example, "the third proportion $\times 0.7 >$ the fourth proportion". For example, the "prescribed relation" in (v) described above may be set on the basis of a comparison result obtained by a comparison between (g) and (h) below.

[0128]

(g) A proportion (hereinafter, a "fifth proportion") of a highest peak value in the second frequency band of the left atrium with respect to a highest peak value in the first frequency band of the left atrium.

[0129]

(h) A proportion (hereinafter, a "sixth proportion") of a highest peak value in the second frequency band of the left ventricle with respect to a highest peak value in the first frequency band of the left ventricle.

In this case, the "prescribed relation" may be, for example, "the fifth proportion $\times 0.7 >$ the sixth proportion".

[0130]

Alternatively, the "prescribed relation" in (iv) and (v) described above may be set on the basis of a comparison result

obtained by a comparison between (p) and (q) below.

[0131]

(p) Comparison criteria individually set for the atriums and ventricles on the basis of average frequencies (Ave) and standard deviations (SD) in the frequency spectra of the atriums and ventricles.

[0132]

(d) A highest peak value in the second frequency band.

In this case, the "prescribed relation" may be, for example, such a relation that "in each of the atriums and ventricles, the highest peak value in the second frequency band $> [\text{Ave} + (n \times \text{SD})]$ ". Alternatively, the "prescribed relation" in (iv) described above may be, for example, such a relation that "in at least one of the right ventricle and left ventricle, the highest peak value in the second frequency band $> [\text{Ave} + (n \times \text{SD})]$ ". In one example, n may be 2.

[0133]

In a case where the frequency spectra of the regions corresponding to the internal spaces of the right atrium, right ventricle, left atrium, and left ventricle obtained from a binarized image obtained by a binarization process carried out on an image of each of the frames are used, the arrhythmia type determination device 1 may refer to information indicating whether a subject case corresponds to at least one of (iv) and (v) described above.

[0134]

With the above configuration, the arrhythmia type determination device 1 can precisely determine that the arrhythmia having occurred is supraventricular tachycardia.

5 [0135]

Determination 3: Determination of Complete Atrioventricular Block

In at least one of the following cases (vi) and (vii), the arrhythmia type determination device 1 may determine that there is a possibility of complete atrioventricular block.

10 [0136]

(vi) (a) A first peak frequency exists in the reference frequency band in at least one of the frequency spectra of the left atrium and right atrium and (b) a first peak frequency is lower in value than the reference frequency band in at least one of the frequency spectra of the left ventricle and right ventricle.

15 [0137]

(vii) (a) A first peak frequency is lower in value than the reference frequency band in each of the frequency spectra of the left atrium and right atrium, (b) a second peak frequency exists in the reference frequency band in each of the frequency spectra of the left atrium and right atrium, and (c) a prescribed relation is satisfied by a proportion between a peak value in the first peak frequency and a peak value in the second peak

frequency in at least one of the frequency spectra of the left atrium and right atrium.

[0138]

The "prescribed relation" in (vii) above may be a relation which can serve as a determination criterion based on which the possibility of complete atrioventricular block can be determined. For example, the "prescribed relation" can be set on the basis of a comparison between (i) the peak value in the first frequency band and (ii) the peak value in the second frequency band. The "prescribed relation" may be, for example, such a relation that "the peak value in the first peak frequency $\times 0.7 <$ the peak value in the second peak frequency".

[0139]

Alternatively, the "prescribed relation" in (vii) described above may be set on the basis of a comparison result obtained by a comparison between (r) and (s) below.

[0140]

(r) Comparison criteria individually set for the atriums and ventricles on the basis of average frequencies (Ave) and standard deviations (SD) in the frequency spectra of the atriums and ventricles.

[0141]

(s) A peak value in the second peak frequency.

In this case, the "prescribed relation" may be, for example, such a relation that "the first peak frequency of the atrium is

lower than the normal range (e.g., the reference frequency band) and the second peak frequency is within the normal range" and "the peak value of the second peak frequency of the atrium $> [\text{Ave of the atrium} + (n \times \text{SD of the atrium})]$ ". In one example, n may be 2.

