

Description

Title of Invention:

PREMATURE CONTRACTION DETERMINATION DEVICE,
PREMATURE CONTRACTION DETERMINATION METHOD, AND
5 PREMATURE CONTRACTION DETERMINATION PROGRAM

Technical Field

[0001]

10 The present invention relates to a technology for determining the presence or absence of a premature contraction from images of a heart.

Background Art

[0002]

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

Citation List

[Patent Literature]

[0003]

5 [Patent Literature 1]

Japanese Patent Application Publication, *Tokukai*, No.
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Summary of Invention

10 Technical Problem

[0004]

Conventionally, electrocardiography has primarily been
used to diagnose arrhythmias. With electrocardiography,
however, it can be difficult to determine whether an
15 arrhythmia that has occurred is a premature contraction. This
leaves room for improvement in terms of accuracy. Premature
contraction is a type of arrhythmia in which abnormal
stimulation occurs in the heart so that additional
contractions occur in addition to normal contractions. It is an
20 object of an aspect of the present invention to determine the
presence or absence of a premature contraction accurately
from images of a heart.

Solution to Problem

[0005]

25 In order to attain the object, a premature contraction

determination device in accordance with an aspect of the present invention includes: an acquisition section that acquires a signal waveform generated by analysis of images of a heart, the signal waveform indicating a time-series change in area of a region of at least one selected from the group consisting of a left atrium, a left ventricle, a right atrium, and a right ventricle; and a determination section that determines whether or not a premature contraction has occurred, by making a comparison between (i) a time interval from a time point at which the area indicated by the signal waveform equals a reference value to a next time point at which the area indicated by the signal waveform equals the reference value, the reference value being set on the basis of displacements on the signal waveform, and (ii) a predetermined threshold.

[0006]

A method in accordance with an aspect of the present invention for determining a premature contraction is a method carried out by one or more information processing devices, the method including: an acquisition step of acquiring a signal waveform generated by analysis of images of a heart, the signal waveform indicating a time-series change in area of a region of at least one selected from the group consisting of a left atrium, a left ventricle, a right atrium, and a right ventricle; and a determination step of determining whether or not a premature contraction has occurred, by making a

comparison between (i) a time interval from a time point at which the area indicated by the signal waveform equals a reference value to a next time point at which the area indicated by the signal waveform equals the reference value, the reference value being set on the basis of displacements on the signal waveform, and (ii) a predetermined threshold.

[0007]

The premature contraction determination device in accordance with the foregoing aspects of the present invention can be realized by a computer. In this case, the present invention encompasses: a control program for the premature contraction determination device which control program causes a computer to operate as the foregoing sections (software elements) of the premature contraction determination device so that the premature contraction determination device can be realized by the computer; and a computer-readable storage medium storing the control program therein.

Advantageous Effects of Invention

[0008]

According to an aspect of the present invention, it is possible to determine the presence or absence of a premature contraction accurately from images of a heart.

Brief Description of Drawings

[0009]

Fig. 1 is a block diagram illustrating an example of a configuration of main parts of a premature contraction determination device in accordance with an embodiment of the present invention.

Fig. 2 is a view illustrating an example of detection of regions of a left atrium, a left ventricle, a right atrium, and a right ventricle from an ultrasound image of a heart.

Fig. 3 is a view illustrating an example of signal waveforms used for determination of a premature contraction.

Fig. 4 is a view for describing methods for setting a reference value and a threshold.

Fig. 5 is a flow chart illustrating an example of a method in accordance with an embodiment of the present invention for determining a premature contraction.

Description of Embodiments

[0010]

[Configuration of premature contraction determination device 1]

The following description will discuss a configuration of a premature contraction determination device 1 in accordance with an embodiment of the present invention, with reference to Fig. 1. As will be described in detail below, the premature contraction determination device 1 has a function of

determining the presence or absence of a premature contraction from images of a heart. The premature contraction determination device 1 makes it possible to output a determination result with higher accuracy in comparison to a case in which the presence or absence of a premature contraction is determined by electrocardiography.

