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(54) **ESTIMATION METHOD AND ESTIMATION DEVICE**

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(52) **U.S. Cl.**

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(57) **ABSTRACT**

Provided is an estimation method executed by a processor of an estimation device. The estimation method includes: acquiring monitor information regarding an electrical characteristic value in an energy treatment tool when non-treatment energy for monitoring is applied to a living tissue from the energy treatment tool; acquiring image information regarding an endoscopic image obtained by imaging the living tissue; and performing estimation regarding thermal invasion in the living tissue based on at least one of the monitor information and the image information and on an output setting value of treatment energy for treating the living tissue with the energy treatment tool.

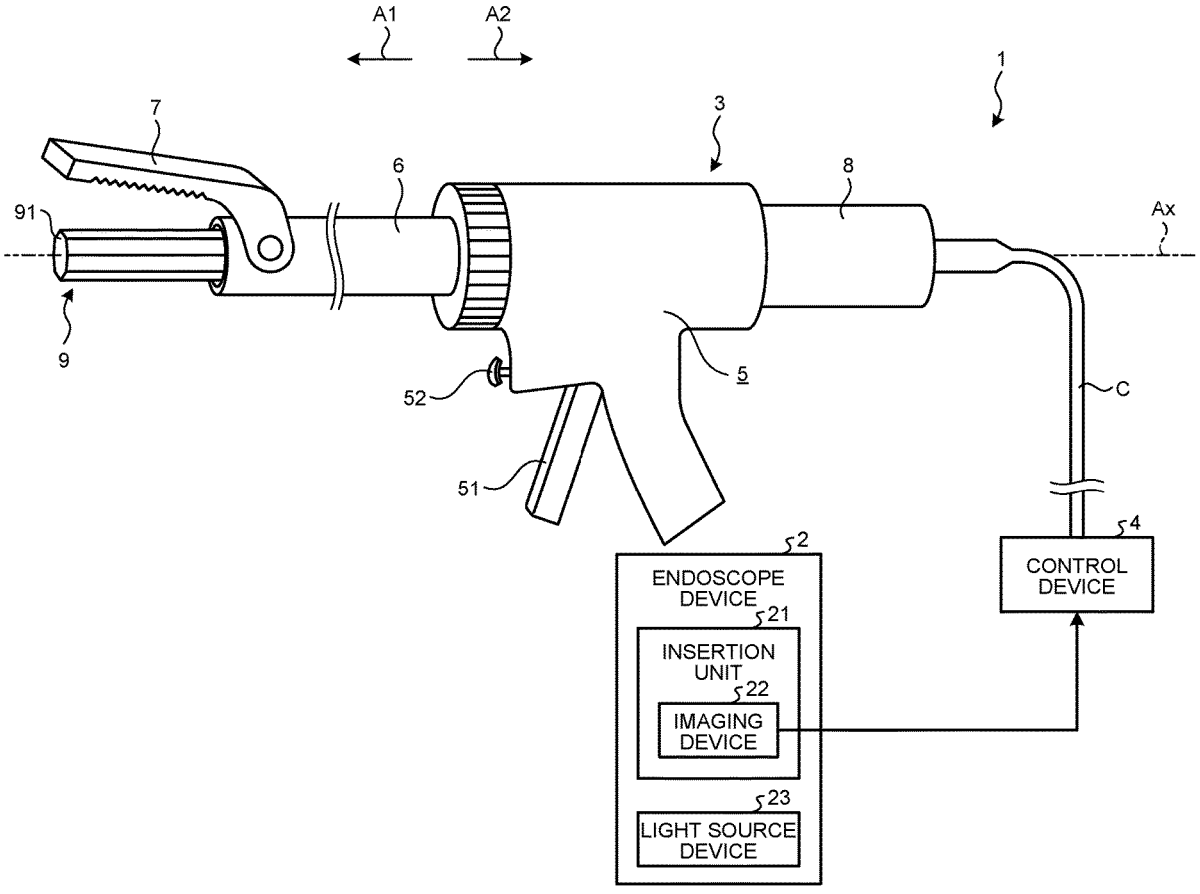


FIG.1

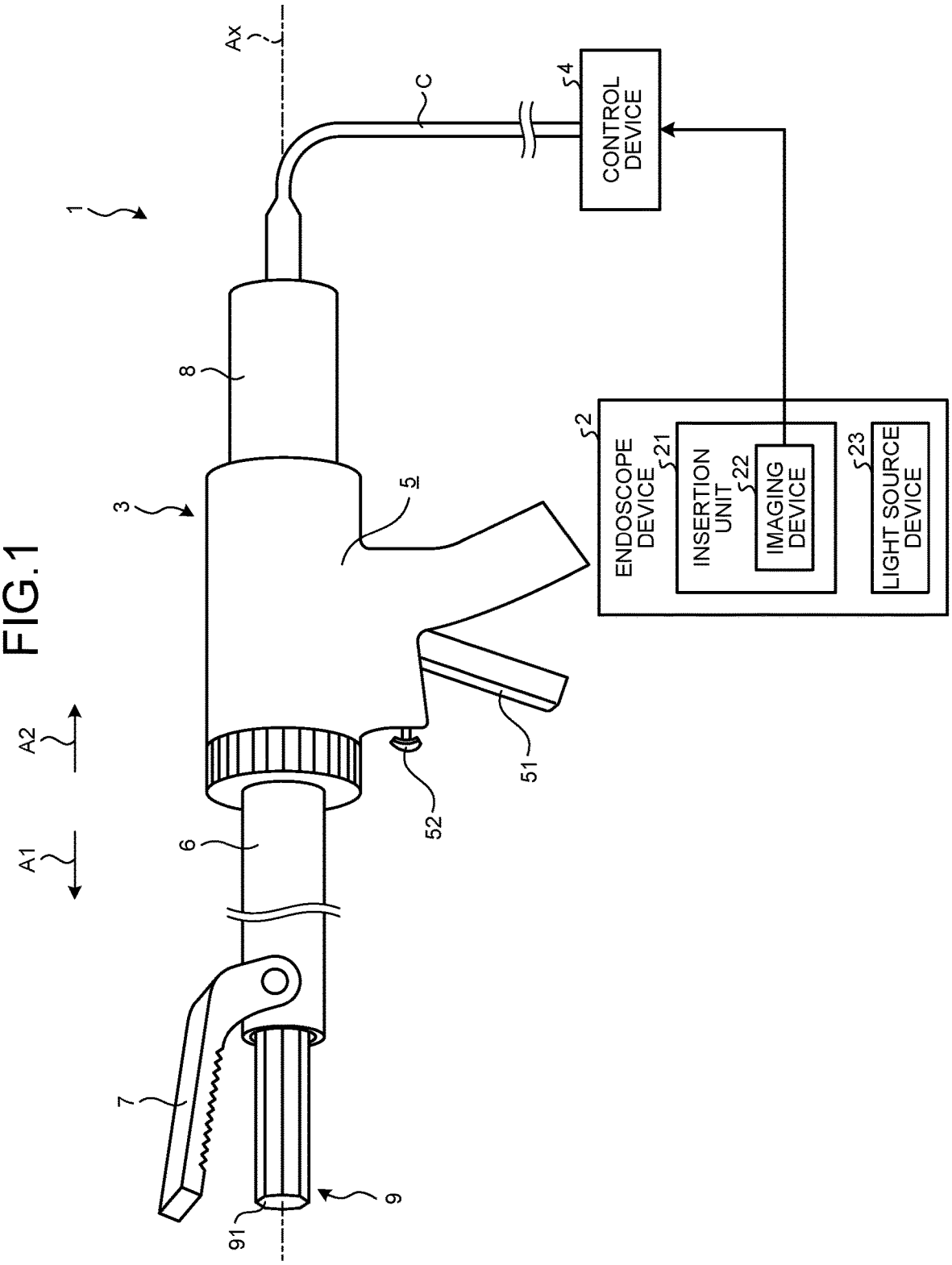

Ax
C
4
CONTROL DEVICE
1
8
3
5
2
ENDOSCOPE DEVICE
21
INSERTION UNIT
22
IMAGING DEVICE
23
LIGHT SOURCE DEVICE
A2
A1
6
52
51
7
9
91