[0142]

With the above configuration, the arrhythmia type determination device 1 can precisely determine that the arrhythmia having occurred is complete atrioventricular block.

[0143]

(Determination 4: Determination of Sinus Bradycardia)

In at least one of the following cases (viii) and (ix), the arrhythmia type determination device 1 may determine that there is a possibility of sinus bradycardia.

[0144]

(viii) (a) A first peak frequency is lower in value than the reference frequency band in each of the frequency spectra of the left atrium and right atrium and (b) a second peak frequency does not exist in at least one of the frequency spectra of the left ventricle and right ventricle.

[0145]

(ix) A first peak frequency is lower in value than the reference frequency band in each of the frequency spectra of the left atrium, right atrium, left ventricle, and right ventricle.

[0146]

With the above configuration, the arrhythmia type determination device 1 can precisely determine that the arrhythmia having occurred is sinus bradycardia.

[0147]

5 Determination 5: Determination of Complete
Atrioventricular Block

In the following case (x), the arrhythmia type determination device 1 may determine that there is a possibility of complete atrioventricular block.

10 [0148]

(x) (a) A first peak frequency exists in the reference frequency band, which is defined as the normal range in advance, in each of the frequency spectra of the left atrium and right atrium, (b) a first peak frequency is lower in value than
15 the reference frequency band in each of the frequency spectra of the left ventricle and right ventricle, and (c) a prescribed relation is satisfied by a proportion between a peak value of the first peak frequency and a highest peak value in the normal range (e.g., the reference frequency band) in each of the
20 frequency spectra of the left ventricle and right ventricle.

[0149]

The "prescribed relation" in (x) described above may be a relation which can serve as a determination criterion based on which the possibility of complete atrioventricular block can be
25 determined. For example, the "prescribed relation" can be set

on the basis of a comparison between (i) the peak value in the first frequency band and (ii) the highest peak value in the reference frequency band. The "prescribed relation" may be, for example, such a relation that "the peak value in the first peak
5 frequency $\times 0.7 <$ the highest peak value in the reference frequency band".

[0150]

Alternatively, the "prescribed relation" in (x) described above may be set on the basis of a comparison result obtained
10 by a comparison between (t) and (u) below.

[0151]

(t) Comparison criteria individually set for the atriums and ventricles on the basis of average frequencies (Ave) and standard deviations (SD) in the frequency spectra of the
15 atriums and ventricles.

[0152]

(u) A highest peak value in the reference frequency band. In this case, the "prescribed relation" may be, for example, such a relation that "the first peak frequency of the ventricle is
20 lower than the normal range (e.g., the reference frequency band) and the second peak frequency is within the normal range" and "the peak value of the second peak frequency of the ventricle $> [\text{Ave of the ventricle} + (n \times \text{SD of the ventricle})]$ ". In one example, n may be 2.

25 [0153]

With the above configuration, the arrhythmia type determination device 1 can precisely determine that the arrhythmia having occurred is complete atrioventricular block. [0154]

5 Supplementary Remarks

The arrhythmia type determination device 1 carries out the process in step S224 shown in Fig. 15 to roughly classify arrhythmia into the following three groups.

- 10 - A group including atrial flutter (AFL) and supraventricular tachycardia (SVT) (the type "1" of arrhythmia shown in Fig. 15).
 - A group including sinus bradycardia and complete atrioventricular block (CAVB) (the type "2" of arrhythmia shown in Fig. 15).
 - 15 - A group including complete atrioventricular block (CAVB), premature atrial contraction (PAC), and premature ventricular contraction (PVC) (the type "3" of arrhythmia shown in Fig. 15).
- The arrhythmia type determination device 1 may roughly classify the type of arrhythmia and then make determinations 1 to 5. With this, it is possible to more precisely determine the
- 20 type of arrhythmia. This will be explained with reference to Figs. 16 and 17. Fig. 16 is a view illustrating an example of a result of rough classification of the type of arrhythmia which rough classification is carried out by the arrhythmia type determination device 1. Fig. 17 is a view illustrating an example
- 25 of a result of determination of the type of arrhythmia which

determination is carried out by the arrhythmia type determination device 1.