[0011]

Fig. 1 is a block diagram illustrating an example of a configuration of main parts of the premature contraction determination device 1. As illustrated in Fig. 1, the premature contraction determination device 1 includes a processor 10, a memory 11, and a storage device 12. The premature contraction determination device 1 may be a personal computer, a server, or a workstation. The processor 10 loads a premature contraction determination program stored in the storage device 12 into the memory 11 and executes the premature contraction determination program to thereby function as sections from an acquisition section 101 to an output control section 106 (described later).

[0012]

The processor 10 can be realized by a logic circuit (hardware) provided in an integrated circuit (IC chip) or the like or can be alternatively realized by software. In a case where the processor 10 is realized by software, the processor 10 may be, for example, constituted by 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. The processor 10 then loads the software into the memory 11 and executes the software.

5 [0013]

The memory 11 and the storage device 12 are each a storage device that stores various data used by the premature contraction determination device 1. The memory 11 is a storage device capable of writing and reading out data at
10 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 also be applied. As the storage
15 device 12, for example, 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 also be applied.

[0014]

The premature contraction determination device 1 also
20 includes an input IF section 13 and an output IF section 14 each serving as an interface (IF) with an external device. The input IF section 13 is an interface for receiving input signals from input devices such as a keyboard and a mouse. The output IF section 14 is an interface for outputting, to an
25 external device, a result of determination of the presence or

absence of a premature contraction, and the like. For example, a display device can be connected to the output IF section 14, and a result of determination of the presence or absence of a premature contraction, and the like can be displayed on the display device.

[0015]

The processor 10 executes the premature contraction determination program to thereby function as the acquisition section 101, the specific component removal section 102, the reference value setting section 103, the determination section 104, the threshold setting section 105, and the output control section 106.

[0016]

The acquisition section 101 acquires a signal waveform that indicates a time-series change in area of a region of at least one selected from the group consisting of a left atrium, a left ventricle, a right atrium, and a right ventricle included in images of a heart. Note that the "signal waveform" is data that indicates a time-series change in area of the above region. The images of the heart, the area of each region, and the signal waveform will be described in detail later.

[0017]

The specific component removal section 102 carries out a process of removing specific frequency components from the signal waveform acquired by the acquisition section 101. As

detailed later, for example, the specific component removal section 102 may subject the signal waveform acquired by the acquisition section 101 to a low-pass filter and a high-pass filter to thereby remove high-frequency components and low-frequency components from the signal waveform.

[0018]

The reference value setting section 103 sets a reference value on the basis of displacements on the signal waveform acquired by the acquisition section 101. The threshold setting section 105 sets a threshold (predetermined threshold) for determining the presence or absence of a premature contraction. The methods of setting the threshold and the reference value will be described later.

[0019]

The determination section 104 determines whether or not a premature contraction has occurred. Specifically, in making the determination, the determination section 104 first identifies a time interval from a time point at which the area indicated by the signal waveform acquired by the acquisition section 101 equals the reference value set by the reference value setting section 103 to a next time point at which the area indicated by the signal waveform equals the reference value. The determination section 104 then compares the identified time interval with the threshold set by the threshold setting section 105 to determine whether or not a premature

contraction has occurred. Details of the determination will be described later.

[0020]

The output control section 106 outputs the result of the determination of the determination section 104 to various output devices. For example, in a case where a display device is connected via the output IF section 14, the output control section 106 may output the result of the determination to the display device. Of course, the output may be carried out in any fashion, and the result of the determination of the determination section 104 may be outputted by display output, audio output, print output, a combination thereof, or the like.