FIG.2

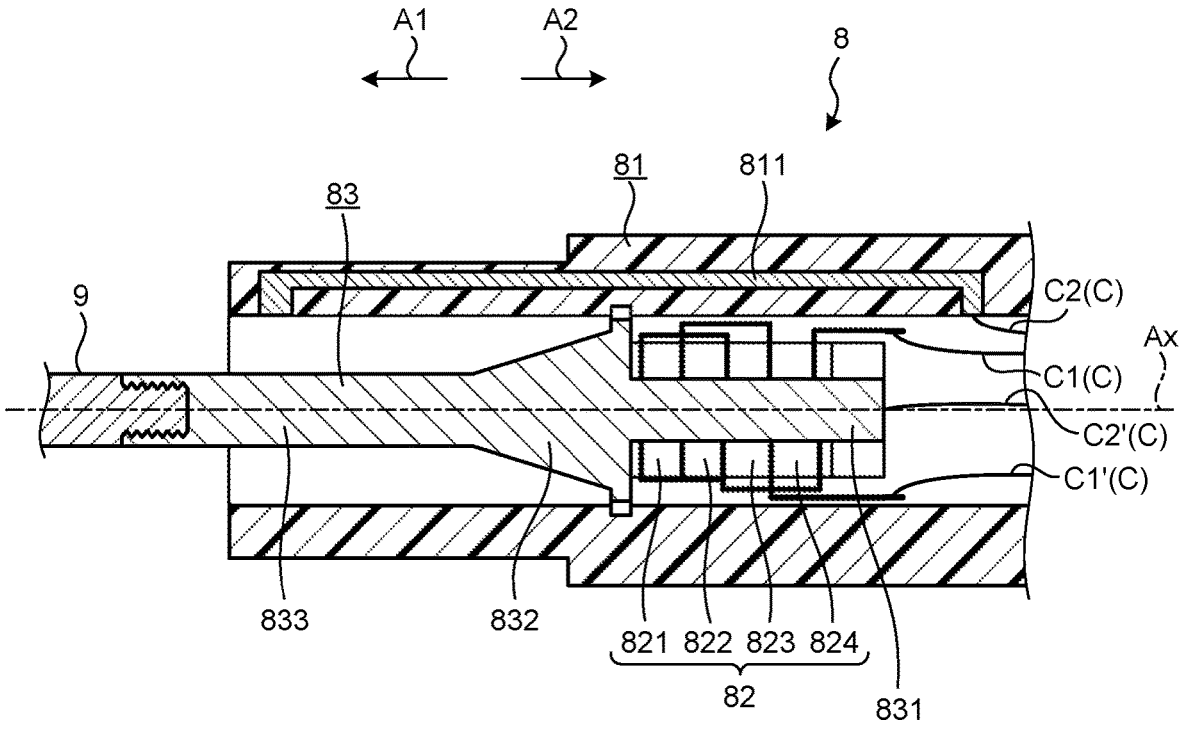

A1
A2
8
81
811
83
9
C2(C)
Ax
C1(C)
C2'(C)
C1'(C)
833
832
821 822 823 824
82
831

FIG.3

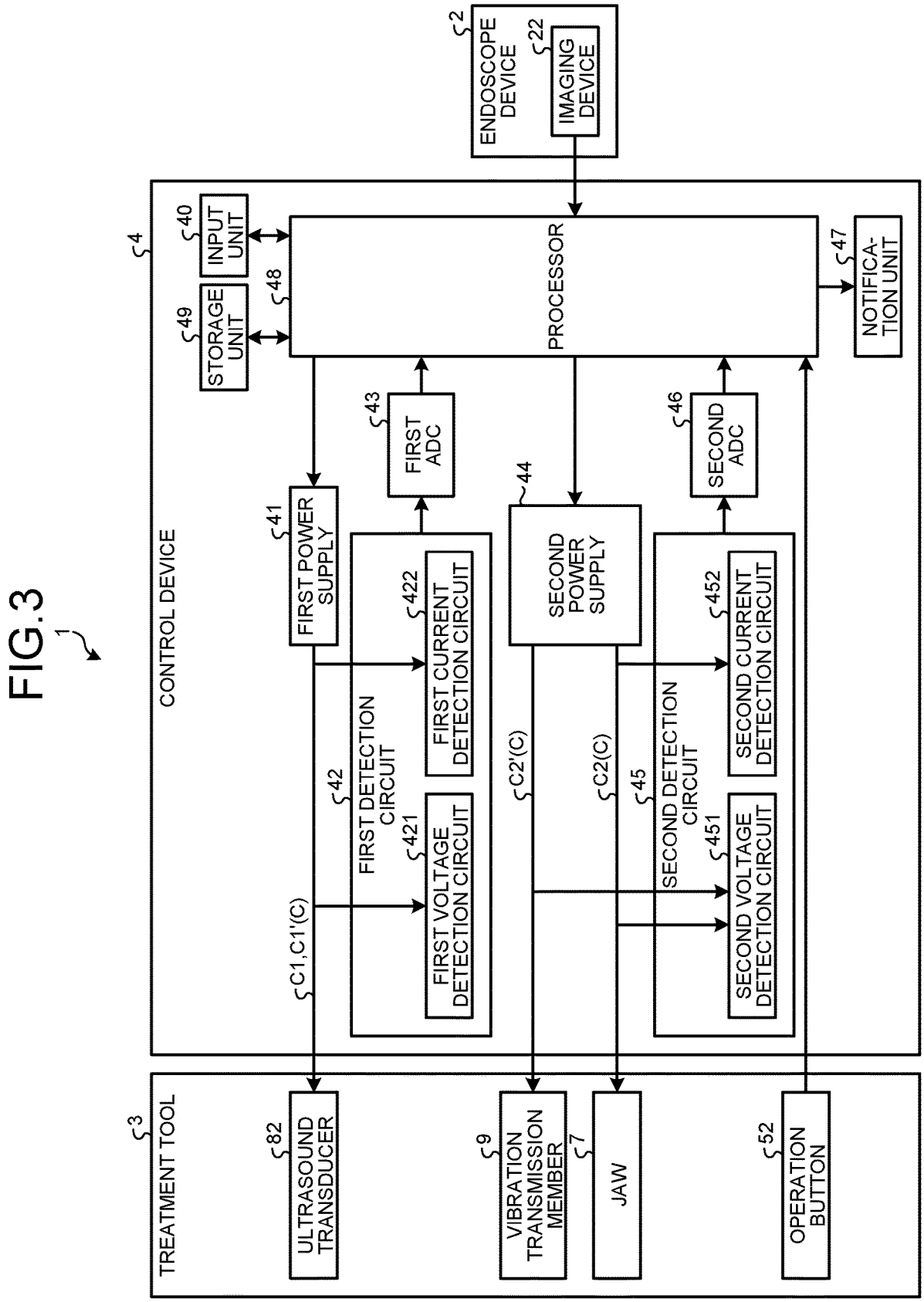

1
2
ENDOSCOPE DEVICE
22
IMAGING DEVICE
4
CONTROL DEVICE
40
INPUT UNIT
48
PROCESSOR
47
NOTIFICA-TION UNIT
49
STORAGE UNIT
43
FIRST ADC
46
SECOND ADC
41
FIRST POWER SUPPLY
44
SECOND POWER SUPPLY
422
FIRST CURRENT DETECTION CIRCUIT
452
SECOND CURRENT DETECTION CIRCUIT
42
FIRST DETECTION CIRCUIT
45
SECOND DETECTION CIRCUIT
421
FIRST VOLTAGE DETECTION CIRCUIT
451
SECOND VOLTAGE DETECTION CIRCUIT
C1,C1'(C)
C2'(C)
C2(C)
3
TREATMENT TOOL
82
ULTRASOUND TRANSDUCER
9
VIBRATION TRANSMISSION MEMBER
7
JAW
52
OPERATION BUTTON

FIG.4

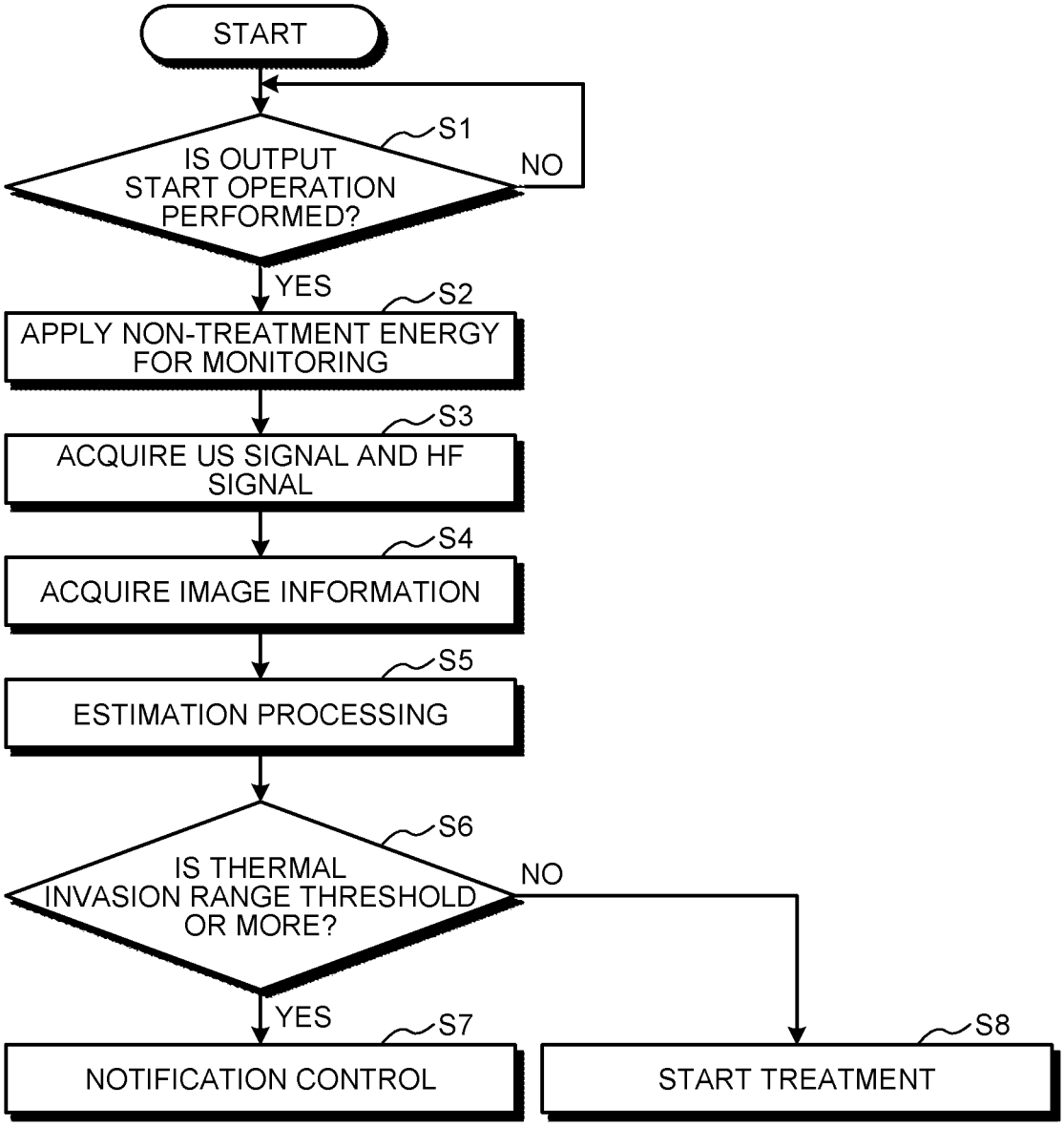

START
S1
IS OUTPUT START OPERATION PERFORMED?
NO
YES
S2
APPLY NON-TREATMENT ENERGY FOR MONITORING
S3
ACQUIRE US SIGNAL AND HF SIGNAL
S4
ACQUIRE IMAGE INFORMATION
S5
ESTIMATION PROCESSING
S6
IS THERMAL INVASION RANGE THRESHOLD OR MORE?
NO
YES
S7
NOTIFICATION CONTROL
S8
START TREATMENT

FIG.5

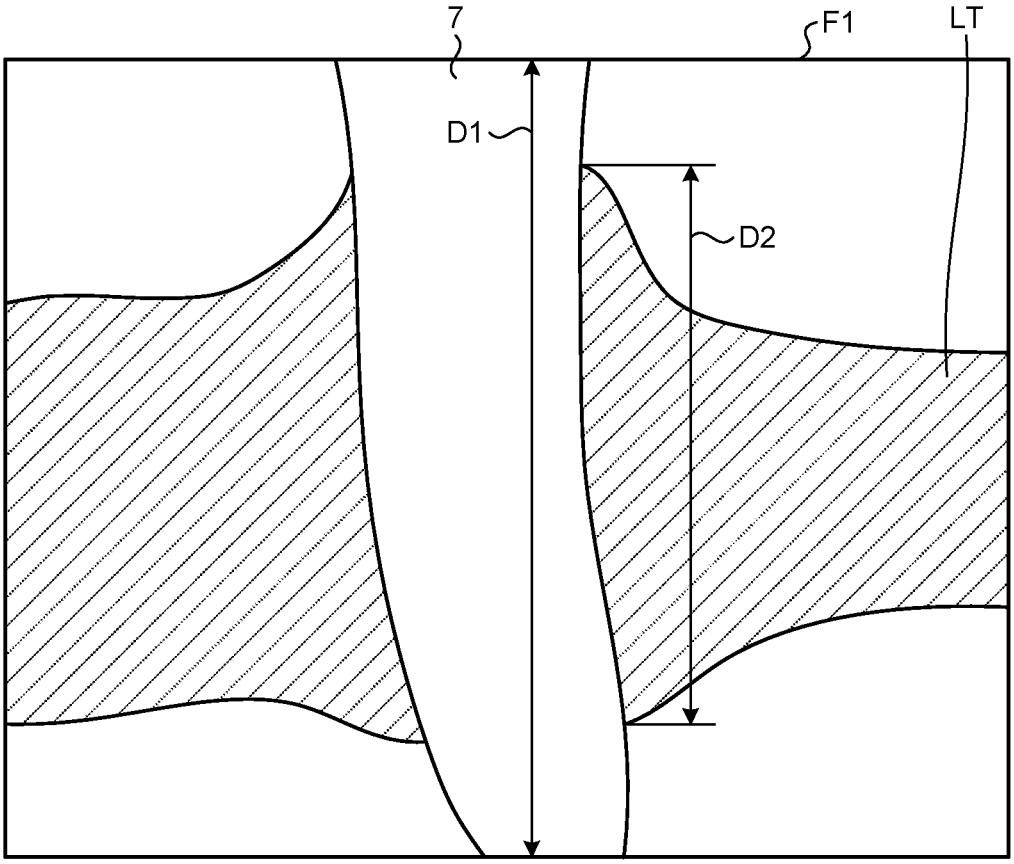


FIG.6

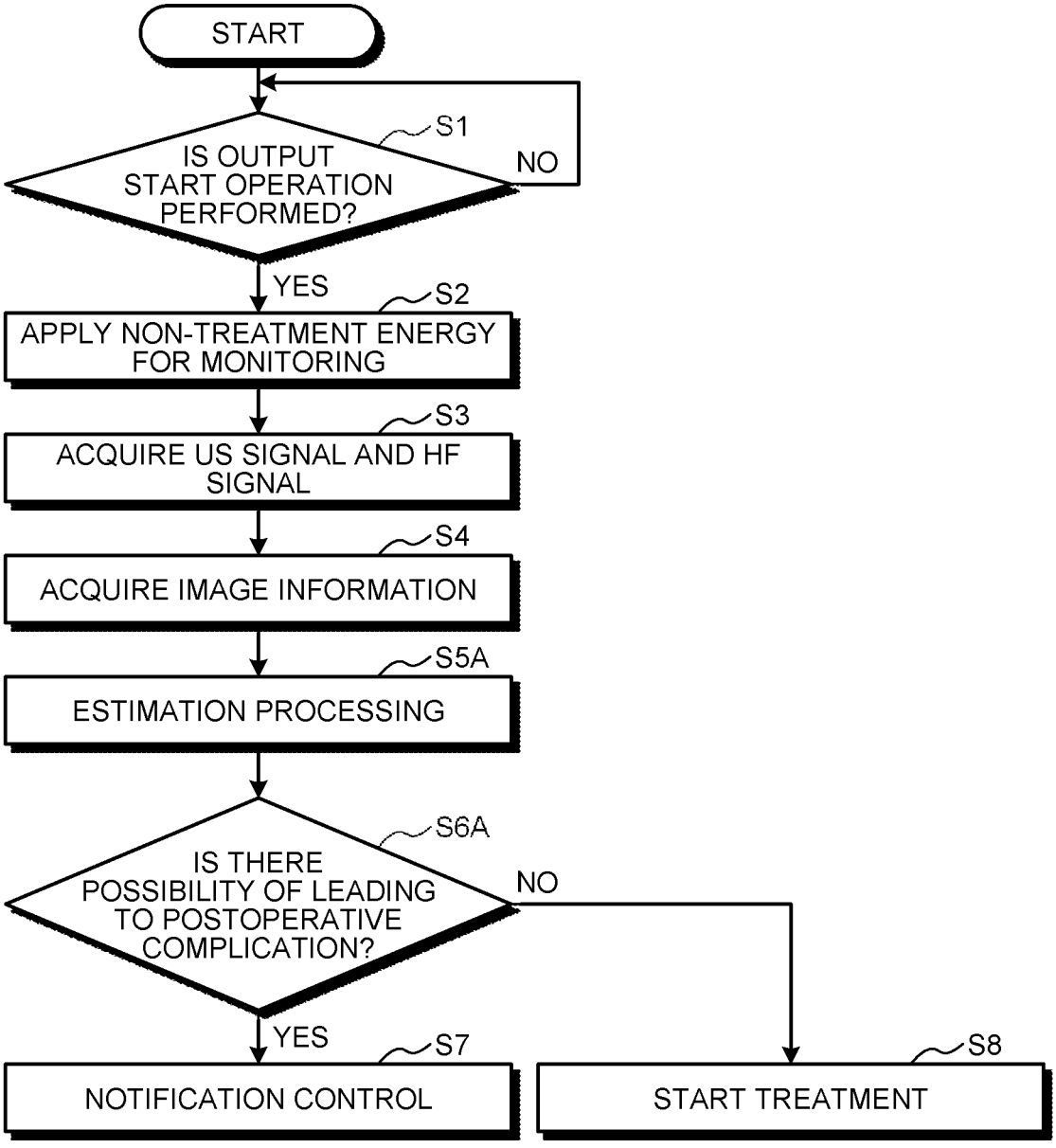

START
S1
IS OUTPUT START OPERATION PERFORMED?
NO
YES
S2
APPLY NON-TREATMENT ENERGY FOR MONITORING
S3
ACQUIRE US SIGNAL AND HF SIGNAL
S4
ACQUIRE IMAGE INFORMATION
S5A
ESTIMATION PROCESSING
S6A
IS THERE POSSIBILITY OF LEADING TO POSTOPERATIVE COMPLICATION?
NO
YES
S7
NOTIFICATION CONTROL
S8
START TREATMENT

