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TAKENOUCHI et al.

(54) PROCESSING DEVICE, ENDOSCOPE DEVICE, AND PROCESSING METHOD

(71) Applicant: **FUJIFILM Corporation**, Tokyo (JP)

(72) Inventors: **Seiya TAKENOUCHI**, Ashigarakami-gun (JP); **Satoru TSUTO**, Ashigarakami-gun (JP)

(73) Assignee: **FUJIFILM Corporation**, Tokyo (JP)

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(57) **ABSTRACT**

A processing device includes a processor configured to: acquire a distance from a reference position on a movement path of an endoscope to a distal end of the endoscope that is moved along the movement path; acquire a captured image that is captured by the endoscope; and determine a reaching site of the distal end of the endoscope inserted into a subject, based on the captured image and the distance.

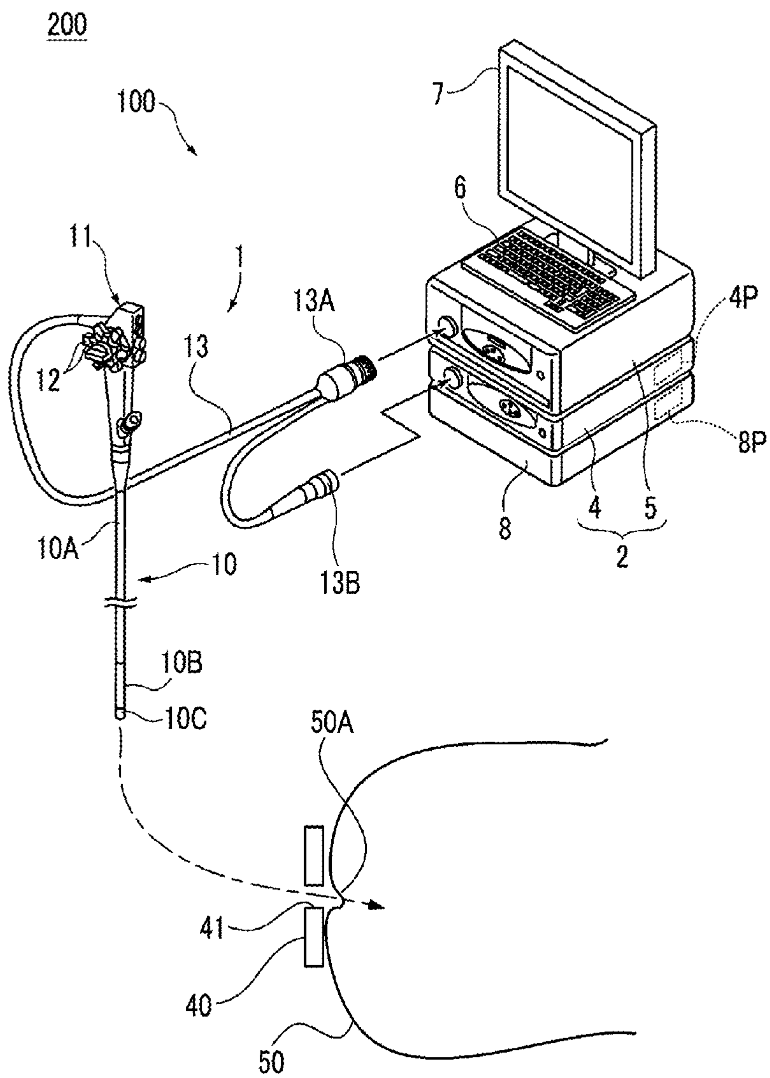


FIG. 1

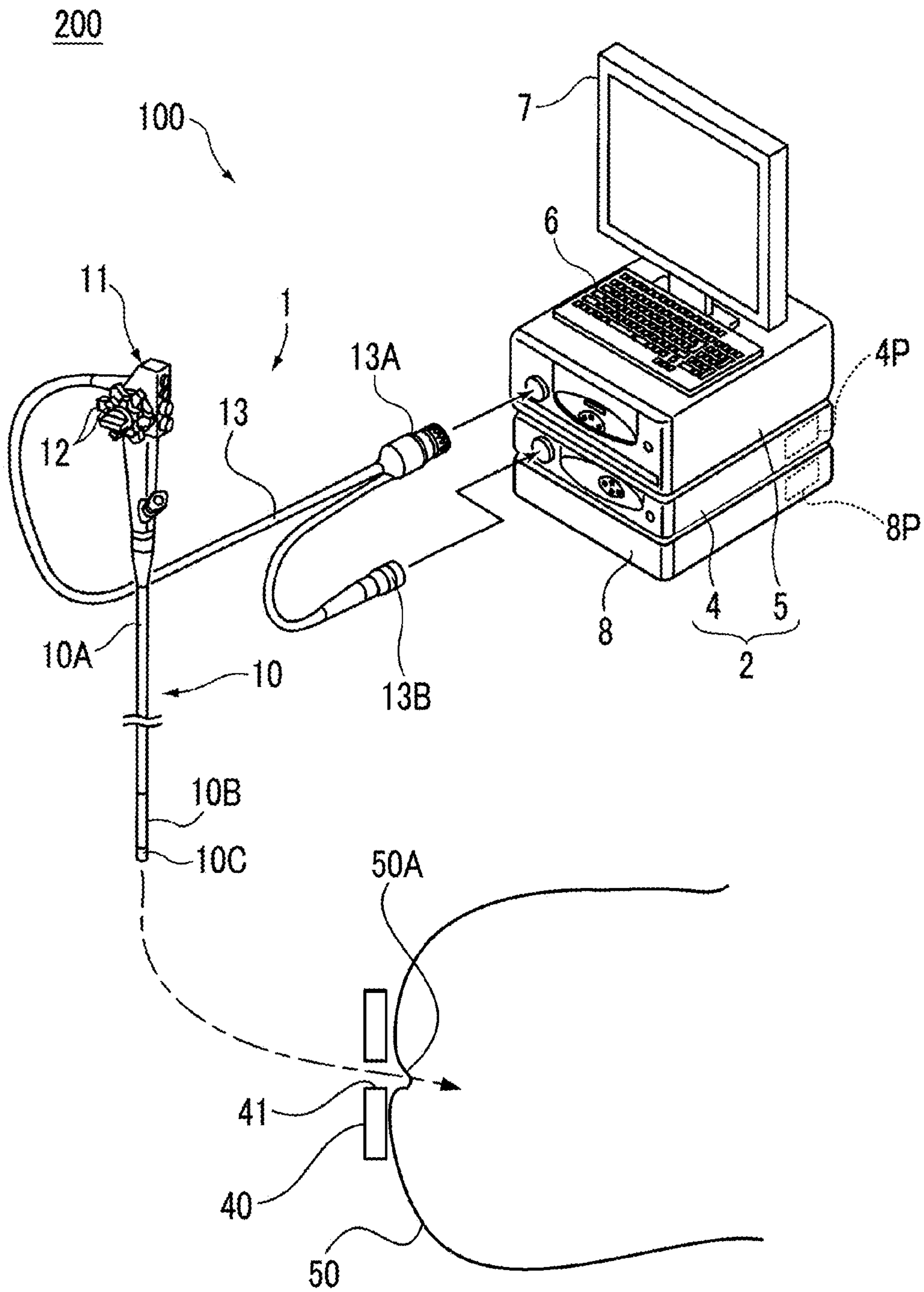


FIG. 2

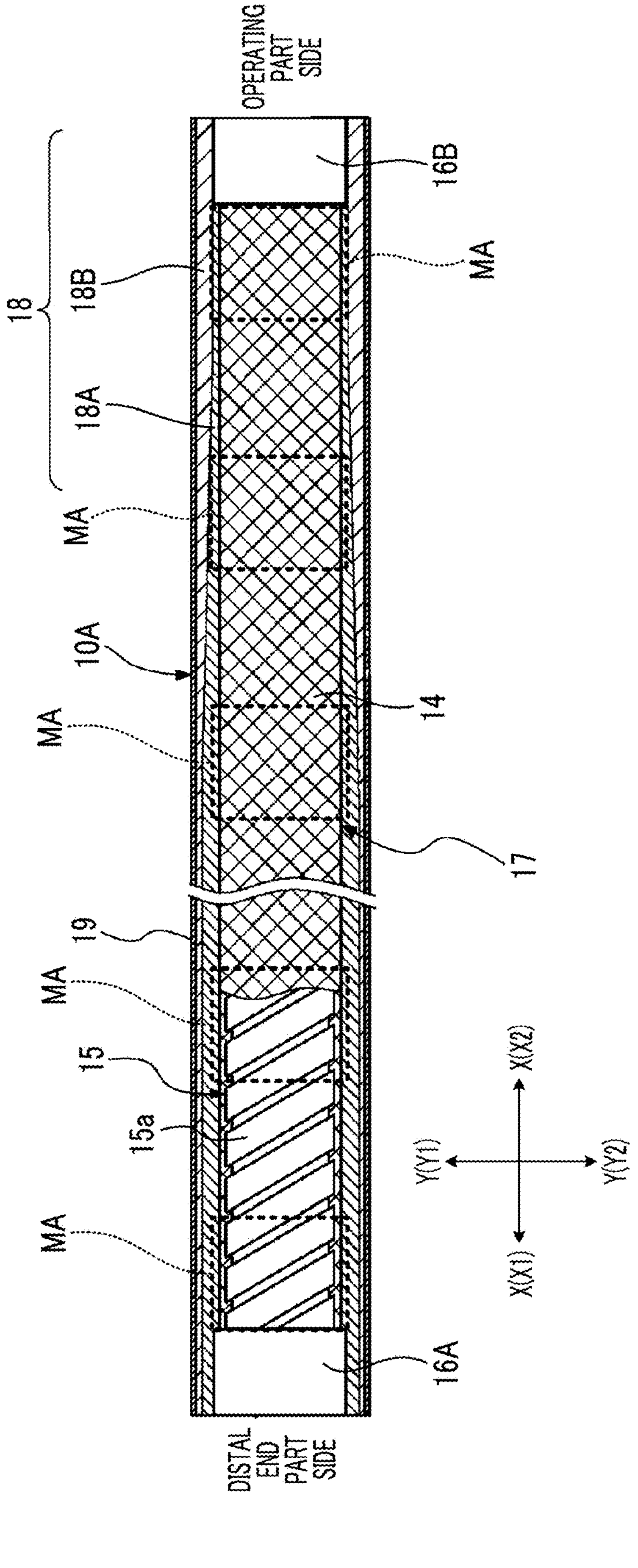

OPERATING PART SIDE
16B
MA
18B
18
18A
MA
10A
MA
14
17
19
MA
15
15a
MA
16A
DISTAL END PART SIDE
X(X2)
Y(Y1)
Y(Y2)
X(X1)

FIG. 3

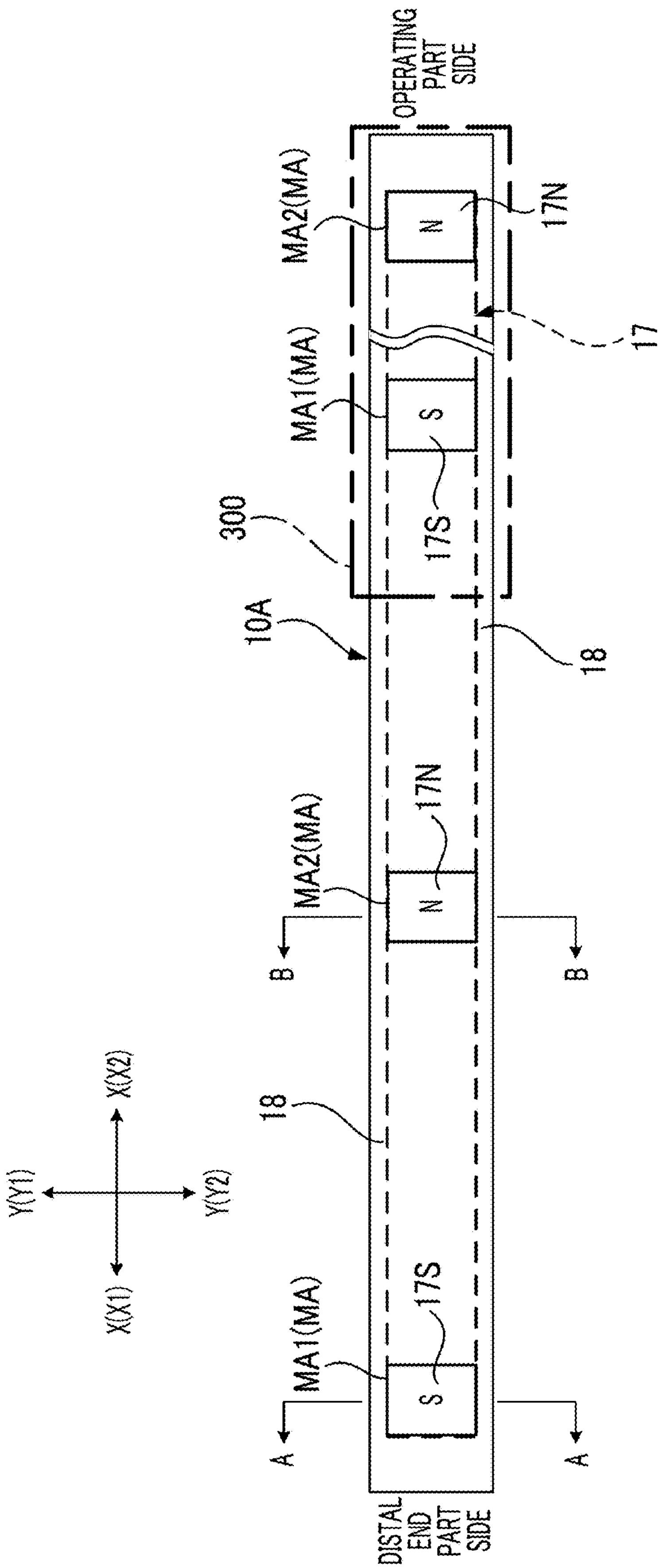

OPERATING PART SIDE
MA2(MA)
17N
N
17
MA1(MA)
S
300
17S
10A
18
MA2(MA)
17N
N
B
B
X(X2)
18
Y(Y1)
Y(Y2)
X(X1)
MA1(MA)
17S
S
A
A
DISTAL END PART SIDE