[0155]

Fig. 16 shows a result of a comparison between (i)
5 "ground truth labels", each of which indicates a type of
arrhythmia based on a result of a diagnosis on a subject having
undergone a diagnosis by a medical worker, and (ii) a result
(classification result) of rough classification of arrhythmia
10 occurring in the heart included in the ultrasound image
obtained by image-capturing of the subject, the rough
classification being carried out by the arrhythmia type
determination device 1. According to Fig. 16, it is shown that
the arrhythmia type determination device 1 can substantially
accurately determine the type of the arrhythmia occurring in
15 the subject's heart.

[0156]

The arrhythmia type determination device 1 can roughly
classify the type of arrhythmia and then a process (e.g.,
determination 3 and/or determination 4) for individually
20 determining the type of arrhythmia. For example, the
arrhythmia type determination device 1 can further carry out
the above-described determination 3 and/or determination 4
for the subject having been classified into the block (the type
"2" of arrhythmia in Fig. 15) including sinus bradycardia and
25 complete atrioventricular block (CAVB). As shown in a left part

of Fig. 17, by carrying out determination 3 and/or
determination 4, sinus bradycardia and complete
atrioventricular block (CAVB), which have not been
discriminated in rough classification, can be discriminated and
determined as shown in a right part of Fig. 17.

[0157]

Software Implementation Example

The functions of the arrhythmia type determination
device 1 (hereinafter, referred to as a "device") can be realized
by a program for causing a computer to function as the device,
the program causing the computer to function as the control
blocks (particularly, the sections included in the processor 10)
of the device.

[0158]

In this case, the device includes a computer that has at
least one control device (for example, a processor) and at least
one memory device (for example, a memory) as hardware for
executing the program. By the control device executing the
program with use of the storage device, the functions described
in the foregoing embodiments are realized.

[0159]

The program can be stored in one or more non-transitory
computer-readable storage media. The storage medium can be
provided in the device, or the storage medium does not need to
be provided in the device. In the latter case, the program can

be supplied to the device via any wired or wireless transmission medium.

[0160]

Alternatively, a part or all of the functions of the control
5 blocks can be realized by a logic circuit. For example, the
present invention encompasses, in its scope, an integrated
circuit in which a logic circuit that functions as each of the
control blocks is formed. In addition, the function of each of
the control blocks can be realized by, for example, a quantum
10 computer.

[0161]

Each of the processes described in the foregoing
embodiments may be carried out by artificial intelligence (AI).
In this case, the AI may be operated by the control device or
15 may be operated by another device (for example, an edge
computer and a cloud server).

[0162]

The present invention is not limited to the embodiments,
but can be altered by a skilled person in the art within the
20 scope of the claims. The present invention also encompasses,
in its technical scope, any embodiment derived by combining
technical means disclosed in differing embodiments.

[0163]

Aspects of the present invention can also be expressed
25 as follows:

An arrhythmia type determination device in accordance with a first aspect of the present invention includes: an obtaining section which obtains peak information about one or more higher-level peak frequencies each having a high peak value, among peak frequencies in frequency spectra of signal waveforms indicative of time-series changes in areas of regions that are a left atrium, a left ventricle, a right atrium, and a right ventricle included in an image obtained by image-capturing of a heart; and a determination section which determines a type of arrhythmia on a basis of the peak information.

[0164]

An arrhythmia type determination device in accordance with a second aspect of the present invention may be configured such that, in the first aspect, the determination section carries out classification of the type on a basis of a magnitude relation between a first number, a second number, and a third number, the first number being the number of frequency spectra in each of which a first peak frequency exists in a reference frequency band, the first peak frequency being, among the peak frequencies, a peak frequency having a highest peak value, and the reference frequency band being defined as a normal range in advance, the second number being the number of frequency spectra in each of which the first peak frequency exists in a frequency band that is higher in value

than the reference frequency band, and the third number being the number of frequency spectra in each of which the first peak frequency exists in a frequency band that is lower in value than the reference frequency band.