[0021]

As described above, the premature contraction determination device 1 includes the acquisition section 101 which acquires a signal waveform that is generated by analysis of images of a heart and that indicates a time-series change in area of a region of at least one selected from the group consisting of a left atrium, a left ventricle, a right atrium, and a right ventricle. The premature contraction determination device 1 also includes the determination section 104 which makes a comparison between (i) a time interval from a time point at which the area indicated by the signal waveform equals a reference value that is set on the

basis of displacements on the signal waveform to a next time point at which the area indicated by the signal waveform equals the reference value and (ii) a predetermined threshold. In this way, the determination section 104 determines whether or not a premature contraction has occurred.

[0022]

The inventors of the present application have discovered that in a case where a premature contraction occurs, a characteristic change appears in the time interval from the time point at which the area indicated by the signal waveform equals the reference value to the next time point at which the area equals the reference value. This makes it possible to accurately determine, from the images of the heart, whether or not a premature contraction has occurred.

[0023]

[Analysis of images of heart]

As described above, the premature contraction determination device 1 determines the presence or absence of a premature contraction with use of a signal waveform that is generated by analysis of images of a heart and that indicates a time-series change in area of a region of at least one selected from the group consisting of a left atrium, a left ventricle, a right atrium, and a right ventricle.

[0024]

The following will describe, with reference to Fig. 2,

analysis of images of a heart for generation of the signal waveform. Fig. 2 is a view illustrating an example of detection of regions of a left atrium, a left ventricle, a right atrium, and a right ventricle from an ultrasound image of a heart. More specifically, an image A1 shown in Fig. 2 is an ultrasound image of the heart, and an image A2 is an image obtained by superimposing results of detection of the regions on the ultrasound image. Note that the ultrasound image is an image of ultrasonic waves emitted to the heart and surroundings thereof and reflected by a surface of the heart etc., and can also be referred to as an echographic image.

[0025]

The heart appears in a region slightly below a center of the image A1. In the region, an outer shape of the heart can be recognized, and it can be seen that an inside of the heart is divided into a plurality of sections. Thus, in the ultrasound image, the two ventricles and the two atria of the heart can be recognized as individual closed regions. As such, by analyzing the ultrasound image, it is possible to detect the regions of the left atrium, the left ventricle, the right atrium, and the right ventricle.

[0026]

For example, it is possible to perform machine learning with use of training data in which regions of left atria, a left ventricles, right atria, and right ventricles in ultrasound

images of a heart are labeled as "left atrium", "left ventricle",
"right atrium", and "right ventricle", respectively, the labels
serving as correct data. Each of the labels can also be referred
to as an annotation. This makes it possible to build a
5 detection model capable of detecting regions from an
ultrasound image of a heart. For example, by building a
detection model of a convolutional neural network, it is
possible to detect regions with high accuracy.

[0027]

10 In the image A2 shown in Fig. 2, results of detection
carried out with use of such a detection model are indicated.
Detected regions R1 to R4 are regions detected as being a right
ventricle, a left ventricle, a left atrium, and a right atrium,
respectively. The detection of the regions enables numerical
15 representation of respective areas of the regions. For example,
an area of a region can be expressed by the number of pixels
contained in the region.

[0028]

[Generation of signal waveform and removal of specific
20 components from signal waveform]

By performing the above-described detection of regions
with respect to each of a plurality of ultrasound images
constituting a time series, it is possible to generate a signal
waveform indicating a time-series change in an area of each
25 of the regions. For example, signal waveforms may be

generated by (i) extracting, from ultrasound images that are a moving image, frame images constituting the respective ultrasound images and (ii) carrying out detection of regions in each of the frame images. An example of signal waveforms generated in this manner is shown in Fig. 3.

[0029]

Fig. 3 is a view illustrating an example of signal waveforms used for determination of a premature contraction. More specifically, B1 in Fig. 3 shows, for each of the regions of a right ventricle, a left ventricle, a left atrium, and a right atrium, a signal waveform indicating a time-series change in the number of pixels contained in that region. Note that the horizontal axis (time) is in seconds.