FIG.7

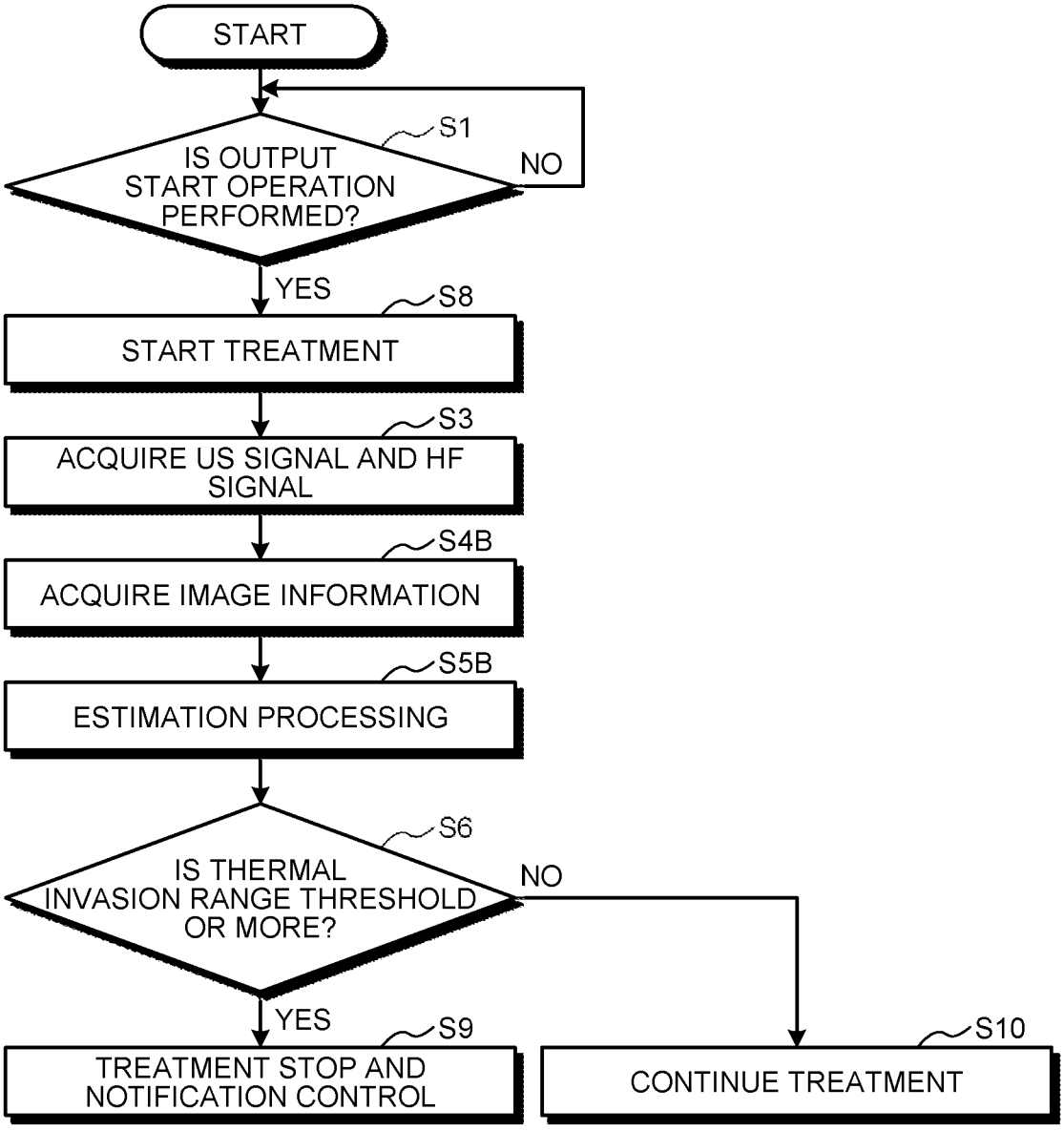

START
S1
IS OUTPUT START OPERATION PERFORMED?
NO
YES
S8
START TREATMENT
S3
ACQUIRE US SIGNAL AND HF SIGNAL
S4B
ACQUIRE IMAGE INFORMATION
S5B
ESTIMATION PROCESSING
S6
IS THERMAL INVASION RANGE THRESHOLD OR MORE?
NO
YES
S9
TREATMENT STOP AND NOTIFICATION CONTROL
S10
CONTINUE TREATMENT