5 [0165]

An arrhythmia type determination device in accordance with a third aspect of the present invention may be configured such that, in the second aspect, in a case where the second number is more than the third number, the determination
10 section determines that there is a possibility of at least one selected from the group consisting of atrial flutter and supraventricular tachycardia; in a case where the third number is more than the second number and the third number is equal to or more than the first number, the determination section
15 determines that there is a possibility of at least one selected from the group consisting of complete atrioventricular block and sinus bradycardia; and in a case where the first number is equal to more than the second number and the first number is equal to or more than the third number, the determination
20 section determines that there is a possibility of at least one selected from the group consisting of premature contraction, complete atrioventricular block, and normocardia.

[0166]

An arrhythmia type determination device in accordance
25 with a fourth aspect of the present invention may be configured

such that, in any one of the first to third aspects, the determination section determines that there is a possibility of atrial flutter, in at least one of cases (i) to (iii), the case (i) being a case where a first peak frequency is a prescribed number or
5 more time a highest frequency in a reference frequency band in at least one of the frequency spectra of the left atrium and right atrium, the first peak frequency being, among the peak frequencies, a peak frequency having a highest peak value, the reference frequency band being defined as a normal range in
10 advance, the case (ii) being a case where a prescribed relation is satisfied by a highest peak value in the first frequency band higher in value than the reference frequency band and a highest peak value in a second frequency band higher in value than the first frequency band in at least one of the frequency
15 spectra of the left atrium and right atrium, and the case (iii) being a case where (a) peaks respectively exist in the first frequency band and the second frequency band in each of the frequency spectra of the left atrium and right atrium and (b) a peak does not exist in at least one of the first frequency band
20 and the second frequency band in each of the frequency spectra of the left ventricle and right ventricle.

[0167]

An arrhythmia type determination device in accordance
25 with a fifth aspect of the present invention may be configured

such that, in any one of the first to fourth aspects, the determination section determines that there is a possibility of supraventricular tachycardia, in at least one of cases (iv) and (v), the case (iv) being a case where a prescribed relation is satisfied by (a) a proportion of a highest peak value in a second frequency band with respect to a highest peak value in a first frequency band in the frequency spectrum of the right atrium and (b) a proportion of a highest peak value in the second frequency band with respect to a highest peak value in the first frequency band in the frequency spectrum of the right ventricle, the second frequency band being higher in value than the first frequency band, the first frequency band being higher in value than a reference frequency band, and the reference frequency band being defined as a normal range in advance, and the case (v) being a case where a prescribed relation is satisfied by (a) a proportion of a highest peak value in the second frequency band with respect to a highest peak value in the first frequency band in the frequency spectrum of the left atrium and (b) a proportion of a highest peak value in the second frequency band with respect to a highest peak value in the first frequency band in the frequency spectrum of the left ventricle, the second frequency band being higher in value than the first frequency band, and the first frequency band being higher in value than the reference frequency band.

An arrhythmia type determination device in accordance with a sixth aspect of the present invention may be configured such that, in any one of the first to fifth aspects, the determination section determines that there is a possibility of complete atrioventricular block, in at least one of cases (vi) and (vii), the case (vi) being a case where (a) a first peak frequency exists in a reference frequency band in at least one of the frequency spectra of the left atrium and right atrium and (b) the first peak frequency is lower in value than the reference frequency band in at least one of the frequency spectra of the left ventricle and right ventricle, the first peak frequency being, among the peak frequencies, a peak frequency having a highest peak value, and the reference frequency band being defined as a normal range in advance, and (vii) (a) the first peak frequency is lower than the reference frequency band in each of the frequency spectra of the left atrium and right atrium, (b) a second peak frequency exists in the reference frequency band in each of the frequency spectra of the left atrium and right atrium, and (c) a prescribed relation is satisfied by a proportion between a peak value in the first peak frequency and a peak value in the second peak frequency in at least one of the frequency spectra of the left atrium and right atrium, the second peak frequency being, among the peak frequencies, a peak frequency having a second highest peak value.