[0030]

As shown in B1, the number of pixels in each region, i.e., the area of each region increases and decreases repeatedly in similar cycles. However, for example, around 2.5 seconds to 3.0 seconds, the periodic pattern of increase and decrease is disrupted. The disruption in the pattern of increase and decrease is caused by arrhythmia. As such, arrhythmia can be detected by detecting the disruption in the periodic pattern of increase and decrease. Further, with the premature contraction determination device 1, it is possible to determine with high accuracy the presence or absence of a premature contraction on the basis of such a pattern of

increase and decrease in a signal waveform.

[0031]

Note that although a signal waveform as shown in B1 can be used as it is to determine the presence or absence of a premature contraction, alternatively, a signal waveform from which specific frequency components have been removed by the specific component removal section 102 may be used to determine the presence or absence of a premature contraction. In this case, the determination section 104 identifies the above-described time interval in the signal waveform from which the specific frequency components have been removed. This makes it possible to identify an appropriate time interval and to thereby improve the accuracy of the determination.

[0032]

B2 in Fig. 3 shows signal waveforms obtained by removing specific frequency components from the signal waveforms shown in B1 in Fig. 3. More specifically, B2 shows signal waveforms each obtained by removing, from a waveform signal, low-frequency band components (low-frequency components) including a DC component and a trend component and high-frequency band components (high-frequency components) including a noise component. By removing the low-frequency components, it is possible to obtain a signal waveform which indicates an increase or

decrease in area and displacements on which have a center value of zero, as shown in B2 of Fig. 3. Further, by removing the high-frequency components, it is possible to obtain a smooth waveform from which the noise component has been removed, as shown in B2 of Fig. 3.

[0033]

Note that a center value of displacements on a signal waveform is an average value of areas indicated by the signal waveform at respective times. For example, for a signal waveform of 10 seconds, a center value of displacements is an average value of all of the area values included in the signal waveform.

[0034]

Note here that in a case where the size of the entire heart shown in an image on which a signal waveform is based is constant, subtracting a center value of displacements from an area value on the signal waveform at each time allows obtaining a waveform which indicates an increase or decrease in area and displacements on which have a center value of zero. However, in a case where the size of the entire heart shown in an image on which a signal waveform is based changes over time, it is not possible, by the process of subtracting a center value of displacements, to obtain an appropriate waveform which indicates an increase or decrease in area and displacements on which have a center value of

zero. Examples of such a case include a case in which an image capturing device is moved during capturing of the image.

[0035]

5 For this reason, it is preferable that the specific component removal section 102 remove low-frequency components from a waveform signal, as described above. In this case, the determination section 104 identifies a time interval in the signal waveform from which the low-frequency
10 components have been removed. Since a trend component such as a change over time in size of the entire heart shown in an image is included among the low-frequency components, the above configuration allows the trend component to be removed as well and thereby makes it possible to obtain an
15 appropriate waveform that indicates an increase or decrease in area and displacements on which have a center value of zero.

[0036]

 As described above, the specific component removal
20 section 102 may also remove high-frequency components. The removal of the high-frequency components makes it possible to obtain a smooth waveform from which noise components have been removed. This contributes to improving the accuracy of determination of the determination section 104.
25 Note that the specific component removal section 102 may

also smooth the signal waveform with use of a moving average or the like, and a similar effect can be obtained also in this case.

[0037]

5 [Methods for setting reference value and threshold]

Methods for setting a reference value and a threshold will be described with reference to Fig. 4. Fig. 4 is a view for describing methods for setting a reference value and a threshold. Note that a signal waveform G1 shown in Fig. 4 is
10 an enlarged portion of one of the four signal waveforms shown in B1 of Fig. 3.