FIG.8

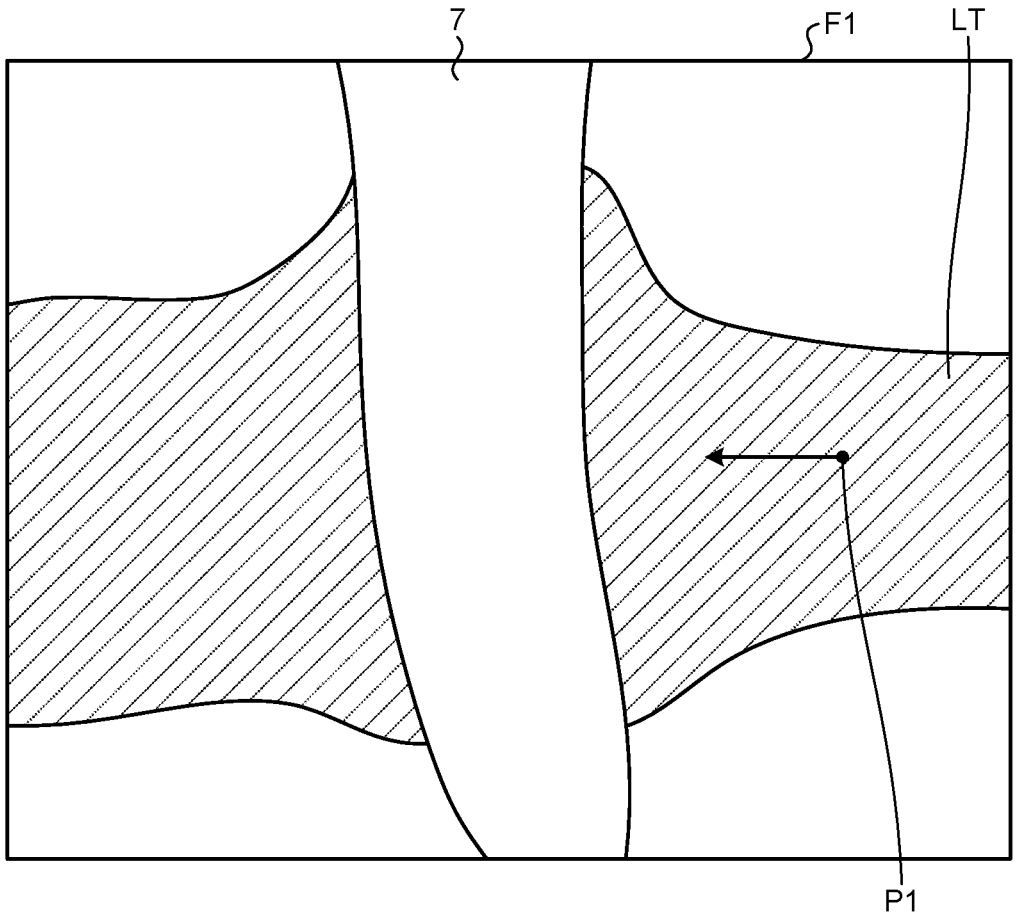


FIG.9

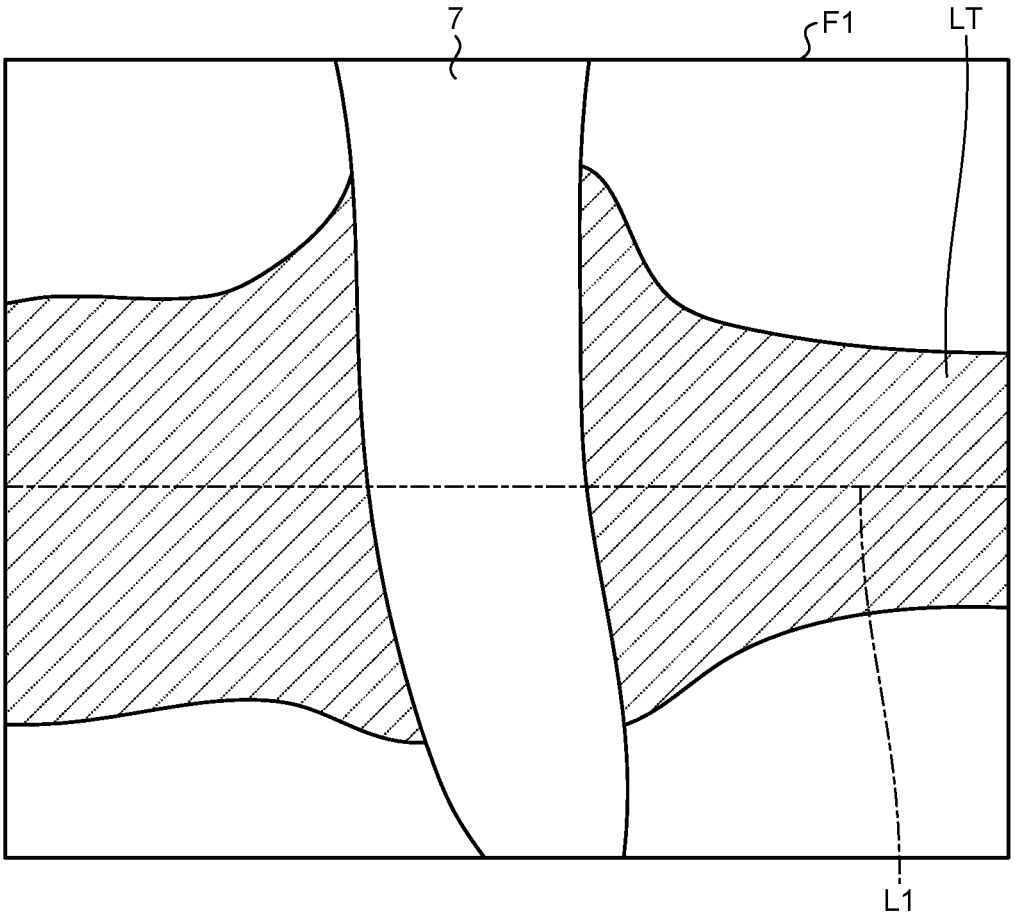


FIG.10

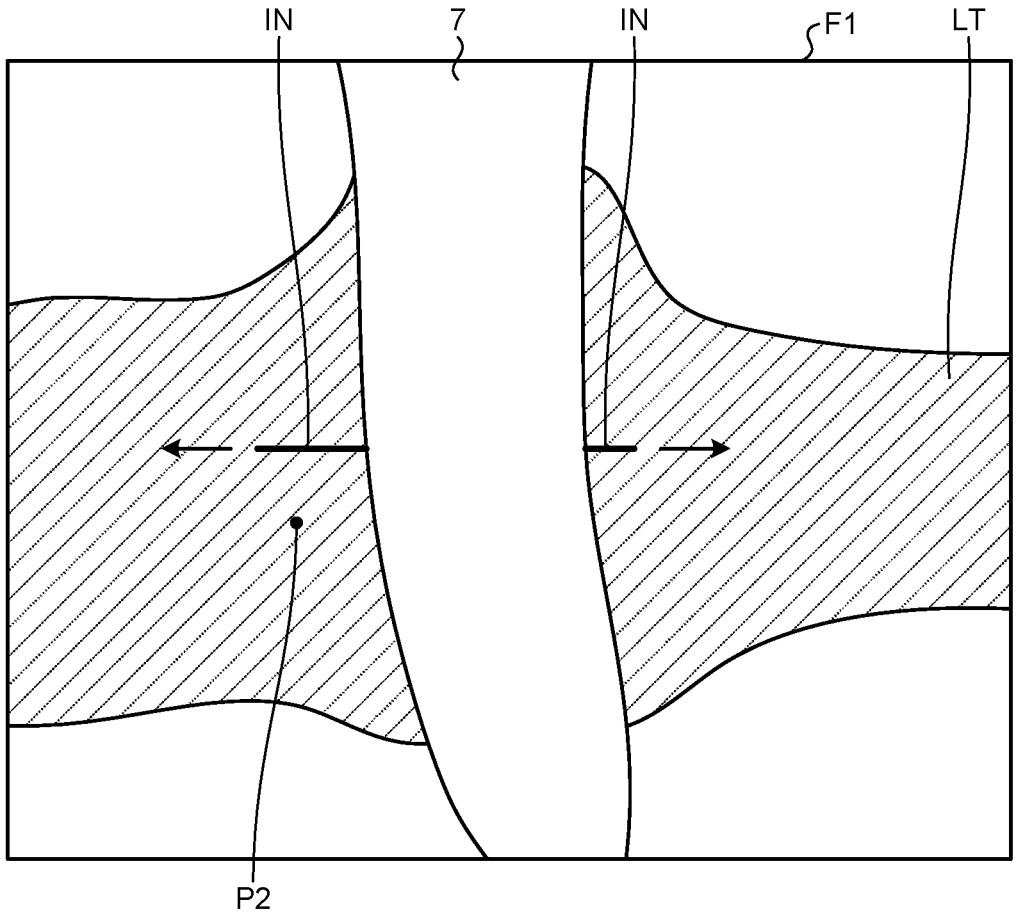


FIG.11

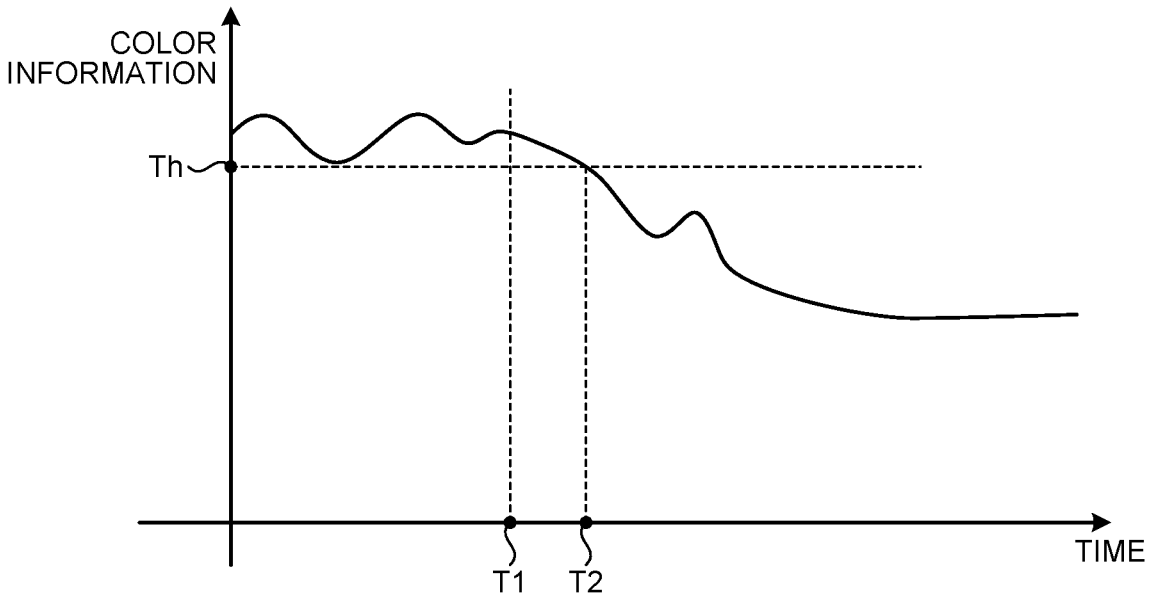
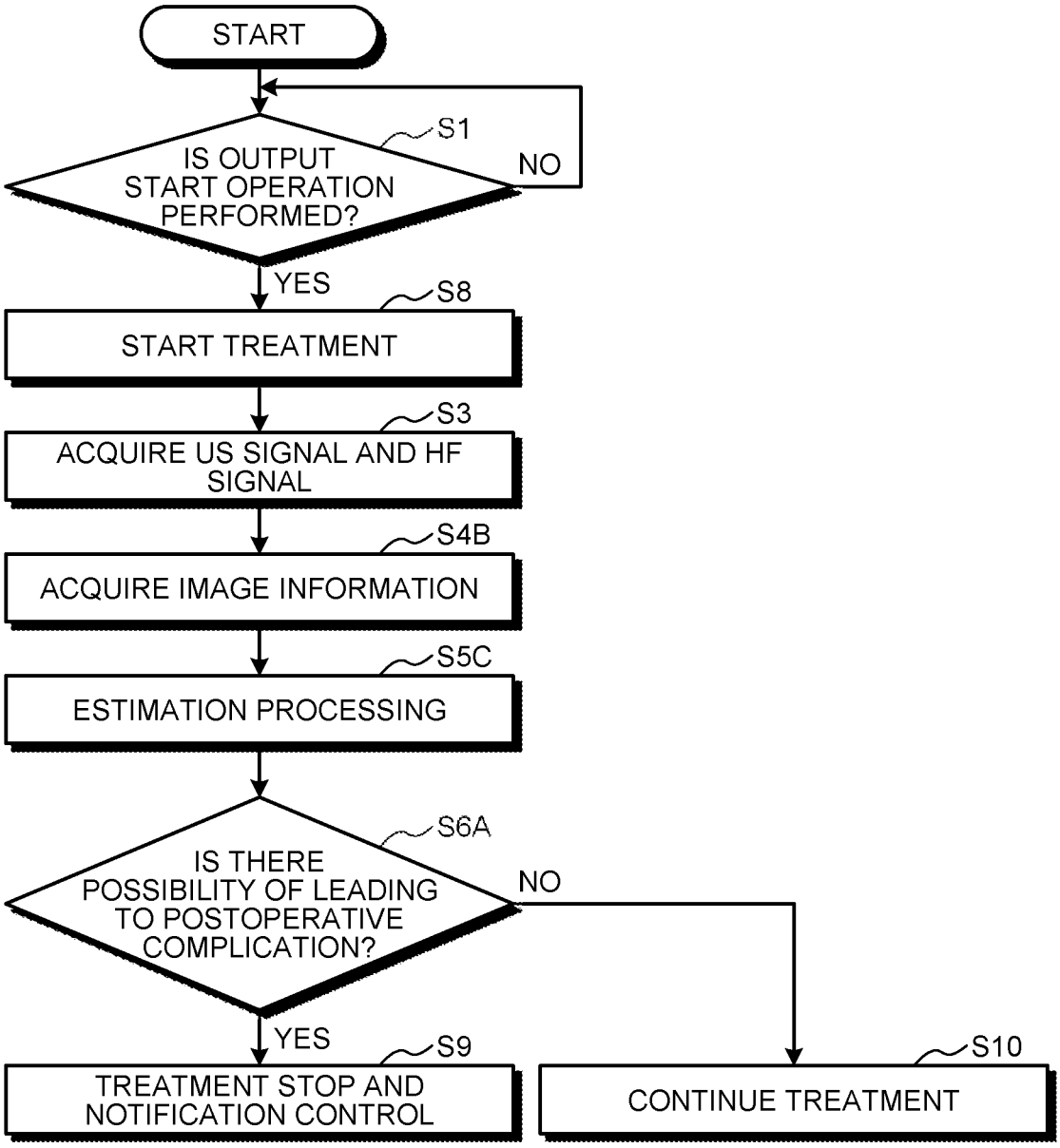


FIG.12


START
S1
IS OUTPUT START OPERATION PERFORMED?
NO
YES
S8
START TREATMENT
S3
ACQUIRE US SIGNAL AND HF SIGNAL
S4B
ACQUIRE IMAGE INFORMATION
S5C
ESTIMATION PROCESSING
S6A
IS THERE POSSIBILITY OF LEADING TO POSTOPERATIVE COMPLICATION?
NO
YES
S9
TREATMENT STOP AND NOTIFICATION CONTROL
S10
CONTINUE TREATMENT

ESTIMATION METHOD AND ESTIMATION DEVICE

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This application is based on and claims priority under 35 U.S.C. § 119 to U.S. Provisional Application No. 63/374,489, filed on Sep. 2, 2022, the entire contents of which are incorporated herein by reference.

FIELD OF DISCLOSURE

[0002] The present disclosure relates to an estimation method and an estimation device.

BACKGROUND

[0003] A treatment system that treats a living tissue by applying treatment energy to the living tissue from an energy treatment tool can be found, for example, in WO 2015/122308 A and WO 2017/187523 A.

[0004] In the treatment system described in WO 2015/122308 A, ultrasonic energy is employed as the treatment energy. Then, in the energy treatment system, the treatment (incision) completion of the living tissue is determined by monitoring the behavior of an ultrasonic impedance value.

[0005] In addition, in the treatment system described in WO 2017/187523 A, high frequency energy is employed as the treatment energy. Then, in the energy treatment system, the operation of the energy treatment tool is controlled by monitoring the behavior of the impedance value of the living tissue.

SUMMARY

[0006] In some embodiments, provided is an estimation method executed by a processor of an estimation device. The estimation method includes: acquiring monitor information regarding an electrical characteristic value in an energy treatment tool when non-treatment energy for monitoring is applied to a living tissue from the energy treatment tool; acquiring image information regarding an endoscopic image obtained by imaging the living tissue; and performing estimation regarding thermal invasion in the living tissue based on at least one of the monitor information and the image information and on an output setting value of treatment energy for treating the living tissue with the energy treatment tool.

[0007] In some embodiments, provided is an estimation method executed by a processor of an estimation device. The estimation method includes: acquiring output information regarding an electrical characteristic value in an energy treatment tool when treatment energy is applied to a living tissue from the energy treatment tool; acquiring image information regarding an endoscopic image obtained by imaging the living tissue; and performing estimation regarding thermal invasion in the living tissue based on the output information and the image information.

[0008] In some embodiments, an estimation device includes at least one processor, the processor being configured to: acquire monitor information regarding an electrical characteristic value in an energy treatment tool when non-treatment energy for monitoring is applied to a living tissue from the energy treatment tool; acquire image information regarding an endoscopic image obtained by imaging the living tissue; and perform estimation regarding thermal invasion in the living tissue based on at least one of the monitor information and the image information and on an output setting value of treatment energy for treating the living tissue with the energy treatment tool.

[0009] In some embodiments, an estimation device includes at least one processor, the processor being configured to: acquire output information regarding an electrical characteristic value in an energy treatment tool when treatment energy is applied to a living tissue from the energy treatment tool; acquire image information regarding an endoscopic image obtained by imaging the living tissue; and perform estimation regarding thermal invasion in the living tissue based on the output information and the image information.

[0010] The above and other features, advantages and technical and industrial significance of this disclosure will be better understood by reading the following detailed description of presently embodiments of the disclosure, when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] FIG. **1** is a view illustrating a treatment system according to a first embodiment;

[0012] FIG. **2** is a view illustrating a transducer unit.

[0013] FIG. **3** is a block diagram illustrating a configuration of a control device;

[0014] FIG. **4** is a flowchart illustrating a control method executed by a processor;

[0015] FIG. **5** is a view for explaining image information (**1**) to image information (**3**);

[0016] FIG. **6** is a flowchart illustrating a control method according to a second embodiment;

[0017] FIG. **7** is a flowchart illustrating a control method according to a third embodiment;

[0018] FIG. **8** is a view for explaining image information (**6**);

[0019] FIG. **9** is a view for explaining image information (**7**);

[0020] FIG. **10** is a view illustrating a modification of the third embodiment;

[0021] FIG. **11** is a diagram illustrating the modification of the third embodiment; and

[0022] FIG. **12** is a flowchart illustrating a control method according to a fourth embodiment.

DETAILED DESCRIPTION

[0023] Hereinafter, modes for carrying out the disclosure (embodiments) will be described with reference to the drawings. Note that the disclosure is not limited by the embodiments described below. Furthermore, in the description of the drawings, the same portions are denoted by the same reference numerals.

First Embodiment

Schematic Configuration of Treatment System

[0024] FIG. **1** is a view illustrating a treatment system **1** according to a first embodiment.

[0025] The treatment system **1** applies treatment energy to a treatment target region (hereinafter, described as a target region) in a living tissue to treat the target region. In the first embodiment, ultrasonic energy and high frequency energy are employed as the treatment energy. In addition, the

treatment is coagulation (sealing) or incision of the target region. Note that as the treatment, the coagulation (sealing) and incision of the target region may be performed simultaneously. As illustrated in FIG. **1**, the treatment system **1** includes an endoscope device **2**, an energy treatment tool **3**, and a control device **4**.

Configuration of Endoscope Device

[0026] The endoscope device **2** is partially inserted into a living body, images the inside of the living body, and outputs an image signal (hereinafter, described as an endoscopic image) generated by the imaging. As illustrated in FIG. **1**, the endoscope device **2** includes an insertion unit **21**, an imaging device **22**, and a light source device **23**.

[0027] The insertion unit **21** is a portion at least a part of which has flexibility and is inserted into the living body.

[0028] The light source device **23** supplies illumination light to irradiate the inside of the living body from the distal end of the insertion unit **21**. In the first embodiment, the light source device **23** can supply, as the illumination light, at least one light of white light, special light, and excitation light, respectively.

[0029] Here, the white light is visible light and is illumination light used in normal light observation.

[0030] The special light is illumination light used in special light observation and has a specific wavelength band. In the first embodiment, the illumination light is used in narrow band imaging (NBI). NBI is an observation method in which a capillary vessel and a mucosal surface structure of a mucosal surface layer of a living tissue are enhanced by utilizing the fact that hemoglobin in blood strongly absorbs light in the vicinity of a wavelength of 415 nm. Then, the special light includes first narrow band light having a wavelength band of about 530 nm to 550 nm and second narrow band light having a wavelength band of about 390 nm to 445 nm.