FIG. 4

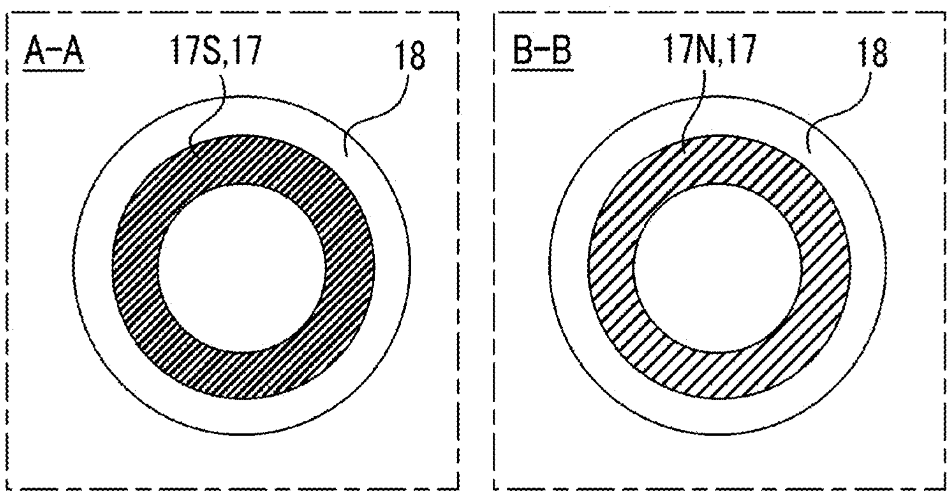


FIG. 5

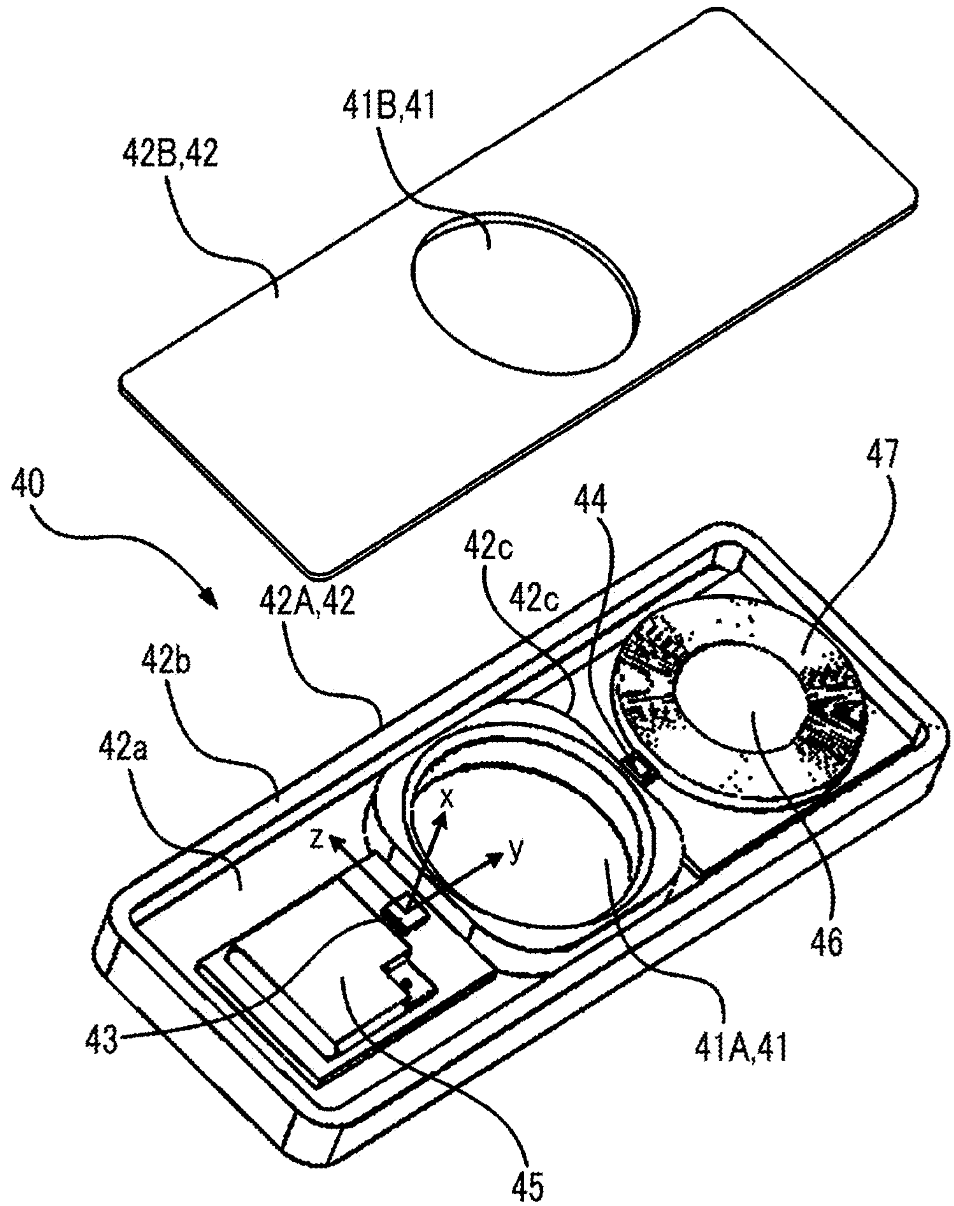


FIG. 6

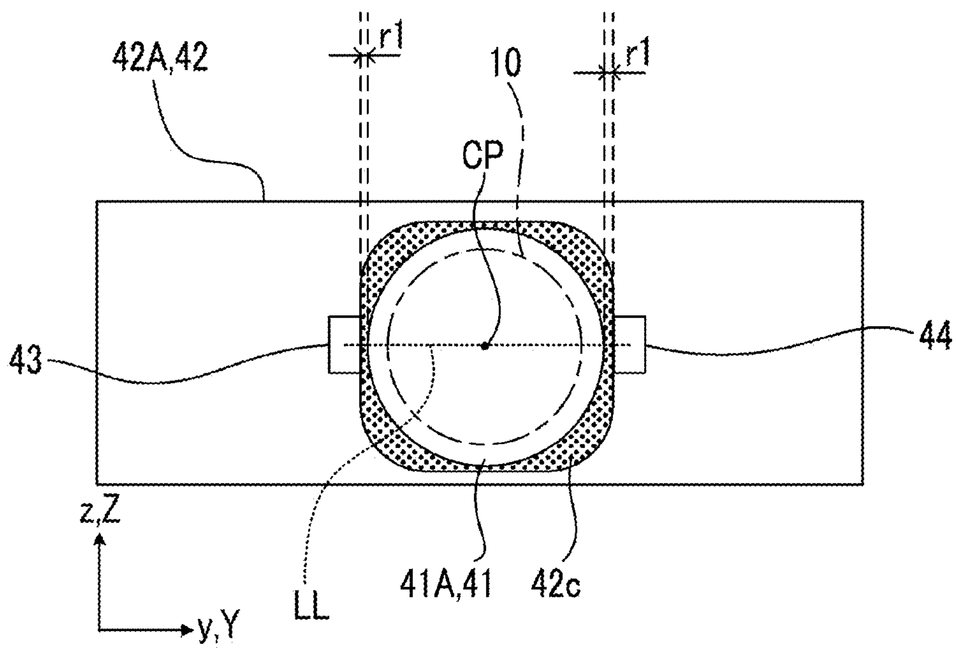


FIG. 7

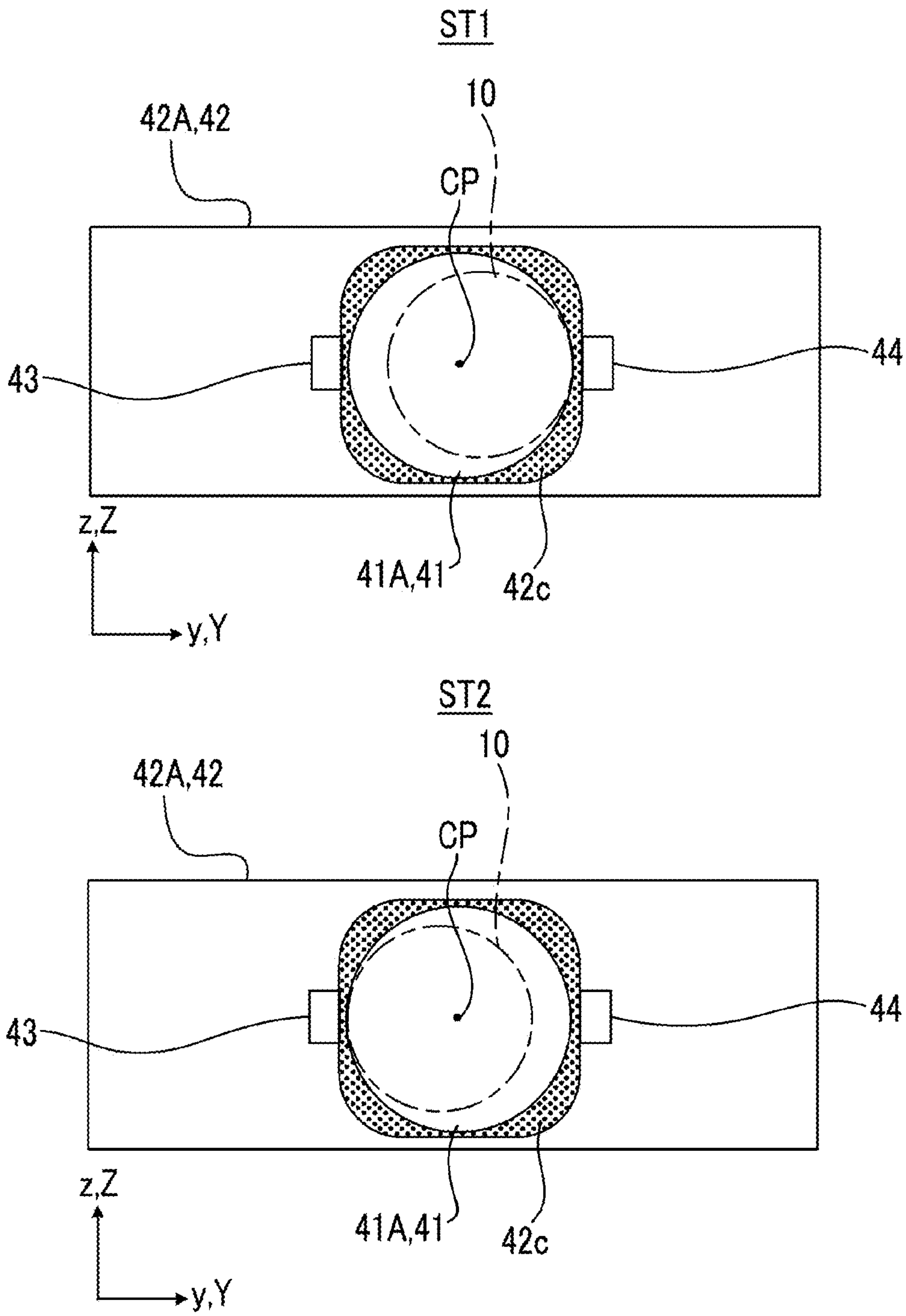

ST1
10
42A,42
CP
43
44
z,Z
y,Y
41A,41
42c
ST2
10
42A,42
CP
43
44
z,Z
y,Y
41A,41
42c