[0038]

As described above, the determination section 104 identifies a time interval from a time point at which an area
15 indicated by a signal waveform equals a reference value that is set on the basis of displacements on the signal waveform to a next time point at which the area indicated by the signal waveform equals the reference value. The reference value set by the reference value setting section 103 is used in the
20 identification of the time interval.

[0039]

The reference value setting section 103 can set any reference value within the range of displacements on the signal waveform. For example, the reference value setting
25 section 103 may set a center value of the displacements on

the signal waveform as a reference value. For example, a reference value in Fig. 4 is 0, and this reference value is indicated by a line segment L. As described above, the center value of the displacements on the signal waveform is an average value of the entire signal or a value of a trend component. This configuration allows an appropriate time interval to be identified, so that the accuracy of the determination can be improved.

[0040]

It is also possible to preset the reference value to 0. In this case, the reference value setting section 103 may be omitted, and the presence or absence of a premature contraction may be determined with use of a signal waveform from which the specific component removal section 102 has removed low-frequency components. Also, for example, the acquisition section 101 may acquire a signal waveform from which low-frequency components have been removed. In this case, the specific component removal section 102 may also be omitted.

[0041]

In a case of thus setting the reference value to 0, it is necessary to remove, from the signal waveform, low-frequency components including a DC component and a trend component. Further, in a case of not removing low-frequency components, the reference value setting section 103 may set

a peak value (a point at which a change from increase to decrease or from decrease to increase has occurred in value of the area), not the 0 point, as a reference point. In this case, the determination section 104 identifies a time interval
5 between reference points and determines, on the basis of the identified time interval, whether or not a premature contraction has occurred. Note that in order to prevent an increase or decrease in value of the area due to noise from being mistakenly regarded as a peak value, it is preferable in
10 this case to smooth the waveform signal by, for example, removal of high-frequency components.

[0042]

In a case the reference value setting section 103 has set the reference value in the above manner, the determination
15 section 104 identifies a time interval from a time point at which the area indicated by the signal waveform equals the reference value, which has been set on the basis of displacements on the signal waveform, to a next time point at which the area indicated by the signal waveform equals the
20 reference value.

[0043]

For example, in the case of the signal waveform G1 in Fig. 4, the determination section 104 identifies a time interval
25 t1 from a point P1 to a point P2, a time interval t2 from the point P2 to a point P3, a time interval t3 from the point P3 to

a point P4, a time interval t4 from the point P4 to a point P5, and the time interval t5 from the point P5 to a point P6. The same applies to the point P6 and beyond.

[0044]

5 The threshold setting section 105 may set a representative value of the thus identified time intervals to be a threshold serving as a reference. By setting the threshold on the basis of the representative value of the time intervals, it is possible to make an appropriate determination that takes
10 into account a difference in fluctuation pattern of the signal waveform due to a difference between individuals and a difference due to a physical condition or the like. Note that the representative value may be any value that represents the identified time intervals. For example, a center value or an
15 average value of the identified time intervals may be used as the representative value. Doubling the center value or the average value of the time intervals yields a value substantially equal to a pulse rate.

[0045]

20 For example, the threshold setting section 105 may set the threshold to a value obtained by adding a predetermined value to the representative value, or may set the threshold to a value obtained by subtracting a predetermined value from the representative value. For example, the threshold setting
25 section 105 may set the threshold to a value obtained by

adding 0.2 seconds to the representative value, or may set the threshold to a value obtained by subtracting 0.2 seconds from the representative value. Further, for example, the threshold setting section 105 may set the threshold to a value that is a predetermined number of times greater than the representative value, or may set the threshold to a value that is a predetermined number of times smaller than the representative value.

[0046]

In a case where a value greater than the representative value is set as the threshold, the determination section 104 determines that a premature contraction has occurred, if a time interval not less than the threshold is included among the identified time intervals. In a case where a value smaller than the representative value is set as the threshold, the determination section 104 determines that a premature contraction has occurred, if a time interval not more than the threshold is included among the identified time intervals.