[0031] In addition, the excitation light is illumination light used in fluorescence observation. In the first embodiment, the excitation light is excitation light for generating fluorescence from advanced glycation endproducts generated by heat treatment of the energy treatment tool **3** on the target region, and is light having a wavelength band of about 400 nm to 430 nm.

[0032] The imaging device **22** is provided at a distal end portion in the insertion unit **21**. Then, the imaging device **22** includes an imaging element such as a charge coupled device (CCD) or a complementary metal oxide semiconductor (CMOS) that receives a subject image and converts the subject image into an electric signal, and outputs an endoscopic image generated by imaging the inside of the living body to the control device **4**.

[0033] Here, in a case where the light source device **23** supplies white light (illumination light), the imaging device **22** generates, as the endoscopic image, a white light image obtained by imaging a living tissue irradiated with the white light.

[0034] In addition, in a case where the light source device **23** supplies special light (illumination light), the imaging device **22** generates, as the endoscopic image, a special light image obtained by imaging a living tissue irradiated with the special light.

[0035] Furthermore, in a case where the light source device **23** supplies excitation light (illumination light), the imaging device **22** generates, as the endoscopic image, a fluorescence image obtained by imaging fluorescence generated from a living tissue (advanced glycation endproducts) by irradiation of the living tissue with the excitation light.

Configuration of Energy Treatment Tool

[0036] The energy treatment tool **3** is an ultrasonic treatment tool having a bolted Langevin-type transducer (BLT). As illustrated in FIG. **1**, the energy treatment tool **3** includes a handle **5**, a sheath **6**, a jaw **7**, a transducer unit **8**, and a vibration transmission member **9**.

[0037] The handle **5** is a portion which an operator holds with their hand. Then, as illustrated in FIG. **1**, the handle **5** is provided with an operation knob **51** and an operation button **52**.

[0038] The sheath **6** has a cylindrical shape. Note that hereinafter, the central axis of the sheath **6** is referred to as a central axis Ax (FIG. **1**). In addition, hereinafter, one side along the central axis Ax is referred to as a distal end side A**1** (FIG. **1**), and the other side is referred to as a proximal end side A**2** (FIG. **1**). Then, the sheath **6** is attached to the handle **5** in a state where a part of the proximal end side A**2** is inserted into the handle **5** from the distal end side A**1** of the handle **5**.

[0039] FIG. **2** is a view illustrating the transducer unit **8**. Specifically, FIG. **2** is a cross-sectional view of the transducer unit **8** taken along a plane including the central axis Ax.

[0040] As illustrated in FIG. **2**, the transducer unit **8** includes a transducer case **81**, an ultrasound transducer **82**, and a horn **83**.

[0041] The transducer case **81** extends linearly along the central axis Ax, and is attached to the handle **5** in a state where a part of the distal end side A**1** is inserted into the handle **5** from the proximal end side A**2** of the handle **5**.

[0042] The ultrasound transducer **82** is housed inside the transducer case **81** and generates ultrasonic vibration under the control of the control device **4**. In the first embodiment, the ultrasonic vibration is a BLT including a plurality of piezoelectric elements **821** to **824** stacked along the central axis Ax. In the first embodiment, the piezoelectric elements are configured by four piezoelectric elements **821** to **824**, but the number of piezoelectric elements is not limited to four, and another number of piezoelectric elements may be used.

[0043] The horn **83** is housed inside the transducer case **81** and expands the amplitude of the ultrasonic vibration generated by the ultrasound transducer **82**. The horn **83** has an elongated shape extending linearly along the central axis Ax. As illustrated in FIG. **2**, the horn **83** has a configuration in which a first attachment portion **831**, a cross-sectional area change portion **832**, and a second attachment portion **833** are arranged from the proximal end side A**2** to the distal end side A**1**.

[0044] The first attachment portion **831** is a portion to which the ultrasound transducer **82** is attached.

[0045] The cross-sectional area change portion **832** has a shape in which the cross-sectional area decreases toward the distal end side A**1**, and is a portion that enlarges the amplitude of the ultrasonic vibration.

[0046] The second attachment portion **833** is a portion to which the end portion of the vibration transmission member **9** on the proximal end side A**2** is attached.

[0047] The jaw **7** and the vibration transmission member **9** grip the target region and apply ultrasonic energy and high frequency energy to the target region to treat the target region.

[0048] Specifically, the jaw **7** is made of a conductive material such as metal, and is rotatably attached to the end portion of the sheath **6** on the distal end side A**1**. Then, the jaw **7** grips the target region with a treatment unit **91** (FIG. **1**) configuring the vibration transmission member **9**.

[0049] Although not specifically illustrated, an opening and closing mechanism for opening and closing the jaw **7** with respect to the treatment unit **91** according to the operation of the operation knob **51** by the operator is provided inside the handle **5** and the sheath **6** described above. In addition, in the jaw **7**, a pad (not illustrated) made of resin is attached to a surface facing the treatment unit **91**. Since the pad has an electrical insulation property, the pad has a function of preventing a short circuit between the jaw **7** and the vibration transmission member **9**. In addition, the pad has a function of preventing that the vibration transmission member **9** which is ultrasonically vibrating is damaged by colliding with the jaw **7** when the incision of the target region by the ultrasonic vibration is completed.

[0050] The vibration transmission member **9** is made of a conductive material such as metal, and has an elongated shape extending linearly along the central axis Ax. As illustrated in FIG. **1**, the vibration transmission member **9** is inserted into the sheath **6** in a state where the treatment unit **91** which is an end portion on the distal end side A**1** protrudes to the outside. In addition, as illustrated in FIG. **2**, the end portion of the vibration transmission member **9** on the proximal end side A**2** is connected to the second attachment portion **833**. Then, the vibration transmission member **9** transmits the ultrasonic vibration, which has been generated by the ultrasound transducer **82** and passed through the horn **83**, from the proximal end side A**2** to the end portion on the distal end side A**1**, and applies the ultrasonic vibration to the target region gripped between the treatment unit **91** and the jaw **7** to treat the target region. That is, the target region is treated by application of ultrasonic energy from the end portion on the distal end side A**1**.

Configuration of Control Device

[0051] FIG. **3** is a block diagram illustrating a configuration of the control device **4**.

[0052] The control device **4** corresponds to an estimation device. The control device **4** is electrically connected to the energy treatment tool **3** by an electric cable C (FIG. **1**) and comprehensively controls the operation of the energy treatment tool **3**. As illustrated in FIG. **3**, the control device **4** includes a first power supply **41**, a first detection circuit **42**, a first analog-to-digital converter (ADC) **43**, a second power supply **44**, a second detection circuit **45**, a second ADC **46**, a notification unit **47**, a processor **48**, a storage unit **49**, and an input unit **40**.

[0053] Here, as illustrated in FIG. **2**, a pair of transducer lead wires C**1** and C**1'** configuring the electric cable C is joined to the ultrasound transducer **82**. Note that in FIG. **3**, only one pair of transducer lead wires C**1** and C**1'** is illustrated for convenience of description.

[0054] Then, the first power supply **41** outputs a first drive signal, which is power for generating ultrasonic vibration, to the ultrasound transducer **82** via the pair of transducer lead wires C**1** and C**1'** under the control of the processor **48**. As a result, the ultrasound transducer **82** generates ultrasonic vibration.

[0055] Hereinafter, for convenience of description, the first drive signal output from the first power supply **41** to the ultrasound transducer **82** is referred to as a first input drive signal, and a signal obtained by changing the first input drive signal according to the frequency response of the energy treatment tool **3** (ultrasound transducer **82**) is referred to as a first output drive signal.

[0056] The first detection circuit **42** includes a first voltage detection circuit **421** which is a voltage sensor which detects a voltage value and a first current detection circuit **422** which is a current sensor which detects a current value, and detects a US signal (analog signal) corresponding to the first output drive signal over time. The US signal corresponds to "an electrical characteristic value in an energy treatment tool".

[0057] Specifically, examples of the US signal include a current value (hereinafter, described as US current) in the first output drive signal, a voltage value (hereinafter, described as US voltage) in the first output drive signal, a power value (hereinafter, described as US power) in the first output drive signal, an impedance value (hereinafter, described as a US impedance value) calculated from the US current and the US voltage, and a frequency (hereinafter, described as US frequency) of the US current or the US voltage.

[0058] The first ADC **43** converts the US signal (analog signal) output from the first detection circuit **42** into a digital signal. Then, the first ADC **43** outputs the converted US signal (digital signal) to the processor **48**.

[0059] Here, as illustrated in FIG. **2**, the transducer case **81** is provided with a first conductive portion **811** extending from the end portion on the proximal end side A**2** to the end portion on the distal end side A**1**. In addition, although not specifically illustrated, the sheath **6** is provided with a second conductive portion extending from the end portion on the proximal end side A**2** to the end portion on the distal end side A**1** and electrically connects the first conductive portion **811** and the jaw **7**. Further, a high frequency lead wire C**2** configuring the electric cable C is joined to the end portion of the first conductive portion **811** on the proximal end side A**2**. In addition, a high frequency lead wire C**2'** configuring the electric cable C is joined to the first attachment portion **831**.

[0060] Under the control of the processor **48**, the second power supply **44** outputs a second drive signal, which is high frequency power, to the jaw **7** and the vibration transmission member **9** via the pair of high frequency lead wires C**2** and C**2'**, the first conductive portion **811**, the second conductive portion, and the horn **83**. As a result, a high frequency current flows through the target region gripped between the jaw **7** and the treatment unit **91**. That is, high frequency energy is applied to the target region. Then, in the target region, Joule heat is generated by the high frequency current flowing therethrough, and the target region is treated.

[0061] As described above, each of the jaw **7** and the treatment unit **91** functions as an electrode.

[0062] Hereinafter, for convenience of description, the second drive signal output from the second power supply **44** to the jaw **7** and the vibration transmission member **9** is referred to as a second input drive signal, and a signal obtained by changing the second input drive signal accord-

ing to the frequency response of the energy treatment tool **3** is referred to as a second output drive signal.

[0063] The second detection circuit **45** includes a second voltage detection circuit **451** which is a voltage sensor which detects a voltage value and a second current detection circuit **452** which is a current sensor which detects a current value, and detects an HF signal (analog signal) corresponding to the second output drive signal over time. The HF signal corresponds to "an electrical characteristic value in an energy treatment tool".

[0064] Specifically, examples of the HF signal include a current value (hereinafter, described as a HF current) in the second output drive signal, a voltage value (hereinafter, described as a HF voltage) in the second output drive signal, a power value (hereinafter, described as HF power) in the second output drive signal, an impedance value (hereinafter, described as a HF impedance value) calculated from the HF current and the HF voltage, and a phase difference (hereinafter, described as a HF phase difference) between the HF current and the HF voltage.

[0065] The second ADC **46** converts the HF signal (analog signal) output from the second detection circuit **45** into a digital signal. Then, the second ADC **46** outputs the converted HF signal (digital signal) to the processor **48**.

[0066] The notification unit **47** notifies predetermined information under the control of the processor **48**. Examples of the notification unit **47** include a light emitting diode (LED) which notifies predetermined information by lighting, blinking, or a color at the time of lighting, a display device which displays predetermined information, and a speaker which outputs predetermined information by voice. Note that the notification unit **47** may be provided in the control device **4** as illustrated in FIG. **3**, or may be provided in the energy treatment tool **3**.

[0067] The processor **48** includes a controller such as a central processing unit (CPU) and a micro processing unit (MPU), or an integrated circuit such as an application specific integrated circuit (ASIC) and a field programmable gate array (FPGA), and controls the entire operation of the treatment system **1**.

[0068] Note that detailed functions of the processor **48** will be described in "Control Method Executed by Processor" described later.

[0069] The storage unit **49** stores various programs executed by the processor **48**, information for processing of the processor **48**, and the like. Examples of the information for the processing of the processor **48** include setting values of the first and second input drive signals, a learning model for object identification, and a learning model for estimation. The setting values of the first and second input drive signals correspond to "an output setting value of treatment energy".

[0070] Note that details of the learning model for object identification and the learning model for estimation will be described in "Control Method Executed by Processor" described later.

[0071] The input unit **40** includes a keyboard, a mouse, a switch, a touch panel, and the like, and receives a user operation by the operator or the like. Examples of the user operation include an input operation of the setting values of the first and second input drive signals described above. Then, the input unit **40** outputs, to the processor **48**, an operation signal corresponding to the user operation.

Control Method Executed by Processor

[0072] Next, a control method executed by the processor **48** will be described. The control method corresponds to an estimation method.

[0073] FIG. **4** is a flowchart illustrating the control method executed by the processor **48**.

[0074] First, the processor **48** constantly monitors whether or not the operator has pressed the operation button **52** (output start operation) (step S**1**).

[0075] When it is determined that there is the output start operation (step S**1**: Yes), the processor **48** controls the operations of the first and second power supplies **41** and **44**. Then, the first power supply **41** outputs the first input drive signal for monitoring to the ultrasound transducer **82** for a certain period of time. Similarly, the second power supply **44** outputs the second input drive signal to the jaw **7** and the vibration transmission member **9** for a certain period of time. As a result, non-treatment energy (ultrasonic energy and high frequency energy) for monitoring is applied to the target region gripped between the jaw **7** and the treatment unit **91** (step S**2**).

[0076] Here, the first and second input drive signals for monitoring are first and second drive signals for applying non-treatment energy for monitoring, which is treatment energy (ultrasonic energy and high frequency energy) to such an extent that a target region is not thermally denatured, to the target region.