FIG. 8

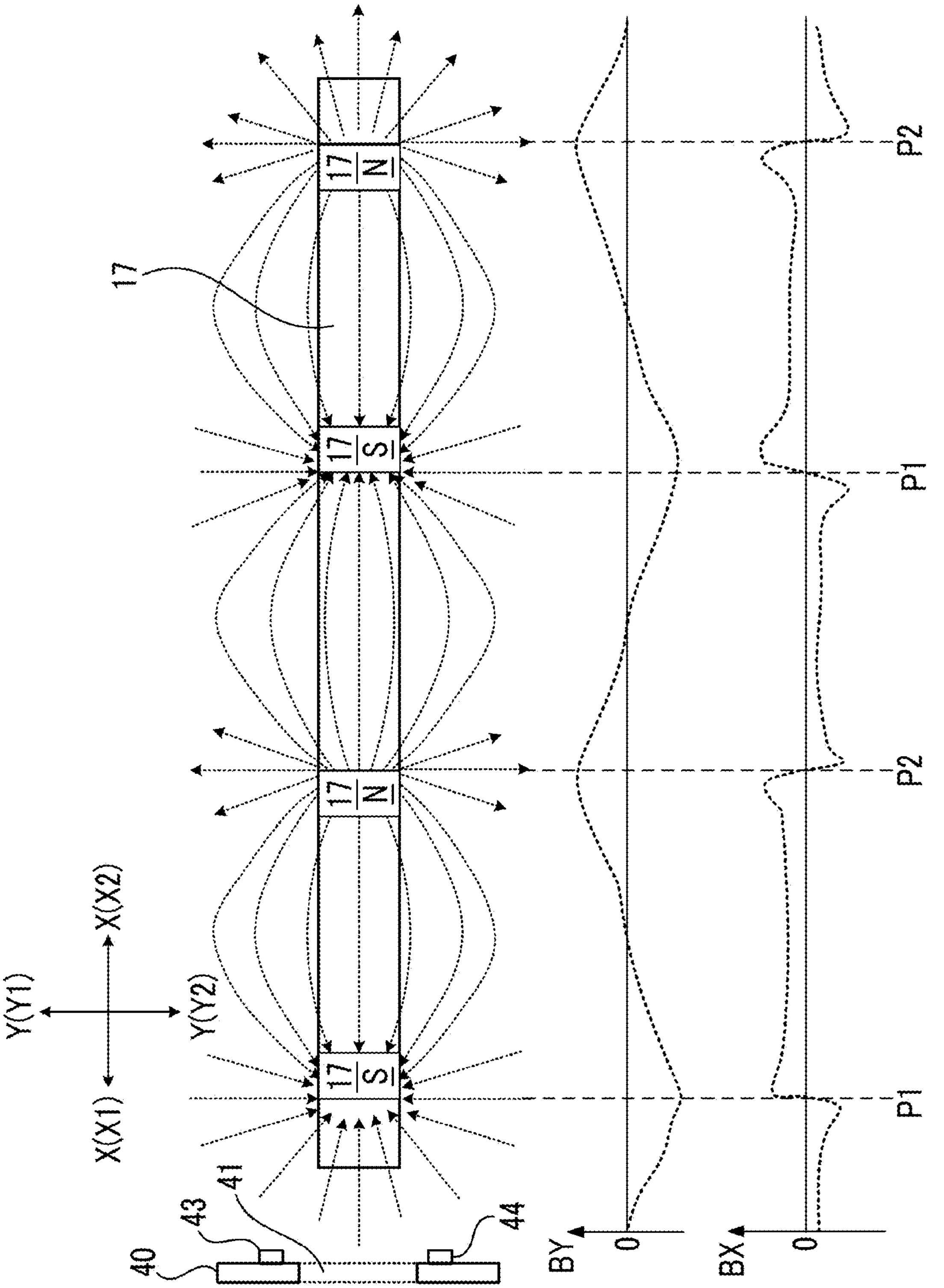
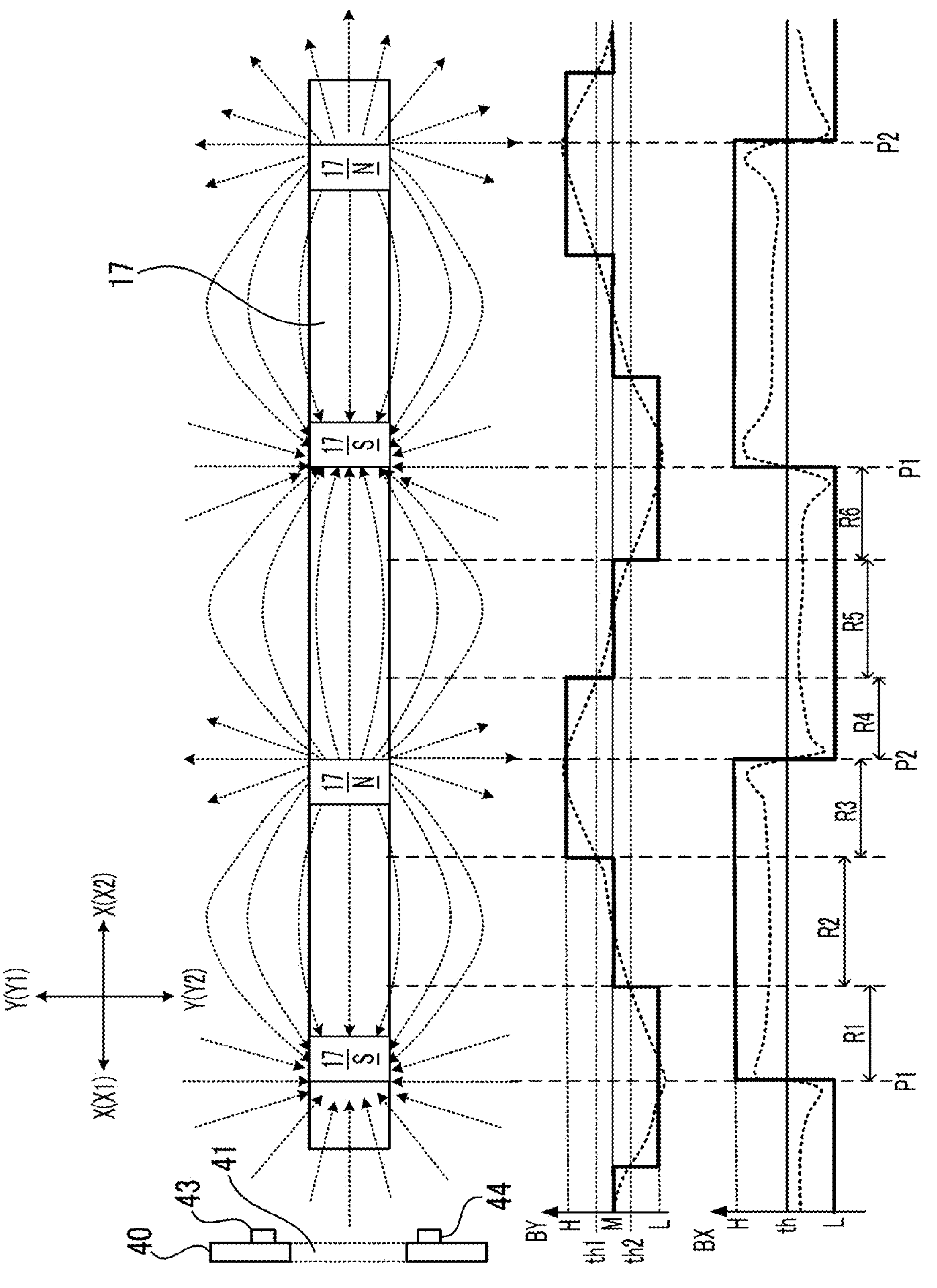