An arrhythmia type determination device in accordance with a seventh aspect of the present invention may be configured such that, in any one of the first to sixth aspects, the determination section determines that there is a possibility of sinus bradycardia, in at least one of cases (viii) and (ix), the case (viii) being a case where (a) a first peak frequency is lower than a reference frequency band in each of the frequency spectra of the left atrium and right atrium and (b) a second peak frequency does not exist within the reference frequency band in at least one of the frequency spectra of the left ventricle and right ventricle, the first peak frequency being, among the peak frequencies, a peak frequency having a highest peak value, the reference frequency band being defined as a normal range in advance, and the second peak frequency being, among the peak frequencies, a peak frequency having a second highest peak value, and the case (ix) being a case where the first peak frequency is lower than the reference frequency band in each of the frequency spectra of the left atrium, right atrium, left ventricle, and right ventricle.

[0170]

An arrhythmia type determination device in accordance with a eighth aspect of the present invention may be configured such that, in any one of the first to seventh aspects, the determination section determines that there is a possibility of complete atrioventricular block, in a case where (a) a first peak

frequency exists in a reference frequency band in each of the frequency spectra of the left atrium and right atrium, (b) the first peak frequency is lower than the reference frequency band in each of the frequency spectra of the left ventricle and right ventricle, and (c) a prescribed relation is satisfied by a proportion between a peak value of the first peak frequency and a second highest peak value in each of the frequency spectra of the left ventricle and right ventricle, the first peak frequency being, among the peak frequencies, a peak frequency having a highest peak value, and the reference frequency band being defined as a normal range in advance.

[0171]

An arrhythmia type determination device in accordance with a ninth aspect of the present invention may be configured such that, in any one of the first to eighth aspects, the determination section determines that the type of the arrhythmia is premature contraction, in a case where a period in which a value of a first peak frequency has changed by a prescribed proportion or more exists in time-frequency analysis data obtained by carrying out time-frequency analysis on at least one of the signal waveforms, the first peak frequency being, among the peak frequencies, a peak frequency having a highest peak value in a corresponding one of the frequency spectra.

[0172]

An arrhythmia type determination device in accordance with a tenth aspect of the present invention may be configured such that, in the ninth aspect, the determination section determines, as the period, a period from (i) a time point at which the value of the first peak frequency starts decreasing toward a value decreased by the prescribed proportion or more to (ii) a time point at which the value of the first peak frequency finishes increasing by the given prescribed or more from the decreased value.

[0173]

An arrhythmia type determination device in accordance with an eleventh aspect of the present invention may be configured such that, in any one of the ninth or tenth aspect, the arrhythmia type determination device further comprising: an attenuating section which carries out attenuation such that, among frequency components in the time-frequency analysis data, a frequency which is farther away from the first peak frequency is attenuated more, the determination section determining whether or not the period exists in the time-frequency analysis data having undergone the attenuation.

[0174]

An arrhythmia type determination method in accordance with a twelfth aspect of the present invention is an arrhythmia type determination method which is executed by one or more information processing devices, the arrhythmia type

determination method including: an obtaining step of obtaining peak information about one or more higher-level peak frequencies each having a high peak value, among peak frequencies in frequency spectra of signal waveforms indicative of time-series changes in an area of each of regions of a left atrium, a left ventricle, a right atrium, and a right ventricle included in an image obtained by image-capturing of a heart; and a determination step of determining a type of arrhythmia on a basis of the peak information.

[0175]

An arrhythmia type determination program for causing a computer to function as an arrhythmia type determination device described in any one of the first to eleventh aspects, the arrhythmia type determination program causing the computer to function as the obtaining section and the determination section.

Reference Signs List

[0176]

1: arrhythmia type determination device

101: obtaining section

102: determination section

104: attenuating section

S21: obtaining step

S22: determination step

Claims

[Claim 1]

An arrhythmia type determination device comprising:

an obtaining section which obtains peak information
5 about one or more higher-level peak frequencies each having a
high peak value, among peak frequencies in frequency spectra
of signal waveforms indicative of time-series changes in an area
of each of regions of a left atrium, a left ventricle, a right atrium,
and a right ventricle included in an image obtained by image-
10 capturing of a heart; and

a determination section which determines a type of
arrhythmia on a basis of the peak information.