[0077] While the non-treatment energy for monitoring is applied to the target region in step S**2**, the processor **48** controls the operations of the first and second detection circuits **42** and **45**, and acquires the US signal and the HF signal detected by the first and second detection circuits **42** and **45** (step S**3**).

[0078] After step S**3**, the processor **48** acquires image information regarding the endoscopic image generated by imaging the target region by the imaging device **22** (step S**4**).

[0079] Here, examples of the image information include the following image information (**1**) to image information (**3**).

[0080] FIG. **5** is a view for explaining the image information (**1**) to the image information (**3**). Specifically, in FIG. **5**, reference numeral "F**1**" denotes the endoscopic image generated by the imaging device **22**. In addition, a reference sign "LT" indicating a hatched portion is the target region.

[0081] The image information (**1**) is information calculated by the processor **48** on the basis of the endoscopic image F**1** as follows.

[0082] Specifically, the processor **48** recognizes at least one of the jaw **7** and the treatment unit **91** included as subjects in the endoscopic image F**1** and a target region LT gripped between the jaw **7** and the treatment unit **91** by image recognition using the learning model for object identification stored in the storage unit **49**. Then, the processor **48** calculates, as the image information (**1**), a ratio of the length D**2** (FIG. **5**) of the target region LT gripped between the jaw **7** and the treatment unit **91** to the entire length D**1** (FIG. **5**) of at least one of the jaw **7** and the treatment unit **91**.

[0083] In a case where the above-described ratio is large, when treatment energy is applied to the target region LT from the jaw **7** and the treatment unit **91**, heat is easily diffused in the target region LT. On the other hand, in a case where the ratio is small, when treatment energy is applied to the target region LT from the jaw **7** and the treatment unit **91**,

heat is intensively applied to the target region LT. That is, the image information (**1**) is information that enables estimation of how heat is transferred to the target region LT. In other words, the image information (**1**) is information that enables estimation of thermal invasion at the target region LT.

[0084] The learning model for object identification is a learning model generated by performing machine learning using teacher data in which the endoscopic image obtained by imaging the jaw **7**, the treatment unit **91**, and the target region LT is associated with the positions of the jaw **7**, the treatment unit **91**, and the target region LT included as subjects in the endoscopic image.

[0085] Here, the learning model for object identification includes a neural network in which each layer has one or a plurality of nodes. In addition, the type of machine learning is not particularly limited, but for example, it is adequate if teacher data is prepared in which a plurality of endoscopic images are associated with the positions of the jaw **7**, the treatment unit **91**, and the target region LT included as subjects in the plurality of endoscopic images, and the teacher data is input to a calculation model based on a multilayer neural network for learning. Furthermore, as a method of the machine learning, for example, a method based on a deep neural network (DNN) of a multilayer neural network such as a convolutional neural network (CNN) or a 3D-CNN is used. Furthermore, as a method of the machine learning, a method based on a recurrent neural network (RNN), a long short-term memory unit (LSTM) obtained by extending the RNN, or the like may be used.

[0086] The image information (**2**) is information calculated by the processor **48** on the basis of the endoscopic image F**1** as follows.

[0087] Specifically, the processor **48** recognizes the target region LT gripped between the jaw **7** and the treatment unit **91** included as subjects in the endoscopic image F**1** by image recognition using the learning model for object identification stored in the storage unit **49**. Then, the processor **48** sets, as the image information (**2**), the color information (pixel value (RGB value)) of the pixel corresponding to the target region LT in the endoscopic image F**1**.

[0088] The color information varies depending on the tissue type (for example, liver, blood vessel, intestinal tract, and the like) of the target region LT. In addition, when treatment energy is applied to the target region LT from the jaw **7** and the treatment unit **91**, how heat is transferred to the target region LT varies depending on the tissue type of the target region LT. That is, the image information (**2**) is information that enables estimation of how heat is transferred to the target region LT. In other words, the image information (**2**) is information that enables estimation of thermal invasion at the target region LT.

[0089] The image information (**3**) is information calculated by the processor **48** on the basis of the endoscopic image F**1** as follows.

[0090] Specifically, the processor **48** recognizes the target region LT gripped between the jaw **7** and the treatment unit **91** included as subjects in the endoscopic image F**1** by image recognition using the learning model for object identification stored in the storage unit **49**. Then, the processor **48** calculates, as the image information (**3**), tissue structure information indicating the tissue structure of the target region LT on the basis of the region corresponding to the target region LT in the endoscopic image F**1**.

[0091] Here, examples of the tissue structure information include frequency feature data (information corresponding to surface roughness, pattern, and the like) obtained by edge extraction or Fourier transform for the above-described region, and internal running information of blood vessels and blood flows in a deep portion of a mucosa when the endoscopic image F**1** is a special light image. Similarly to the image information (**2**), the tissue structure information varies depending on the tissue type of the target region LT. That is, the image information (**3**) is information that enables estimation of how heat is transferred to the target region LT. In other words, the image information (**3**) is information that enables estimation of thermal invasion at the target region LT.

[0092] After step S**4**, the processor **48** executes estimation processing (step S**5**).

[0093] Specifically, in step S**5**, by using the learning model for estimation stored in the storage unit **49**, the processor **48** uses, as input data, at least one of thirteen pieces of information of monitor information (**1**) to monitor information (**10**) described below and the image information (**1**) to the image information (**3**) and the setting values of the first and second input drive signals stored in the storage unit **49**, and outputs (estimates), as output data, the thermal invasion range of the target region LT. The thermal invasion range indicates how far the thermal invasion occurs from the jaw **7** and the treatment unit **91** in the target region LT.

[0094] The monitor information (**1**) is the US current among the US signals acquired in step S**3** when the non-treatment energy for monitoring is applied to the target region LT.

[0095] The monitor information (**2**) is the US voltage among the US signals acquired in step S**3** when the non-treatment energy for monitoring is applied to the target region LT.

[0096] The monitor information (**3**) is the US power among the US signals acquired in step S**3** when the non-treatment energy for monitoring is applied to the target region LT.

[0097] The monitor information (**4**) is the US impedance value among the US signals acquired in step S**3** when the non-treatment energy for monitoring is applied to the target region LT.

[0098] The monitor information (**5**) is the US frequency among the US signals acquired in step S**3** when the non-treatment energy for monitoring is applied to the target region LT.

[0099] The monitor information (**6**) is the HF current among the HF signals acquired in step S**3** when the non-treatment energy for monitoring is applied to the target region LT.

[0100] The monitor information (**7**) is the HF voltage among the HF signals acquired in step S**3** when the non-treatment energy for monitoring is applied to the target region LT.

[0101] The monitor information (**8**) is the HF power among the HF signals acquired in step S**3** when the non-treatment energy for monitoring is applied to the target region LT.

[0102] The monitor information (**9**) is the HF impedance value among the HF signals acquired in step S**3** when the non-treatment energy for monitoring is applied to the target region LT.

[0103] The monitor information (**10**) is the HF phase difference among the HF signals acquired in step S**3** when the non-treatment energy for monitoring is applied to the target region LT.

[0104] The monitor information (**1**) to the monitor information (**10**) varies depending on the tissue type of the target region LT similarly to the image information (**2**). That is, the monitor information (**1**) to the monitor information (**10**) are information that enables estimation of how heat is transferred to the target region LT. In other words, the monitor information (**1**) to the monitor information (**10**) are information that enables estimation of thermal invasion at the target region LT.

[0105] The learning model for estimation is a learning model generated by machine learning using teacher data in which at least one of thirteen pieces of information of the monitor information (**1**) to the monitor information (**10**), which are acquired when the non-treatment energy for monitoring is applied to the target region LT, and the image information (**1**) to the image information (**3**), the setting values of the first and second input drive signals, and the thermal invasion range in the target region LT in a case where the treatment energy according to the setting values of the first and second input drive signals is applied to the target region LT are associated with each other.

[0106] Here, the learning model for estimation includes a neural network in which each layer has one or a plurality of nodes. In addition, the type of machine learning is not particularly limited, but for example, it is sufficient if teacher data is prepared in which at least one of thirteen pieces of information of the monitor information (**1**) to the monitor information (**10**), which are acquired when the non-treatment energy for monitoring is applied to the target region LT, and the image information (**1**) to the image information (**3**), the setting values of the first and second input drive signals, and the thermal invasion range in the target region LT in a case where the treatment energy according to the setting values of the first and second input drive signals is applied to the target region LT are associated with each other, and the learning is performed by inputting the teacher data to the calculation model based on the multilayer neural network. Furthermore, as a method of the machine learning, for example, a method based on DNN of a multilayer neural network such as CNN or 3D-CNN is used. Furthermore, as a method of the machine learning, a method based on a recurrent neural network (RNN), an LSTM obtained by extending an RNN, or the like may be used.

[0107] After step S**5**, the processor **48** determines whether or not the thermal invasion range estimated in step S**5** is equal to or more than a threshold (step S**6**).

[0108] In a case where it is determined that the thermal invasion range is equal to or more than the threshold (step S**6**: Yes), the processor **48** controls the operation of the notification unit **47** without starting the treatment of the target region LT, and causes the notification unit **47** to notify that the thermal invasion range is equal to or more than the threshold (step S**7**).

[0109] On the other hand, in a case where it is determined that the thermal invasion range is less than the threshold (step S**6**: No), the processor **48** starts the treatment of the target region LT (step S**8**). Specifically, the processor **48** controls the operations of the first and second power supplies **41** and **44**, and causes the first and second power supplies **41** and **44** to output the first and second input drive signals of the setting values stored in the storage unit **49**. As a result, the treatment energy (ultrasonic energy and high frequency energy) corresponding to the setting values of the first and second input drive signals is applied to the target region LT gripped between the jaw **7** and the treatment unit **91**.

[0110] According to the first embodiment described above, the following effects are obtained.

[0111] Since the control method (estimation method) executed by the processor **48** according to the first embodiment estimates the thermal invasion range as described above, it is possible to appropriately estimate how far the thermal invasion occurs from the jaw **7** and the treatment unit **91** in the target region LT. That is, the target region LT can be appropriately treated by the estimation.

[0112] In particular, since the thermal invasion range can be estimated before the treatment energy is applied to the target region LT, the target region LT can be appropriately treated without performing the treatment in which the thermal invasion is predicted to occur unnecessarily.

Second Embodiment

[0113] Next, a second embodiment will be described.

[0114] In the following description, the same reference numerals are given to the same configurations as those of the first embodiment described above, and a detailed description thereof will be omitted or simplified.

[0115] FIG. **6** is a flowchart illustrating a control method according to the second embodiment.

[0116] The second embodiment is different from the first embodiment in the estimation processing executed by the processor **48**. That is, in the control method according to the second embodiment, as illustrated in FIG. **6**, steps S**5**A and S**6**A are adopted instead of steps S**5** and S**6** in the control method described in the first embodiment described above. Hereinafter, only steps S**5**A and S**6**A will be mainly described.

[0117] Step S**5**A is executed after step S**4**.

[0118] Specifically, in step S**5**A, by using the learning model for estimation stored in the storage unit **49**, the processor **48** uses, as input data, at least one of thirteen pieces of information of the monitor information (**1**) to the monitor information (**10**) and the image information (**1**) to the image information (**3**), and the setting values of the first and second input drive signals stored in the storage unit **49**, and outputs (estimates), as output data, a possibility of leading to a postoperative complication.

[0119] Here, the learning model for estimation according to the second embodiment is different from the learning model for estimation described in the first embodiment described above.

[0120] The learning model for estimation according to the second embodiment is a learning model generated by machine learning using teacher data in which at least one of thirteen pieces of information of the monitor information (**1**) to the monitor information (**10**), which are acquired when the non-treatment energy for monitoring is applied to the target region LT, and the image information (**1**) to the image information (**3**), the setting values of the first and second input drive signals, and the possibility of leading to a postoperative complication in a case where the treatment energy according to the setting values of the first and second input drive signals is applied to the target region LT are associated with each other.

[0121] Here, the learning model for estimation according to the second embodiment includes a neural network in which each layer includes one or a plurality of nodes. In addition, the type of machine learning is not particularly limited, but for example, it is sufficient if teacher data is prepared in which at least one of thirteen pieces of information of the monitor information (**1**) to the monitor information (**10**), which are acquired when the non-treatment energy for monitoring is applied to the target region LT, and the image information (**1**) to the image information (**3**), the setting values of the first and second input drive signals, and the possibility of leading to a postoperative complication in a case where the treatment energy according to the setting values of the first and second input drive signals is applied to the target region LT are associated with each other, and the learning is performed by inputting the teacher data to the calculation model based on the multilayer neural network. Furthermore, as a method of the machine learning, for example, a method based on DNN of a multilayer neural network such as CNN or 3D-CNN is used. Furthermore, as a method of the machine learning, a method based on a recurrent neural network (RNN), an LSTM obtained by extending an RNN, or the like may be used.

[0122] Then, in a case where in step S**5**A, the processor **48** estimates that there is the possibility of leading to a postoperative complication (step S**6**A: Yes), the process proceeds to step S**7**.

[0123] On the other hand, in a case where in step S**5**A, the processor **48** estimates that there is no possibility of leading to a postoperative complication (step S**6**A: No), the process proceeds to step S**8**.

[0124] According to the second embodiment described above, the following effects are obtained.