[0047]

Further, the threshold setting section 105 may set both a threshold greater than the representative value and a threshold smaller than the representative value. In this case, the determination section 104 may determine that a premature contraction has occurred, if the identified time intervals include at least one selected from the group

consisting of: a time interval not less than the threshold greater than the representative value; and a time interval not more than the threshold smaller than the representative value.

5 [0048]

[Method for determining premature contraction]

A method for determining a premature contraction in accordance with the present embodiment will be described with reference to Fig. 5. Fig. 5 is a flow chart illustrating an example of the method for determining a premature contraction in accordance with the present embodiment.

[0049]

In S1 (acquisition step), the acquisition section 101 acquires a signal waveform generated by analysis of images of a heart, the signal waveform indicating a time-series change in area of a region of at least one selected from the group consisting of a left atrium, a left ventricle, a right atrium, and a right ventricle during a predetermined period. For example, the acquisition section 101 may acquire a signal waveform inputted via the input IF section 13. Note that, below, an example of acquiring signal waveforms corresponding to the left atrium, the left ventricle, the right atrium, and the right ventricle, respectively, will be described.

[0050]

25 In S2, the specific component removal section 102

removes specific frequency components from the signal waveform acquired in S1. For example, as described above, the specific component removal section 102 may remove high-frequency components with use of a low-pass filter and low-frequency components with use of a high-pass filter. This process is carried out for each of the signal waveforms corresponding to the left atrium, the left ventricle, the right atrium, and the right ventricle. The same applies to the processes in S3 to S5.

[0051]

In S3, the reference value setting section 103 sets a reference value on the basis of displacements on the signal waveform from which the specific frequency components have been removed in S2. For example, the reference value setting section 103 may set a center value of the displacements on the signal waveform as the reference value. In a case where low-frequency components are removed in S2 so that a center value of the displacements on the signal waveform is zero, the reference value may be set to zero in advance and the process of S3 may be omitted.

[0052]

In S4, the determination section 104 identifies a time interval from a time point at which an area indicated by the signal waveform from which the specific frequency components have been removed in S2 equals the reference

value set in S3 to a next time point at which the area indicated by the signal waveform equals the reference value. This process is carried out for the entire signal waveform in a predetermined period, and a plurality of time intervals are identified.

[0053]

In S5, the threshold setting section 105 sets a threshold for determining the presence or absence of a premature contraction on the basis of the time intervals identified in S4.

For example, the threshold setting section 105 may set a threshold on the basis of a representative value of the time intervals identified in S4. Further, the threshold setting section 105 may set at least one selected from the group consisting of: a threshold greater than the representative value; and a threshold smaller than the representative value.

[0054]

In S6 (determination step), the determination section 104 determines whether or not a premature contraction has occurred, by comparing a time interval identified in S4 with the threshold value set in S5. This determination is carried out for each of the left atrium, the left ventricle, the right atrium, and the right ventricle, and a result of determination is obtained for each of these regions as to whether or not a premature contraction has occurred. This makes it possible to not only identify the presence or absence of a premature

contraction but also identify in which region of the heart the premature contraction has occurred.

[0055]

Note that the determination section 104 may make a final determination as to whether or not a premature contraction has occurred, on the basis of the respective results of determination for the plurality of regions. For example, the determination section 104 may make a final determination such that in a case where a determination result for at least one of the plurality of regions indicates that a premature contraction has occurred, a result of the final determination indicates that a premature contraction has occurred. Further, for example, the determination section 104 may make a final determination such that only in a case where the determination results for the plurality of regions coincide with each other and indicate that a premature contraction has occurred, final determination results for the plurality of regions each indicate that a premature contraction has occurred.

[0056]

Further, instead of making determinations for all of the four regions, the determination section 104 may make determinations for only the left and right atria or for only the left and right ventricles. Also, the determination section 104 may make a determination for only one of the four regions.