FIG. 9



Y(Y1)
X(X1)
X(X2)
Y(Y2)
17
N
S
40
41
43
44
BY
H
M
L
th1
th2
BX
th
P1
P2
R1
R2
R3
R4
R5
R6

FIG. 10

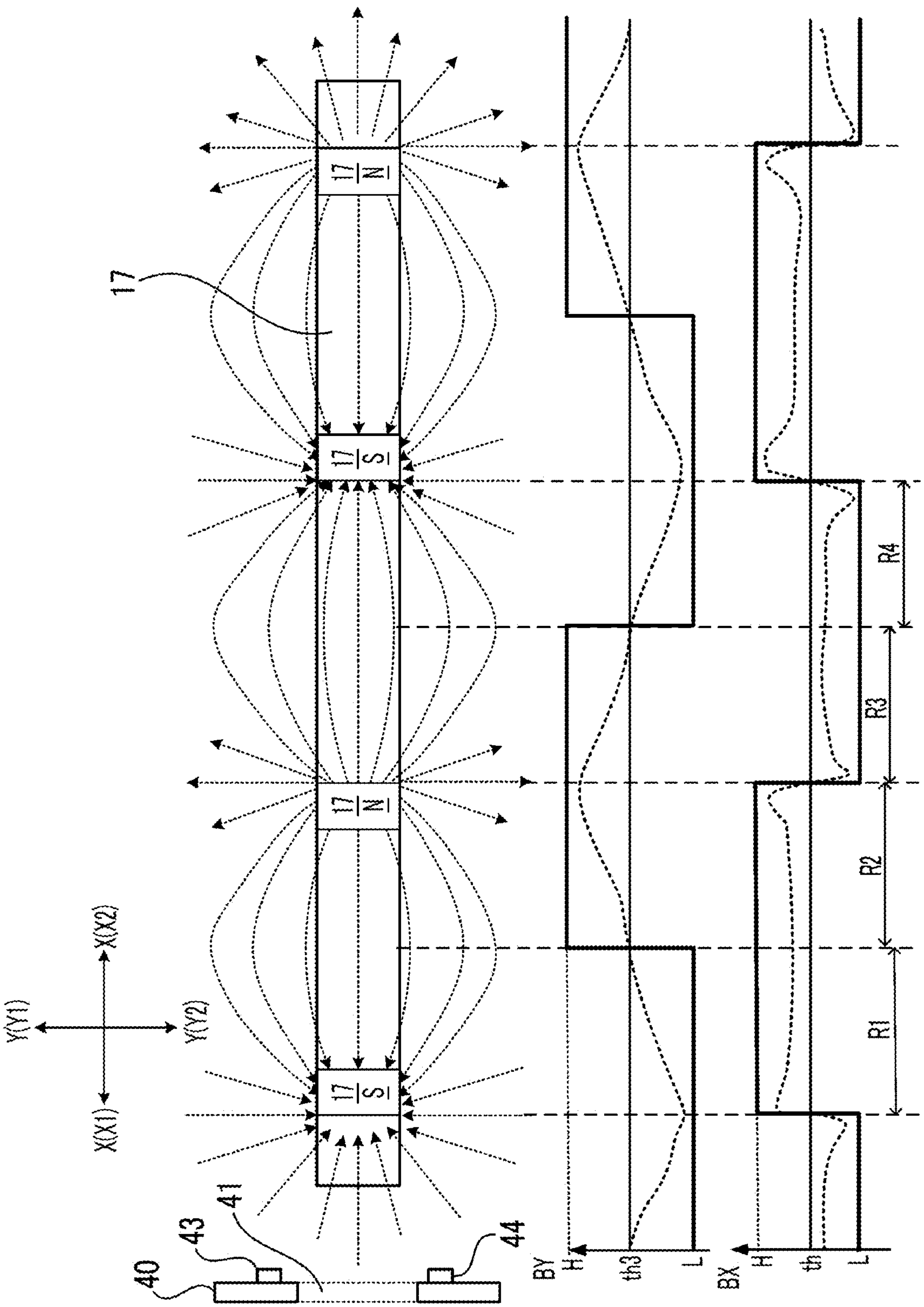


FIG. 11

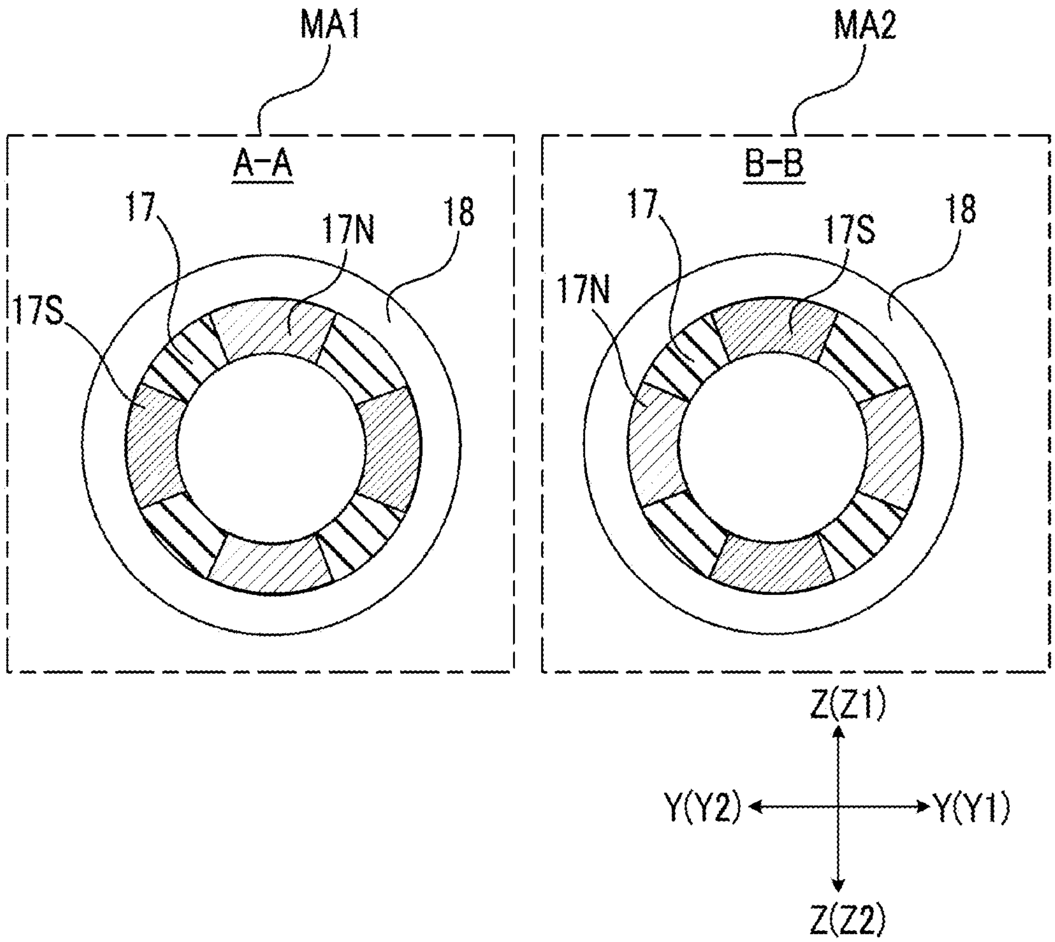


FIG. 12

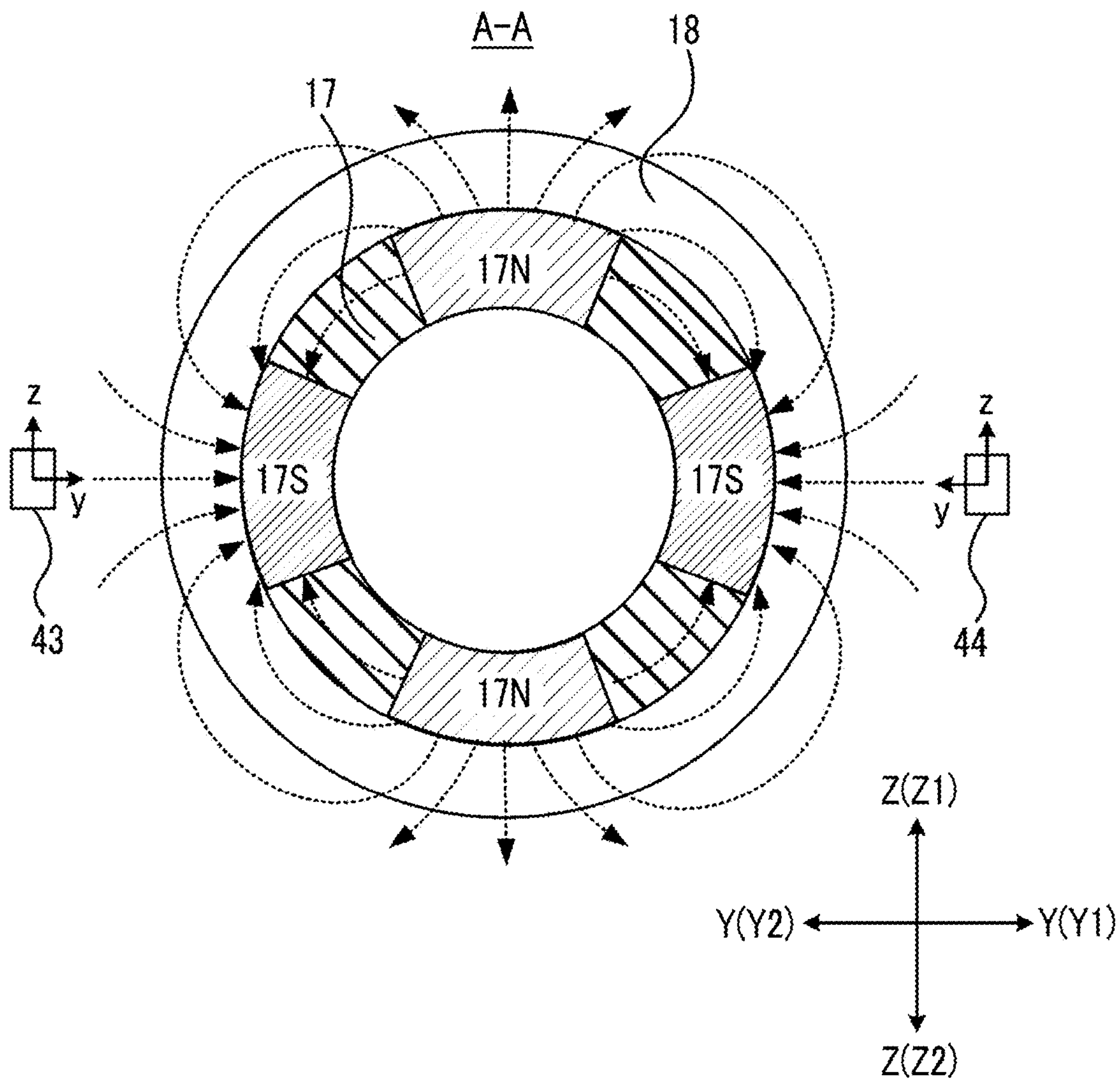


FIG. 13

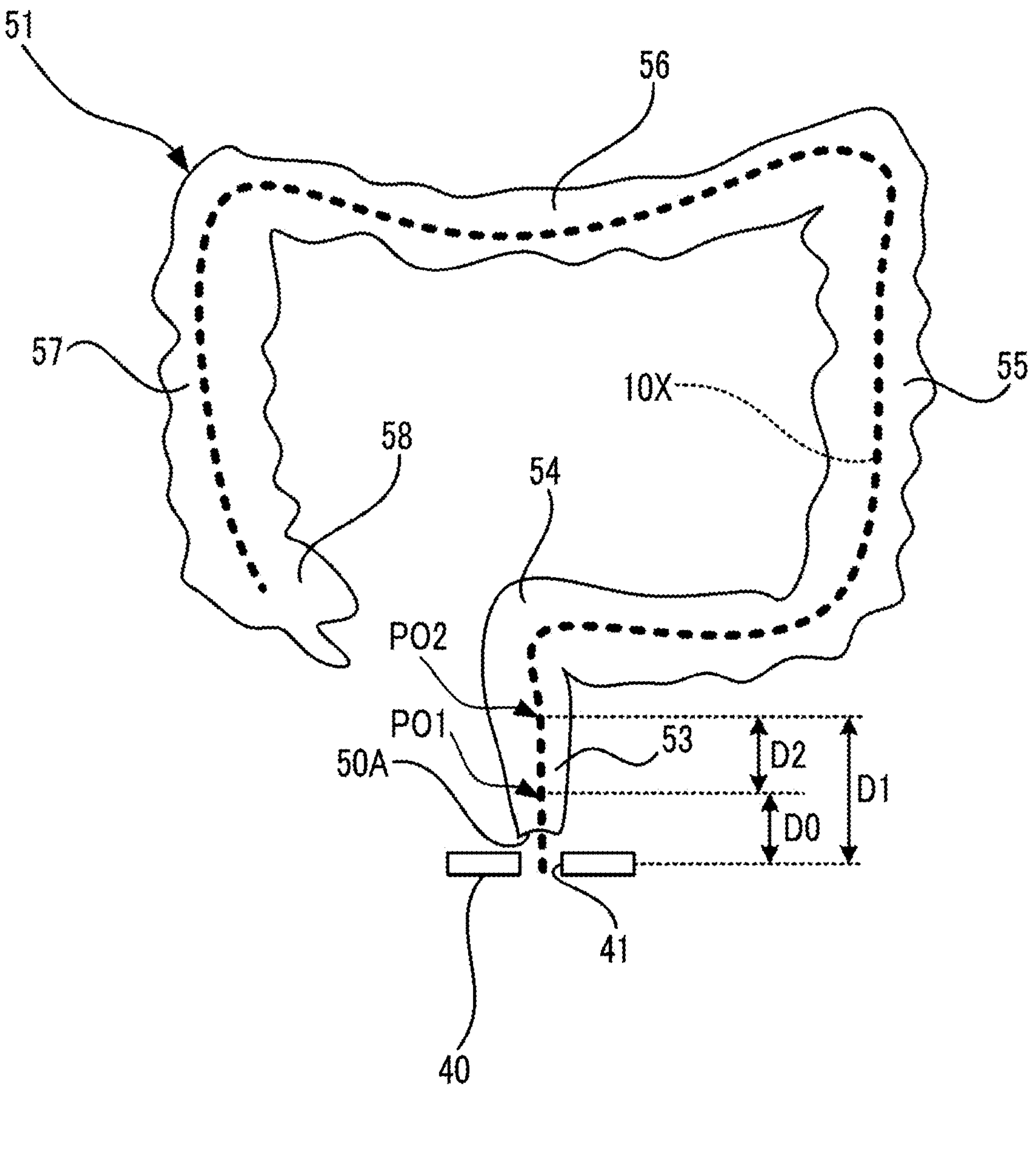


FIG. 14