[Claim 2]

15 The arrhythmia type determination device according to
claim 1, wherein:

the determination section carries out classification of the
type on a basis of a magnitude relation between a first number,
a second number, and a third number,

20 the first number being the number of frequency spectra
in each of which a first peak frequency exists in a reference
frequency band, the first peak frequency being, among the peak
frequencies, a peak frequency having a highest peak value, and
the reference frequency band being defined as a normal range
25 in advance,

the second number being the number of frequency spectra in each of which the first peak frequency exists in a frequency band that is higher in value than the reference frequency band, and

5 the third number being the number of frequency spectra in each of which the first peak frequency exists in a frequency band that is lower in value than the reference frequency band.

[Claim 3]

10 The arrhythmia type determination device according to claim 2, wherein:

 in a case where the second number is more than the third number, the determination section determines that there is a possibility of at least one selected from the group consisting of
15 atrial flutter and supraventricular tachycardia;

 in a case where the third number is more than the second number and the third number is equal to or more than the first number, the determination section determines that there is a possibility of at least one selected from the group consisting of
20 complete atrioventricular block and sinus bradycardia; and

 in a case where the first number is equal to more than the second number and the first number is equal to or more than the third number, the determination section determines that there is a possibility of at least one selected from the group
25 consisting of premature contraction, complete atrioventricular

block, and normocardia.

[Claim 4]

The arrhythmia type determination device according to
5 any one of claims 1 to 3, wherein:

the determination section determines that there is a
possibility of atrial flutter, in at least one of cases (i) to (iii),

the case (i) being a case where a first peak frequency is
a prescribed number or more time a highest frequency in a
10 reference frequency band in at least one of the frequency
spectra of the left atrium and right atrium, the first peak
frequency being, among the peak frequencies, a peak frequency
having a highest peak value, the reference frequency band
being defined as a normal range in advance,

15 the case (ii) being a case where a prescribed relation is
satisfied by a highest peak value in the first frequency band
higher in value than the reference frequency band and a
highest peak value in a second frequency band higher in value
than the first frequency band in at least one of the frequency
20 spectra of the left atrium and right atrium, and

the case (iii) being a case where (a) peaks respectively
exist in the first frequency band and the second frequency band
in each of the frequency spectra of the left atrium and right
atrium and (b) a peak does not exist in at least one of the first
25 frequency band and the second frequency band in each of the

frequency spectra of the left ventricle and right ventricle.

[Claim 5]

The arrhythmia type determination device according to
5 any one of claims 1 to 3, wherein:

the determination section determines that there is a possibility of supraventricular tachycardia, in at least one of cases (iv) and (v),

the case (iv) being a case where a prescribed relation is
10 satisfied by (a) a proportion of a highest peak value in a second frequency band with respect to a highest peak value in a first frequency band in the frequency spectrum of the right atrium and (b) a proportion of a highest peak value in the second frequency band with respect to a highest peak value in the first
15 frequency band in the frequency spectrum of the right ventricle, the second frequency band being higher in value than the first frequency band, the first frequency band being higher in value than a reference frequency band, and the reference frequency band being defined as a normal range in advance, and

20 the case (v) being a case where a prescribed relation is satisfied by (a) a proportion of a highest peak value in the second frequency band with respect to a highest peak value in the first frequency band in the frequency spectrum of the left atrium and (b) a proportion of a highest peak value in the
25 second frequency band with respect to a highest peak value in

the first frequency band in the frequency spectrum of the left ventricle, the second frequency band being higher in value than the first frequency band, and the first frequency band being higher in value than the reference frequency band.