[0057]

In S7, the output control section 106 outputs the determination result of S6 to a predetermined output device, so that the process in Fig. 5 is ended. Note that the process
5 may be ended by storing the determination result in the storage device 12 or the like instead of outputting the determination result.

[0058]

As described above, the method for determining a
10 premature contraction in accordance with the present embodiment includes the acquisition step (S1) of acquiring a signal waveform that is generated by analysis of images of a heart and that indicates a time-series change in area of a region of at least one selected from the group consisting of a
15 left atrium, a left ventricle, a right atrium, and a right ventricle. The method for determining a premature contraction also includes the determination step (S6). In the determination step, a comparison is made between (i) a time interval from a time point at which the area indicated by the
20 signal waveform equals a reference value that is set on the basis of displacements on the signal waveform to a next time point at which the area indicated by the signal waveform equals the reference value and (ii) a predetermined threshold. In this way, whether or not a premature contraction has
25 occurred is determined in the determination step. This makes

it possible to accurately determine the presence or absence of a premature contraction.

[0059]

(Variations)

5 The processes described in the foregoing embodiments can each be carried out by any entity, which is not limited to the foregoing examples. That is, a premature contraction determination system having functions similar to those of the premature contraction determination device 1 can be
10 constructed by a plurality of information processing devices that can communicate with each other. For example, it is possible to construct the premature contraction determination system having functions similar to those of the premature contraction determination device 1, by dispersedly
15 providing, in the plurality of information processing devices, the blocks included in the processor 10 illustrated in Fig. 1.

[0060]

 For example, the steps in the method for determining a premature contraction illustrated in Fig. 5 may be carried out
20 by a single information processing device (the premature contraction determination device 1) or by a plurality of information processing devices.

[0061]

 Further, the present invention also encompasses a
25 premature contraction determination system that includes: an

image capturing device or an image generating device; an information processing device; and the premature contraction determination device 1. The image capturing device captures an image of a heart, and the image generating device generates an image of a heart. The information processing device analyzes the captured or generated image to generate the signal waveform described above. The premature contraction determination device 1 determines the presence or absence of a premature contraction with use of the generated signal waveform. Further, the premature contraction determination system may include an output device that outputs a result of the determination of the presence or absence of a premature contraction.

[0062]

[Software Implementation Example]

As described above, functions of the premature contraction determination device 1 can be realized by a premature contraction determination program for causing a computer to function as the premature contraction determination device 1, the program causing the computer to function as control blocks of the device.

[0063]

The program can be stored in one or more non-transitory computer-readable storage media. The one or more storage media may be included in the premature contraction

determination device 1 or may not be included in the premature contraction determination device 1. In the latter case, the program can be made available to the premature contraction determination device 1 via any wired or wireless transmission medium.

[0064]

Further, all or part of the functions of the premature contraction determination device 1 can also be realized by a logic circuit. For example, an integrated circuit in which a logic circuit functioning as the control blocks (the sections included in the processor 10) illustrated in Fig. 1 is formed is included in the scope of the present invention. Apart from the above, the functions of the control blocks can also be realized, for example, by a quantum computer.

[0065]

The present invention is not limited to the above-described embodiments, and can be altered in various ways within the scope of the claims. The present invention also encompasses, in its technical scope, any embodiment derived by combining technical means disclosed in the embodiments.

[0066]

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

A premature contraction determination device in accordance with Aspect 1 of the present invention includes:

an acquisition section that acquires a signal waveform generated by analysis of images of a heart, the signal waveform indicating a time-series change in area of a region of at least one selected from the group consisting of a left atrium, a left ventricle, a right atrium, and a right ventricle; and a determination section that determines whether or not a premature contraction has occurred, by making a comparison between (i) a time interval from a time point at which the area indicated by the signal waveform equals a reference value to a next time point at which the area indicated by the signal waveform equals the reference value, the reference value being set on the basis of displacements on the signal waveform, and (ii) a predetermined threshold.