[0125] Since the control method (estimation method) executed by the processor **48** according to the second embodiment estimates the possibility of leading to a postoperative complication as described above, the possibility of leading to a postoperative complication can be appropriately estimated.

[0126] In particular, since the possibility of leading to a postoperative complication can be estimated before the treatment energy is applied to the target region LT, the target region LT can be appropriately treated without performing the treatment predicted to lead to a postoperative complication.

Third embodiment

[0127] Next, a third embodiment will be described.

[0128] In the following description, the same reference numerals are given to the same configurations as those of the first embodiment described above, and a detailed description thereof will be omitted or simplified.

[0129] FIG. **7** is a flowchart illustrating a control method according to the third embodiment.

[0130] As illustrated in FIG. **7**, the third embodiment is different from the first embodiment in the control method executed by the processor **48**.

[0131] Specifically, in the control method according to the third embodiment, the processing order of step S**8** is changed, steps S**4**B and S**5**B are adopted instead of steps S**4** and S**5**, and steps S**9** and S**10** are added. Hereinafter, only steps S**8**, S**4**B, S**5**B, S**9**, and S**10** will be mainly described. Step S**8** is executed in a case where it is determined that the output start operation has been performed (step S**1**: Yes). Thereafter, the processor **48** proceeds to step S**3**.

[0132] Specifically, in step S**8**, the processor **48** controls the operations of the first and second power supplies **41** and **44**, and causes the first and second power supplies **41** and **44** to output the first and second input drive signals of the setting values stored in the storage unit **49**. As a result, the treatment energy (ultrasonic energy and high frequency energy) corresponding to the setting values of the first and second input drive signals is applied to the target region LT gripped between the jaw **7** and the treatment unit **91**.

[0133] Step S**4**B is executed after step S**3**.

[0134] Specifically, in step S**4**B, the processor **48** acquires image information regarding the endoscopic image F**1** generated by imaging the target region LT by the imaging device **22**.

[0135] Here, examples of the image information include the following image information (**4**) to image information (**7**).

[0136] The image information (**4**) is information calculated by the processor **48** on the basis of the endoscopic image F**1** as follows.

[0137] Specifically, the processor **48** recognizes at least one of the jaw **7** and the treatment unit **91** included as subjects in the endoscopic image F**1** and a target region LT gripped between the jaw **7** and the treatment unit **91** by image recognition using the learning model for object identification stored in the storage unit **49**. Then, the processor **48** calculates, as the image information (**4**), a difference (tissue contraction amount) between the length D**2** (FIG. **5**) of the target region LT before the treatment energy is applied to the target region LT in step S**8** and the length D**2** after a lapse of a specific time from the start of the application of the treatment energy in step S**8**.

[0138] The tissue contraction amount varies depending on the tissue type of the target region LT, the amount of heat input to the target region LT, and the like. That is, the image information (**4**) is information that enables estimation of thermal invasion at the target region LT.

[0139] The image information (**5**) is information calculated by the processor **48** on the basis of the endoscopic image F**1** as follows.

[0140] Specifically, the processor **48** recognizes at least one of the jaw **7** and the treatment unit **91** included as subjects in the endoscopic image F**1** and a target region LT gripped between the jaw **7** and the treatment unit **91** by image recognition using the learning model for object identification stored in the storage unit **49**. Then, the processor **48** calculates, as the image information (**5**), the time (contraction start time) from the start of the application of the treatment energy to the target region LT in step S**8** to the change in the length D**2** of the target region LT before the start of the application of the treatment energy.

[0141] The contraction start time varies depending on the tissue type of the target region LT, the amount of heat input to the target region LT, and the like. That is, the image information (**5**) is information that enables estimation of thermal invasion at the target region LT.

[0142] FIG. **8** is a view corresponding to FIG. **5**, and is a view for explaining the image information (**6**).

[0143] The image information (**6**) is information calculated by the processor **48** on the basis of the endoscopic image F**1** as follows.

[0144] Specifically, the processor **48** recognizes at least one of the jaw **7** and the treatment unit **91** included as subjects in the endoscopic image F**1** and a target region LT gripped between the jaw **7** and the treatment unit **91** by image recognition using the learning model for object identification stored in the storage unit **49**. Then, the processor **48** focuses on the specific pixel position P**1** (FIG. **8**) in the region corresponding to the target region LT in the endoscopic image F**1**, and calculates, as the image information (**6**), the movement amount by which the pixel position P**1** moves toward at least one of the jaw **7** and the treatment unit **91** until a specific time elapses after the application of the treatment energy to the target region LT is started in step S**8**.

[0145] The movement amount has the same characteristics as the above-described tissue contraction amount.

[0146] FIG. **9** is a view corresponding to FIG. **5**, and is a view for explaining the image information (**7**).

[0147] The image information (**7**) is information calculated by the processor **48** on the basis of the endoscopic image F**1** as follows.

[0148] Specifically, the processor **48** recognizes at least one of the jaw **7** and the treatment unit **91** included as subjects in the endoscopic image F**1** and a target region LT gripped between the jaw **7** and the treatment unit **91** by image recognition using the learning model for object identification stored in the storage unit **49**. In addition, the processor **48** focuses on the variation in color information (pixel values (RGB values)) of pixels on a line L**1** (FIG. **9**) orthogonal to the longitudinal direction (in FIG. **9**, a vertical direction) of the region corresponding to at least one of the jaw **7** and the treatment unit **91** among the pixels corresponding to the target region LT in the endoscopic image F**1**. Then, the processor **48** calculates, as the image information (**7**), a change amount of the variation until a specific time elapses since the application of the treatment energy to the target region LT is started in step S**8**.

[0149] When tension is generated by the contraction force of the target region LT, the unevenness of the surface of the target region LT is reduced, so that the change amount of the variation decreases. That is, the change amount of the variation has the same characteristics as the above-described tissue contraction amount.

[0150] After step S**4**B, by using the learning model for estimation stored in the storage unit **49**, the processor **48** uses, as input data, at least one of fifteen pieces of information of output information (**1**) to output information (**11**) described below and the image information (**4**) to the image information (**7**) and outputs (estimates), as output data, the thermal invasion range in the target region LT (step S**5**B). The thermal invasion range indicates how far the thermal invasion occurs from the jaw **7** and the treatment unit **91** in the target region LT. Thereafter, the processor **48** proceeds to step S**6**.

[0151] The output information (**1**) is the elapsed time from the start of application of the treatment energy to the target region LT in step S**8**.

[0152] The output information (**2**) is the US current among the US signals acquired in step S**3** when the treatment energy is applied to the target region LT.

[0153] The output information (**3**) is the US voltage among the US signals acquired in step S**3** when the treatment energy is applied to the target region LT.

[0154] The output information (**4**) is the US power among the US signals acquired in step S**3** when the treatment energy is applied to the target region LT.

[0155] The output information (**5**) is the US impedance value among the US signals acquired in step S**3** when the treatment energy is applied to the target region LT.

[0156] The output information (**6**) is the US frequency among the US signals acquired in step S**3** when the treatment energy is applied to the target region LT.

[0157] The output information (**7**) is the HF current among the HF signals acquired in step S**3** when the treatment energy is applied to the target region LT.

[0158] The output information (**8**) is the HF voltage among the HF signals acquired in step S**3** when the treatment energy is applied to the target region LT.

[0159] The output information (**9**) is the HF power among the HF signals acquired in step S**3** when the treatment energy is applied to the target region LT.

[0160] The output information (**10**) is the HF impedance value among the HF signals acquired in step S**3** when the treatment energy is applied to the target region LT.

[0161] The output information (**11**) is the HF phase difference among the HF signals acquired in step S**3** when the treatment energy is applied to the target region LT.

[0162] The output information (**1**) to the output information (**11**) are information that enables estimation of the amount of heat input to the target region LT. That is, the output information (**1**) to the output information (**11**) are information that enables estimation of thermal invasion at the target region LT.

[0163] Here, the learning model for estimation according to the third embodiment is different from the learning model for estimation described in the first embodiment described above.

[0164] The learning model for estimation according to the third embodiment is a learning model generated by machine learning using teacher data in which at least one of fifteen pieces of information of the output information (**1**) to the output information (**11**), which are acquired when the treatment energy is applied to the target region LT, and the image information (**4**) to the image information (**7**) is associated with the thermal invasion range in the target region LT when the treatment energy is applied to the target region LT.

[0165] Here, the learning model for estimation according to the third embodiment includes a neural network in which each layer includes one or a plurality of nodes. In addition, the type of machine learning is not particularly limited, but for example, it is sufficient if teacher data is prepared in which at least one of fifteen pieces of information of the output information (**1**) to the output information (**11**), which are acquired when treatment energy is applied to the target region LT, and the image information (**4**) to the image information (**7**) is associated with the thermal invasion range in the target region LT when the treatment energy is applied to the target region LT, and the learning is performed by inputting the teacher data to the calculation model based on the multilayer neural network. Furthermore, as a method of the machine learning, for example, a method based on DNN of a multilayer neural network such as CNN or 3D-CNN is used. Furthermore, as a method of the machine learning, a method based on a recurrent neural network (RNN), an LSTM obtained by extending an RNN, or the like may be used.

[0166] Step S**9** is executed in a case where it is determined that the thermal invasion range is equal to or more than the threshold (step S**6**: Yes).

[0167] Specifically, in step S**9**, the processor **48** stops the operations of the first and second power supplies **41** and **44**, stops the treatment of the target region LT, and causes the notification unit **47** to notify that the thermal invasion range is equal to or more than the threshold similarly to step S**7**.

[0168] Step S**10** is executed in a case where it is determined that the thermal invasion range is less than the threshold (step S**6**: No).

[0169] Specifically, in step S**10**, the processor **48** continuously operates the first and second power supplies **41** and **44** to continue the treatment of the target region LT.

[0170] According to the third embodiment described above, the following effects are obtained.

[0171] Since the control method (estimation method) executed by the processor **48** according to the third embodiment estimates the thermal invasion range as described above, it is possible to appropriately estimate how far the thermal invasion occurs from the jaw **7** and the treatment unit **91** in the target region LT. That is, the target region LT can be appropriately treated by the estimation.

[0172] In particular, since the thermal invasion range can be estimated while the treatment energy is applied to the target region LT, if it is predicted that the thermal invasion occurs unnecessarily, the treatment can be immediately stopped, and the target region LT can be

Modification of Third Embodiment

[0173] FIGS. **10** and **11** are views illustrating a modification of the third embodiment. Specifically, FIG. **10** is a view corresponding to FIG. **5**. FIG. **11** is a diagram illustrating temporal changes of color information (pixel values (RGB values)) at a pixel position P**2** illustrated in FIG. **5**.

[0174] In the third embodiment described above, the processor **48** estimates the thermal invasion range in the target region LT by using the learning model for estimation, but the disclosure is not limited thereto, and the thermal invasion range may be estimated as in the present modification illustrated in FIGS. **10** and **11**.

[0175] Specifically, the processor **48** recognizes at least one of the jaw **7** and the treatment unit **91** included as subjects in the endoscopic image F**1** and a target region LT gripped between the jaw **7** and the treatment unit **91** by image recognition using the learning model for object identification stored in the storage unit **49**. In addition, the processor **48** sets, as a threshold, a value obtained by subtracting the standard deviation of the color information from the average value of the color information for each pixel of the region corresponding to the target region LT on the basis of a plurality of endoscopic images captured by the imaging device **22** by the timing T**1** (FIG. **11**) at which the application of the treatment energy to the target region LT is started. For example, for the pixel position P**2** illustrated in FIG. **10**, a threshold Th (FIG. **11**) is set as the threshold. Furthermore, the processor **48** constantly monitors whether or not the color information has become equal to or less than the set threshold for each pixel of the region corresponding to the target region LT on the basis of the endoscopic image F**1** (FIG. **10**) captured by the imaging device **22** after the application of the treatment energy to the target region LT is started. For example, the color information of the pixel position P**2** illustrated in FIG. **10** becomes equal to or less than the threshold Th at a timing T**2** as illustrated in FIG. **11**. The timing T**2** means that the thermal invasion occurs at a position corresponding to the pixel position P**2** in the target region LT at the timing T**2**. Then, the processor **48** generates a superimposed image in which an indicator IN (FIG. **10**) is superimposed on a region, in which the thermal invasion occurs, in the region corresponding to the target region LT in the endoscopic image F**1**, and causes the notification unit **47** (display device) to display the superimposed image. For example, in the example illustrated in FIG. **10**, in a case where the thermal invasion occurs at all pixel positions arranged along the longitudinal direction (in FIG. **10**, the vertical direction) of the region corresponding to at least one of the jaw **7** and the treatment unit **91** in the region corresponding to the target region LT in the endoscopic image F**1**, the processor **48** superimposes the indicator IN on the center position in the longitudinal direction at all the pixel positions. As a result, with the lapse of time from the start of the application of the treatment energy to the target region LT, the indicator IN superimposed on the endoscopic image F**1** extends in a bar graph shape in a direction away from the region corresponding to at least one of the jaw **7** and the treatment unit **91**.

[0176] As described above, in the present modification, the processor **48** estimates the thermal invasion range on the basis of the image information (color information) calculated on the basis of the endoscopic image F**1**.

[0177] Even in a case where the thermal invasion range is estimated as in the present modification described above, the same effects as those of the third embodiment described above are obtained.

Fourth Embodiment

[0178] Next, a fourth embodiment will be described.