5

[Claim 6]

The arrhythmia type determination device according to any one of claims 1 to 3, wherein:

10 the determination section determines that there is a possibility of complete atrioventricular block, in at least one of cases (vi) and (vii),

15 the case (vi) being a case where (a) a first peak frequency exists in a reference frequency band in at least one of the frequency spectra of the left atrium and right atrium and (b) the first peak frequency is lower in value than the reference frequency band in at least one of the frequency spectra of the left ventricle and right ventricle, the first peak frequency being, among the peak frequencies, a peak frequency having a highest peak value, and the reference frequency band being defined as
20 a normal range in advance, and

(vii) (a) the first peak frequency is lower than the reference frequency band in each of the frequency spectra of the left atrium and right atrium, (b) a second peak frequency exists in the reference frequency band in each of the frequency
25 spectra of the left atrium and right atrium, and (c) a prescribed

relation is satisfied by a proportion between a peak value in the first peak frequency and a peak value in the second peak frequency in at least one of the frequency spectra of the left atrium and right atrium, the second peak frequency being, among the peak frequencies, a peak frequency having a second highest peak value.

[Claim 7]

The arrhythmia type determination device according to any one of claims 1 to 3, wherein:

the determination section determines that there is a possibility of sinus bradycardia, in at least one of cases (viii) and (ix),

the case (viii) being a case where (a) a first peak frequency is lower than a reference frequency band in each of the frequency spectra of the left atrium and right atrium and (b) a second peak frequency does not exist within the reference frequency band in at least one of the frequency spectra of the left ventricle and right ventricle, the first peak frequency being, among the peak frequencies, a peak frequency having a highest peak value, the reference frequency band being defined as a normal range in advance, and the second peak frequency being, among the peak frequencies, a peak frequency having a second highest peak value, and

the case (ix) being a case where the first peak frequency

is lower than the reference frequency band in each of the frequency spectra of the left atrium, right atrium, left ventricle, and right ventricle.

5 [Claim 8]

The arrhythmia type determination device according to any one of claims 1 to 3, wherein:

the determination section determines that there is a possibility of complete atrioventricular block, in a case where
10 (a) a first peak frequency exists in a reference frequency band in each of the frequency spectra of the left atrium and right atrium, (b) the first peak frequency is lower than the reference frequency band in each of the frequency spectra of the left ventricle and right ventricle, and (c) a prescribed relation is
15 satisfied by a proportion between a peak value of the first peak frequency and a second highest peak value in each of the frequency spectra of the left ventricle and right ventricle, the first peak frequency being, among the peak frequencies, a peak frequency having a highest peak value, and the reference
20 frequency band being defined as a normal range in advance.

[Claim 9]

The arrhythmia type determination device according to any one of claims 1 to 3, wherein:

25 the determination section determines that the type of the

arrhythmia is premature contraction, in a case where a period in which a value of a first peak frequency has changed by a prescribed proportion or more exists in time-frequency analysis data obtained by carrying out time-frequency analysis on at least one of the signal waveforms, the first peak frequency being, among the peak frequencies, a peak frequency having a highest peak value in a corresponding one of the frequency spectra.

10 [Claim 10]

The arrhythmia type determination device according to claim 9, wherein:

15 the determination section determines, as the period, a period from (i) a time point at which the value of the first peak frequency starts decreasing toward a value decreased by the prescribed proportion or more to (ii) a time point at which the value of the first peak frequency finishes increasing by the given prescribed or more from the decreased value.

20 [Claim 11]

The arrhythmia type determination device according to claim 9, further comprising:

25 an attenuating section which carries out attenuation such that, among frequency components in the time-frequency analysis data, a frequency which is farther away from the first

peak frequency is attenuated more,

the determination section determining whether or not the period exists in the time-frequency analysis data having undergone the attenuation.

5

[Claim 12]

An arrhythmia type determination method which is executed by one or more information processing devices, the arrhythmia type determination method comprising:

10 an obtaining step of obtaining peak information about one or more higher-level peak frequencies each having a high peak value, among peak frequencies in frequency spectra of signal waveforms indicative of time-series changes in an area of each of regions of a left atrium, a left ventricle, a right atrium,
15 and a right ventricle included in an image obtained by image-capturing of a heart; and

a determination step of determining a type of arrhythmia on a basis of the peak information.

20 [Claim 13]

An arrhythmia type determination program for causing a computer to function as an arrhythmia type determination device recited in claim 1, the arrhythmia type determination program causing the computer to function as the obtaining
25 section and the determination section.