[0067]

A premature contraction determination device in accordance with Aspect 2 of the present invention may be configured such that, in Aspect 1, the premature contraction determination device further includes: a specific component removal section that removes low-frequency components of the signal waveform, the determination section determining the time interval in the signal waveform from which the low-frequency components have been removed.

[0068]

A premature contraction determination device in accordance with Aspect 3 of the present invention may be

configured such that, in Aspect 1 or 2, the reference value is a center value of the displacements on the signal waveform.

[0069]

A premature contraction determination device in accordance with Aspect 4 of the present invention may be configured such that, in any one of Aspects 1 to 3, the predetermined threshold is a value that is set on the basis of a representative value of the time interval.

[0070]

A method in accordance with Aspect 5 of the present invention for determining a premature contraction is a method carried out by one or more information processing devices, the method including: an acquisition step of acquiring a signal waveform generated by analysis of images of a heart, the signal waveform indicating a time-series change in area of a region of at least one selected from the group consisting of a left atrium, a left ventricle, a right atrium, and a right ventricle; and a determination step of determining whether or not a premature contraction has occurred, by making a comparison between (i) a time interval from a time point at which the area indicated by the signal waveform equals a reference value to a next time point at which the area indicated by the signal waveform equals the reference value, the reference value being set on the basis of displacements on the signal waveform, and (ii) a predetermined threshold.

[0071]

A premature contraction determination program for causing a computer to function as a premature contraction determination device described in any one of Aspects 1 to 4,
5 the premature contraction determination program causing the computer to function as the acquisition section and the determination section.

Reference Signs List

10 [0072]

1: Premature contraction determination device

101: Acquisition section

102: Specific component removal section

104: Determination section

15 S1: Acquisition step

S6: Determination step

Claims

[Claim 1]

A premature contraction determination device,
5 comprising:

an acquisition section that acquires a signal waveform
generated by analysis of images of a heart, the signal
waveform indicating a time-series change in area of a region
of at least one selected from the group consisting of a left
10 atrium, a left ventricle, a right atrium, and a right ventricle;
and

a determination section that determines whether or not
a premature contraction has occurred, by making a
comparison between (i) a time interval from a time point at
15 which the area indicated by the signal waveform equals a
reference value to a next time point at which the area
indicated by the signal waveform equals the reference value,
the reference value being set on the basis of displacements on
the signal waveform, and (ii) a predetermined threshold.

20 [Claim 2]

The premature contraction determination device as set
forth in claim 1, further comprising:

a specific component removal section that removes low-
25 frequency components of the signal waveform,

the determination section determining the time interval in the signal waveform from which the low-frequency components have been removed.

5 [Claim 3]

The premature contraction determination device as set forth in claim 1 or 2, wherein the reference value is a center value of the displacements on the signal waveform.

10 [Claim 4]

The premature contraction determination device as set forth in claim 1 or 2, wherein the predetermined threshold is a value that is set on the basis of a representative value of the time interval.

15 [Claim 5]

A method for determining a premature contraction, the method being carried out by one or more information processing devices,

20 the method comprising:

an acquisition step of acquiring a signal waveform generated by analysis of images of a heart, the signal waveform indicating a time-series change in area of a region of at least one selected from the group consisting of a left atrium, a left ventricle, a right atrium, and a right ventricle;

25

and

a determination step of determining whether or not a premature contraction has occurred, by making a comparison between (i) a time interval from a time point at which the area indicated by the signal waveform equals a reference value to a next time point at which the area indicated by the signal waveform equals the reference value, the reference value being set on the basis of displacements on the signal waveform, and (ii) a predetermined threshold.

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[Claim 6]

A premature contraction determination program for causing a computer to function as a premature contraction determination device recited in claim 1, the premature contraction determination program causing the computer to function as the acquisition section and the determination section.

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