[0179] In the following description, the same reference numerals are given to the same configurations as those of the third embodiment described above, and a detailed description thereof will be omitted or simplified.

[0180] FIG. **12** is a flowchart illustrating a control method according to the fourth embodiment.

[0181] The fourth embodiment is different from the third embodiment in the estimation processing executed by the processor **48**. That is, in the control method according to the fourth embodiment, as illustrated in FIG. **12**, steps S**5**C and S**6**A are adopted instead of steps S**5**B and S**6** in the control method described in the above-described third embodiment. Hereinafter, only steps S**5**C and S**6**A will be mainly described.

[0182] Step S**5**C is executed after step S**4**B.

[0183] Specifically, in step S**5**C, by using the learning model for estimation stored in the storage unit **49**, the processor **48** uses, as input data, at least one of fifteen pieces of information of the output information (**1**) to the output information (**11**) and the image information (**4**) to the image information (**7**) and output (estimates), as output data, the possibility of leading to a postoperative complication.

[0184] Here, the learning model for estimation according to the fourth embodiment is different from the learning model for estimation described in the third embodiment described above.

[0185] The learning model for estimation according to the fourth embodiment is a learning model generated by machine learning using teacher data in which at least one of fifteen pieces of information of the output information (**1**) to

the output information (**11**), which are acquired when the treatment energy is applied to the target region LT, and the image information (**4**) to the image information (**7**) is associated with the possibility of leading to a postoperative complication in a case where the treatment energy is applied to the target region LT.

[0186] Here, the learning model for estimation according to the fourth embodiment includes a neural network in which each layer includes one or a plurality of nodes. In addition, the type of machine learning is not particularly limited, but for example, it is sufficient if teacher data is prepared in which at least one of fifteen pieces of information of the output information (**1**) to the output information (**11**), which are acquired when the treatment energy is applied to the target region LT, and the image information (**4**) to the image information (**7**) is associated with the possibility of leading to a postoperative complication in a case where the treatment energy is applied to the target region LT, and the learning is performed by inputting the teacher data to the calculation model based on the multilayer neural network. Furthermore, as a method of the machine learning, for example, a method based on DNN of a multilayer neural network such as CNN or 3D-CNN is used. Furthermore, as a method of the machine learning, a method based on a recurrent neural network (RNN), an LSTM obtained by extending an RNN, or the like may be used.

[0187] Then, in a case where in step S**5**C, the processor **48** estimates that there is the possibility of leading to a postoperative complication (step S**6**A: Yes), the process proceeds to step S**9**.

[0188] On the other hand, in a case where in step S**5**C, the processor **48** estimates that there is no possibility of leading to a postoperative complication (step S**6**A: No), the process proceeds to step S**10**.

[0189] According to the fourth embodiment described above, the following effects are obtained.

[0190] Since the control method (estimation method) executed by the processor **48** according to the third embodiment estimates the thermal invasion range as described above, it is possible to appropriately estimate how far the thermal invasion occurs from the jaw **7** and the treatment unit **91** in the target region LT. That is, the target region LT can be appropriately treated by the estimation.

[0191] In particular, since the thermal invasion range can be estimated while the treatment energy is applied to the target region LT, if it is predicted that the thermal invasion occurs unnecessarily, the treatment can be immediately stopped, and the target region LT can be

Other Embodiments

[0192] Although the embodiments for carrying out the disclosure have been described so far, the disclosure should not be limited only by the first to fourth embodiments described above.

[0193] In the first to fourth embodiments described above, the ultrasonic energy and the high frequency energy are adopted as the treatment energy applied to the target region LT, but the disclosure is not limited thereto, and only one of the ultrasonic energy and the high frequency energy may be adopted. In addition, thermal energy may be employed as the treatment energy. Note that "applying thermal energy to the target region" means transferring heat generated in a heater to the target region.

[0194] The configuration described in the first embodiment described above and the configuration described in the third embodiment described above may be combined. That is, the thermal invasion range in the target region LT may be estimated from at least one of thirteen pieces of information of the monitor information (**1**) to the monitor information (**10**) and the image information (**1**) to the image information (**3**) and at least one of fifteen pieces of information of the output information (**1**) to the output information (**11**) and the image information (**4**) to the image information (**7**).

[0195] Similarly, the configuration described in the second embodiment described above and the configuration described in the fourth embodiment described above may be combined. That is, the possibility of leading to a postoperative complication may be estimated from at least one of thirteen pieces of information of the monitor information (**1**) to the monitor information (**10**) and the image information (**1**) to the image information (**3**) and at least one of fifteen pieces of information of the output information (**1**) to the output information (**11**) and the image information (**4**) to the image information (**7**).

[0196] In the first to fourth embodiments described above, the learning model for estimation is used for the estimation of the thermal invasion range in the target region LT and the estimation of the possibility of leading to a postoperative complication, but the disclosure is not limited thereto.

[0197] For example, the processor **48** may perform the estimation of the thermal invasion range in the target region LT and the estimation of the possibility of leading to a postoperative complication by using at least one of the tissue type specified by tissue type specifying processing described below, the tissue change amount specified by tissue change amount specifying processing described below, or the heat amount specified by heat amount specifying processing described below.

[0198] The tissue type specifying processing is processing of specifying the tissue type of the target region LT.

[0199] For example, the processor **48** specifies the tissue type of the target region LT by comparing at least one of the monitor information (**4**), the monitor information (**5**), the monitor information (**9**), the monitor information (**10**), the image information (**2**), or the image information (**3**) with a specific threshold.

[0200] The tissue change amount specifying processing is processing of specifying the tissue change amount of the target region LT after the treatment energy is applied.

[0201] For example, the processor **48** specifies the tissue change amount from at least one of nine pieces of information of the output information (**1**), the output information (**5**), the output information (**6**), the output information (**10**), the output information (**11**), and the image information (**4**) to the image information (**7**).

[0202] The heat amount specifying processing is processing of specifying an amount of heat input to the target region LT after the treatment energy is applied.

[0203] For example, the processor **48** specifies the heat amount from at least one of nine pieces of information of the output time (**1**) to the output time (**5**), the output time (**7**) to the output time (**9**), and the image information (**1**).

[0204] In the first to fourth embodiments described above, in a case where the endoscopic image F**1** is a fluorescence image, a region, in which fluorescence intensity (pixel value or luminance value) is equal to or more than a specific

threshold, among all pixels of the fluorescence image may be estimated as a region where the thermal invasion occurs.

[0205] According to the estimation method and the estimation device according to the disclosure, it is possible to appropriately perform estimation regarding the thermal invasion in the living tissue.

[0206] Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the disclosure in its broader aspects is not limited to the specific details and representative embodiments shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

[0207] In this document the terms "a" or "an" are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of "at least one" or "one or more." In this document, the term "or" is used to refer to a nonexclusive or, such that "A or B" includes "A but not B," "B but not A," and "A and B," unless otherwise indicated. In this document, the term "and/or" is used to refer to a nonexclusive or, such that "A and/or B" includes "A but not B," "B but not A," and "A and B," unless otherwise indicated. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Also, in the following claims, the terms "including" and "comprising" are open-ended, that is, a system, device, article, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

[0208] The above description is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects thereof) may be used in combination with each other. Other embodiments may be used, such as by one of ordinary skill in the art upon reviewing the above description. The Abstract is to allow the reader to quickly ascertain the nature of the technical disclosure and is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure. This should not be interpreted as intending that an unclaimed disclosed feature is essential to any claim. Rather, inventive subject matter may lie in less than all features of a particular disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description, with each claim standing on its own as a separate embodiment. The scope of the embodiments should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

What is claimed is:

1. An estimation method executed by a processor of an estimation device, the estimation method comprising:

acquiring monitor information regarding an electrical characteristic value in an energy treatment tool when non-treatment energy for monitoring is applied to a living tissue from the energy treatment tool;

acquiring image information regarding an endoscopic image obtained by imaging the living tissue; and

performing an estimation regarding thermal invasion in the living tissue based on at least one of: the monitor information or the image information and on an output setting value of treatment energy for treating the living tissue with the energy treatment tool.

2. The estimation method according to claim **1**, wherein the energy treatment tool applies, as the treatment energy, ultrasonic energy to the living tissue according to a supplied first drive signal, and wherein the electrical characteristic value includes an electrical characteristic value corresponding to a changed first drive signal that includes a drive signal applied after the supplied first drive signal is changed by a frequency response of the energy treatment tool.

3. The estimation method according to claim **1**, wherein the energy treatment tool applies, as the treatment energy, high frequency energy to the living tissue according to a supplied second drive signal, and wherein the electrical characteristic value includes an electrical characteristic value corresponding to a changed second drive signal that includes a drive signal applied after the supplied second drive signal is changed by a frequency response of the energy treatment tool.

4. The estimation method according to claim **1**, wherein the endoscopic image includes at least one of a white light image obtained by imaging the living tissue irradiated with white light, a special light image obtained by imaging the living tissue irradiated with special light in a specific wavelength band, or a fluorescence image obtained by imaging fluorescence generated from the living tissue by irradiation of the living tissue with excitation light.

5. The estimation method according to claim **1**, wherein the image information includes information calculated based on the endoscopic image and is information regarding a length of a part, which is gripped by the energy treatment tool, of the living tissue.

6. The estimation method according to claim **1**, wherein the image information includes color information of a pixel corresponding to the living tissue in the endoscopic image.

7. The estimation method according to claim **1**, wherein the image information is information calculated based on the endoscopic image and includes information regarding at least one of a tissue structure of the living tissue, a tissue contraction amount of the living tissue after application of the treatment energy is started, or a time from start of application of the treatment energy to start of contraction of the living tissue.

8. The estimation method according to claim **1**, wherein in the estimation regarding the thermal invasion in the living tissue, a thermal invasion range in the living tissue is estimated.

9. The estimation method according to claim **1**, wherein in the estimation regarding the thermal invasion in the living tissue, a possibility of leading to a postoperative complication is estimated.

10. The estimation method according to claim **1**, wherein in the estimation regarding the thermal invasion in the living tissue, the estimation regarding the thermal invasion in the living tissue is performed by using a learning model generated by machine learning.

11. The estimation method according to claim **1**, wherein in the estimation regarding the thermal invasion in the living tissue, the estimation regarding the thermal invasion in the living tissue is performed by using at least one of a tissue type of the living tissue, a tissue change amount of the living

tissue after the treatment energy is applied, or an amount of heat input to the living tissue after the treatment energy is applied.

12. The estimation method according to claim **1**, wherein after an output start operation of starting application of the treatment energy to the living tissue is received, the non-treatment energy for monitoring is applied from the energy treatment tool to the living tissue and the monitor information is acquired, and wherein after the estimation regarding the thermal invasion in the living tissue is performed, when a result of the estimation is a specific result, application of the treatment energy from the energy treatment tool to the living tissue is started.

13. An estimation method executed by a processor of an estimation device, the estimation method comprising:

acquiring output information regarding an electrical characteristic value in an energy treatment tool when treatment energy is applied to a living tissue from the energy treatment tool;

acquiring image information regarding an endoscopic image obtained by imaging the living tissue; and

performing an estimation regarding thermal invasion in the living tissue based on the output information and the image information.

14. The estimation method according to claim **13**, wherein after an output start operation of starting application of the treatment energy to the living tissue is received, the treatment energy is applied from the energy treatment tool to the living tissue and the output information is acquired, and wherein after the estimation regarding the thermal invasion in the living tissue is performed, when a result of the estimation is a specific result, application of the treatment energy from the energy treatment tool to the living tissue is continued.

15. An estimation device comprising:

at least one processor, the at least one processor being configured to:

acquire monitor information regarding an electrical characteristic value in an energy treatment tool when non-treatment energy for monitoring is applied to a living tissue from the energy treatment tool;

acquire image information regarding an endoscopic image obtained by imaging the living tissue; and

perform an estimation regarding thermal invasion in the living tissue based on at least one of the monitor information and the image information and on an output setting value of treatment energy for treating the living

16. The estimation device according to claim **15**, wherein the energy treatment tool applies, as the treatment energy, ultrasonic energy to the living tissue according to a supplied first drive signal, and wherein the electrical characteristic value includes an electrical characteristic value corresponding to a changed first drive signal that includes a drive signal applied after the supplied first drive signal is changed by a frequency response of the energy treatment tool.

17. The estimation device according to claim **15**, wherein the energy treatment tool applies, as the treatment energy, high frequency energy to the living tissue according to a supplied second drive signal, and wherein the electrical characteristic value includes an electrical characteristic value corresponding to a changed second drive signal that includes a drive signal applied after the supplied second drive signal is changed by a frequency response of the energy treatment tool. tissue with the energy treatment tool.

18. An estimation device comprising:

at least one processor, the at least one processor being configured to:

acquire output information regarding an electrical characteristic value in an energy treatment tool when treatment energy is applied to a living tissue from the energy treatment tool;

acquire image information regarding an endoscopic image obtained by imaging the living tissue; and

perform an estimation regarding thermal invasion in the living tissue based on the output information and the image information.

19. The estimation device according to claim **18**, wherein after an output start operation of starting application of the treatment energy to the living tissue is received, the treatment energy is applied from the energy treatment tool to the living tissue and the output information is acquired, and wherein after the estimation regarding the thermal invasion in the living tissue is performed, when a result of the estimation is a specific result, application of the treatment energy from the energy treatment tool to the living tissue is continued.

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