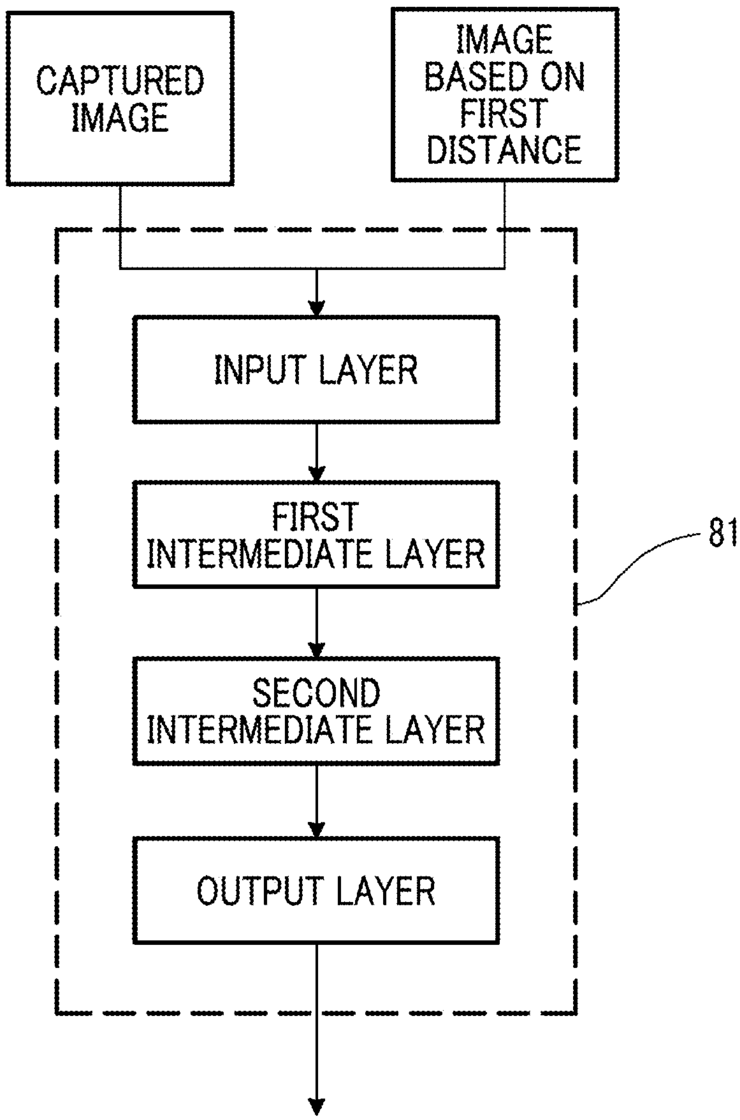

CAPTURED IMAGE
IMAGE BASED ON FIRST DISTANCE
INPUT LAYER
FIRST INTERMEDIATE LAYER
SECOND INTERMEDIATE LAYER
OUTPUT LAYER
81

FIG. 15

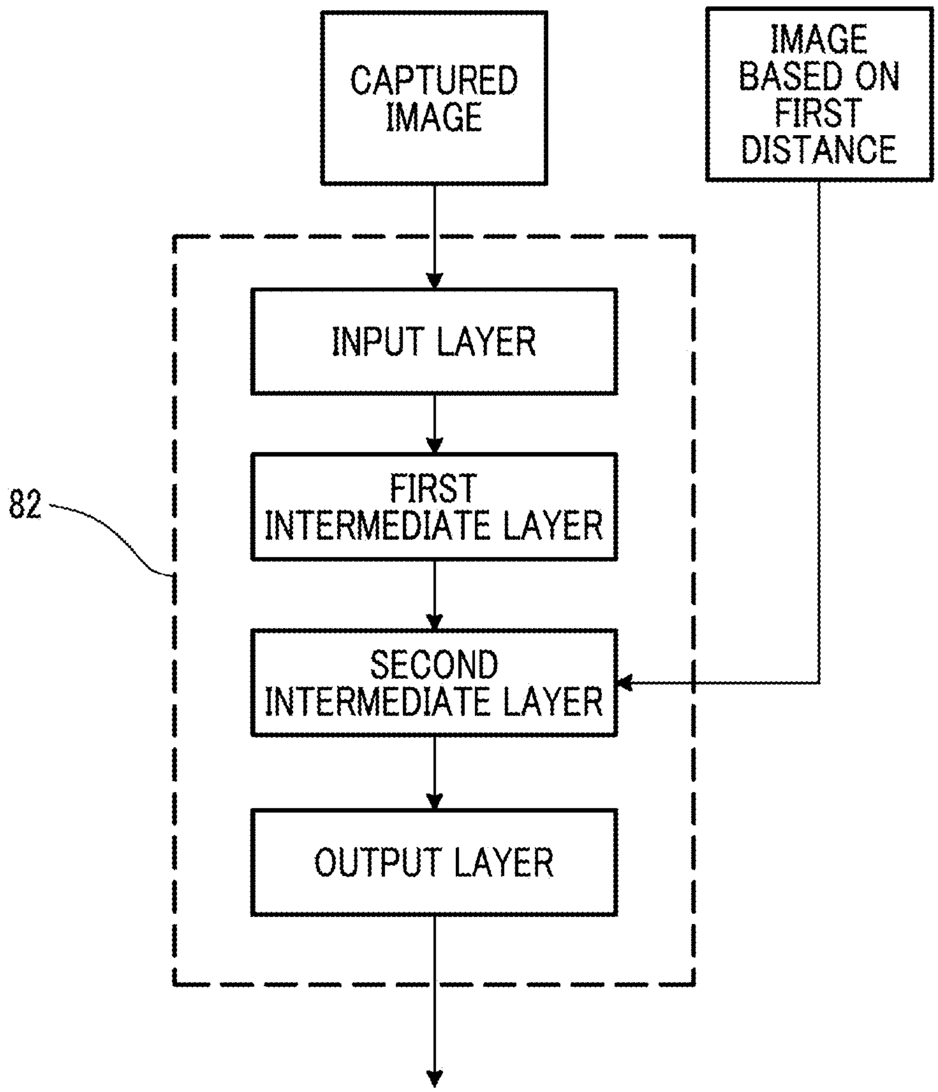

CAPTURED IMAGE
IMAGE BASED ON FIRST DISTANCE
INPUT LAYER
FIRST INTERMEDIATE LAYER
SECOND INTERMEDIATE LAYER
OUTPUT LAYER
82

FIG. 16

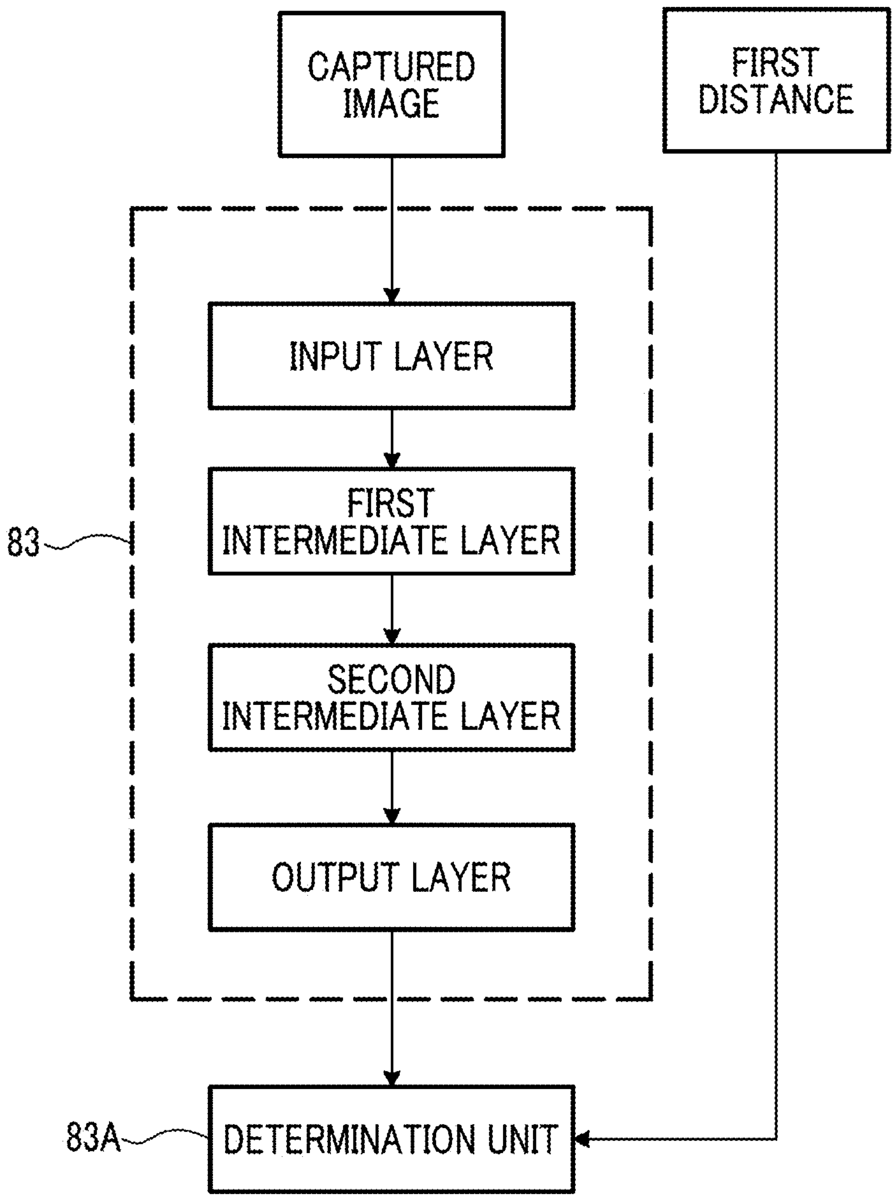
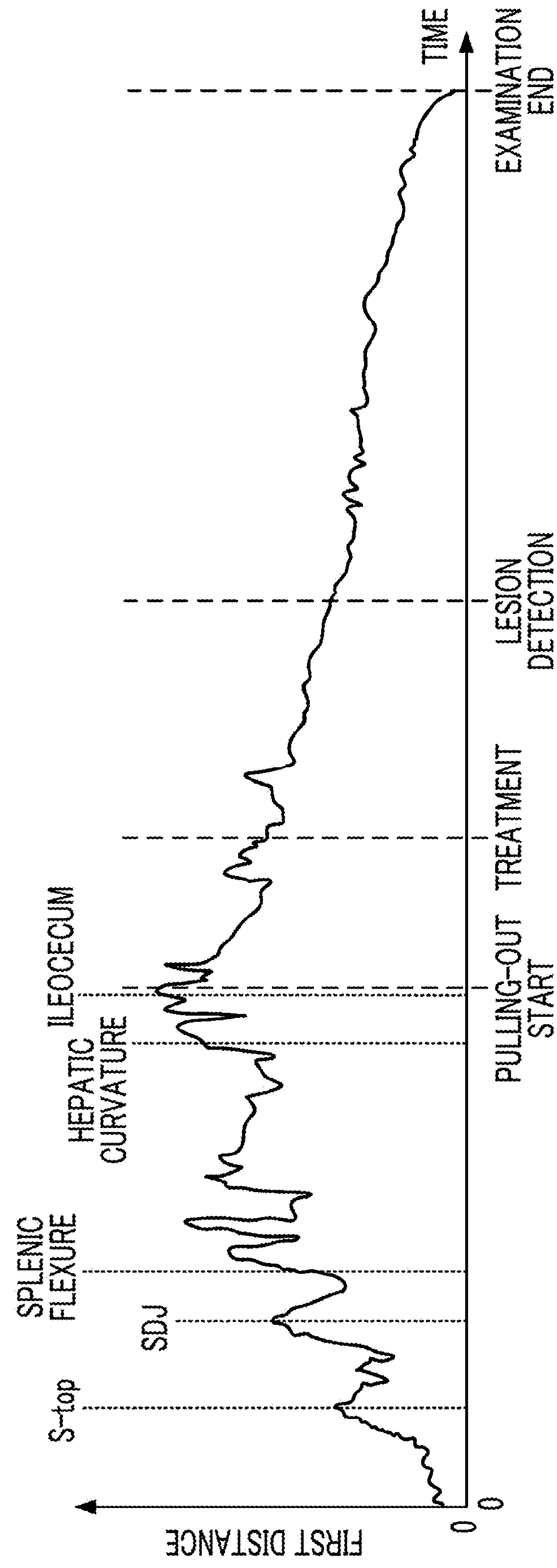

CAPTURED IMAGE
FIRST DISTANCE
83
INPUT LAYER
FIRST INTERMEDIATE LAYER
SECOND INTERMEDIATE LAYER
OUTPUT LAYER
83A
DETERMINATION UNIT

FIG. 17



FIRST DISTANCE
0
0
TIME
S-top
SDJ
SPLENIC FLEXURE
HEPATIC CURVATURE
ILEOCECUM
PULLING-OUT START
TREATMENT
LESION DETECTION
EXAMINATION END

PROCESSING DEVICE, ENDOSCOPE DEVICE, AND PROCESSING METHOD

CROSS REFERENCE TO RELATED APPLICATION

[0001] This is a continuation of International Application No. PCT/JP2023/038545 filed on Oct. 25, 2023, and claims priority from Japanese Patent Application No. 2022-174971 filed on Oct. 31, 2022, the entire disclosures of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0002] The present invention relates to a processing device, an endoscope device, and a processing method.

2. Description of the Related Art

[0003] WO2018/211674A discloses an image processing apparatus comprising an acquisition unit that acquires information including an image captured by an endoscope, and a technique level evaluation value calculation unit that calculates a technique level evaluation value indicating a technique level of an operator who operates the endoscope based on the information, in which the technique level evaluation value calculation unit includes a specific scene determination unit that determines a specific scene captured in the image, and an image recording unit that adds identification information for identifying the image to the image in which the specific scene determined by the specific scene determination unit is captured, and records the image.

SUMMARY OF THE INVENTION

[0004] In the present disclosure, a technique capable of determining a position of an endoscope in a subject with high accuracy is provided.

[0005] A processing device according to an aspect of the present disclosure comprises: a processor configured to: acquire a distance from a reference position on a movement path of an endoscope to a distal end of the endoscope that is moved along the movement path; acquire a captured image that is captured by the endoscope; and determine a reaching site of the distal end of the endoscope inserted into a subject, based on the captured image and the distance.

[0006] An endoscope device according to an aspect of the present disclosure comprises: the processing device and the endoscope.

[0007] A processing method according to an aspect of the present disclosure comprises: acquiring a distance from a reference position on a movement path of an endoscope to a distal end of the endoscope that is moved along the movement path; acquiring a captured image that is captured by the endoscope; and determining a reaching site of the distal end of the endoscope inserted into a subject, based on the captured image and the distance.

[0008] According to the present disclosure, it is possible to determine the position of the endoscope in the subject with high accuracy.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a diagram illustrating a schematic configuration of an endoscope system **200**.

[0010] FIG. **2** is a partial cross-sectional view illustrating a detailed configuration of a soft portion **10**A of an endoscope **1**.

[0011] FIG. **3** is a schematic diagram illustrating details of a magnetic pattern formed on a tubular member **17**.

[0012] FIG. **4** is a schematic cross-sectional view taken along each of an A-A arrow and a B-B arrow in FIG. **3**.

[0013] FIG. **5** is an exploded perspective view illustrating a configuration example of a detection unit **40**.

[0014] FIG. **6** is a schematic diagram of a body part **42**A of the detection unit **40** illustrated in FIG. **5** as viewed from a direction x.

[0015] FIG. **7** is a diagram illustrating an example of a position at which an insertion part **10** can be located in a through-hole **41**.

[0016] FIG. **8** is a schematic diagram illustrating an example of a magnetic flux density detected by a magnetic detection unit **43**.

[0017] FIG. **9** is a schematic diagram illustrating an example of a result of classifying the magnetic flux density illustrated in FIG. **8** according to magnitude thereof.

[0018] FIG. **10** is a schematic diagram illustrating another example of the result of classifying the magnetic flux density illustrated in FIG. **8** according to the magnitude thereof.

[0019] FIG. **11** is a schematic cross-sectional view illustrating a modification example of magnetic pole portions MA**1** and MA**2** illustrated in FIG. **3** taken along the A-A arrow and the B-B arrow.

[0020] FIG. **12** is a diagram schematically illustrating a magnetic flux line generated in the magnetic pole portion MA**1** having the configuration illustrated in FIG. **11**.

[0021] FIG. **13** is a schematic diagram illustrating a movement path of the insertion part **10** in an examination performed using the endoscope **1**.

[0022] FIG. **14** is a schematic diagram for describing a first determination example of a reaching site.

[0023] FIG. **15** is a schematic diagram for describing a second determination example of the reaching site.

[0024] FIG. **16** is a schematic diagram for describing a third determination example of the reaching site.

[0025] FIG. **17** is a graph illustrating a display example of examination data associated and recorded by a processor **8**P.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0026] FIG. **1** is a diagram illustrating a schematic configuration of an endoscope system **200**. The endoscope system **200** includes an endoscope device **100** having an endoscope **1** as an example of medical equipment that is used by being inserted into a body for examination, surgery, and the like, and a detection unit **40**.

[0027] The endoscope **1** includes: an insertion part **10** which is an elongated instrument extending in one direction and is inserted into the body; an operating part **11** which is provided in a base end part of the insertion part **10** and is provided with an operation member for performing an observation mode switching operation, an imaging recording operation, a forceps operation, an air supply and water supply operation, a suction operation, an electric cautery operation, or the like; an angle knob **12** provided adjacent to the operating part **11**; and a universal cord **13** including connector portions **13**A and **13**B that respectively connect the endoscope **1** to a light source device **5** and a processor device **4** in an attachable and detachable manner.

[0028] The operating part **11** is provided with a forceps port into which biopsy forceps as a treatment tool for collecting a biological tissue such as a cell or a polyp are inserted. It should be noted that, although the illustration is omitted in FIG. **1**, various channels such as a forceps channel through which the biopsy forceps inserted from the forceps port are inserted, a channel for air supply and water supply, a channel for suction are provided inside the operating part **11** and the insertion part **10**.

[0029] The insertion part **10** includes a soft portion **10**A having flexibility, a bendable part **10**B provided at a distal end of the soft portion **10**A, and a distal end part **10**C that is provided at a distal end of the bendable part **10**B, and is harder than the soft portion **10**A. An imaging element and an imaging optical system are built in the distal end part **10**C.

[0030] The bendable part **10**B is configured to be bendable by a rotational movement operation of the angle knob **12**. Depending on a site or the like of a subject in which the endoscope **1** is used, the bendable part **10**B can be bent in any direction and at any angle, and the distal end part **10**C can be directed in a desired direction.

[0031] Hereinafter, a direction in which the insertion part **10** extends will be referred to as a longitudinal direction X. Further, one of radial directions of the insertion part **10** will be referred to as a radial direction Y. In addition, one of circumferential directions of the insertion part **10** (one of tangential directions of an outer peripheral edge of the insertion part **10**) will be referred to as a circumferential direction Z. In the longitudinal direction X, a direction from a base end (operating part **11** side) of the endoscope **1** toward a distal end will be referred to as a longitudinal direction X**1**, and a direction from the distal end of the endoscope **1** to the base end will be referred to as a longitudinal direction X**2**. In addition, in the radial direction Y, one side will be referred to as a radial direction Y**1**, and the other side will be referred to as a radial direction Y**2**. The longitudinal direction X is one of directions different from the radial direction Y and the circumferential direction Z. The radial direction Y is one of directions different from the longitudinal direction X and the circumferential direction Z. In the present specification, the longitudinal direction X constitutes a first direction. Further, the radial direction Y constitutes a second direction intersecting the first direction. Further, the circumferential direction Z constitutes a third direction different from the first direction and the second direction.

[0032] In the example of FIG. **1**, the insertion part **10** of the endoscope **1** is inserted into the body of a subject **50** from an anus **50**A of the subject **50**. The detection unit **40** has a rectangular plate shape as an example, and has a through-hole **41** into which the insertion part **10** can be inserted. The detection unit **40** is disposed between buttocks of the subject **50** and the insertion part **10** (that is, a movement path of the insertion part **10**). The insertion part **10** reaches the anus **50**A through the through-hole **41** of the detection unit **40**, and is inserted into the body of the subject **50** from the anus **50**A. In the present specification, the insertion part **10** constitutes an elongated instrument that is used by being relatively moved with respect to the detection unit **40**.

[0033] The endoscope device **100** includes: the endoscope **1**; a body part **2** consisting of the processor device **4** and the light source device **5** to which the endoscope **1** is connected; a display device **7** that displays a captured image and the like; an input unit **6** that is an interface for inputting various kinds of information to the processor device **4**; and an expansion device **8** for expanding various functions.

[0034] The processor device **4** has various processors **4**P that control the endoscope **1**, the light source device **5**, and the display device **7**. The expansion device **8** has a processor **8**P that performs various kinds of processing. Each of the processor **4**P and the processor **8**P is a central processing unit (CPU) as a general-purpose processor that executes software (a program including a display control program) to perform various functions, a programmable logic device (PLD) as a processor of which a circuit configuration can be changed after the manufacture, such as a field programmable gate array (FPGA), and a dedicated electric circuit as a processor having a circuit configuration specially designed for executing specific processing, such as an application specific integrated circuit (ASIC). Each of the processor **4**P and the processor **8**P may be composed of one processor, or composed of a combination of two or more processors of the same type or a different type (for example, a combination of a plurality of FPGAs or a combination of a CPU and an FPGA). More specifically, the hardware structure of each of the processor **4**P and the processor **8**P is an electric circuit (circuitry) in which circuit elements such as semiconductor elements are combined.

[0035] The expansion device **8** includes the processor **8**P, a communication interface (an interface for communicating with the processor device **4** and the detection unit **40** to be described later) (not illustrated), and a memory composed of a recording medium such as a random access memory (RAM), a read only memory (ROM), a solid state drive (SSD), or a hard disk drive (HDD), and constitutes a processing device.

[0036] The processor **8**P may perform lesion recognition processing of acquiring a captured image captured by the endoscope **1** from the processor device **4** and recognizing a lesion region in the captured image, treatment tool recognition processing of recognizing whether or not a treatment tool such as forceps or a needle is included in the captured image, and the like. The lesion recognition processing and the treatment tool recognition processing each constitute recognition processing related to the endoscope examination.

[0037] The lesion recognition processing refers to processing for performing detection of the lesion region from the captured image, and identification of the detected lesion region. In the lesion recognition processing, the processing for detecting the lesion region is referred to as detection processing, and the processing for identifying the lesion region is referred to as identification processing. The lesion recognition processing may be processing including at least the detection processing. The detection of the lesion region refers to finding a lesion region suspected of a lesion such as a malignant tumor or a benign tumor (lesion candidate region), from the captured image. The identification of the lesion region refers to identifying the type, nature, and the like of the detected lesion region, such as whether the lesion region detected by the detection processing is malignant or benign, what kind of disease in a case where the lesion region is malignant, or how much the degree of progress of the disease is. For example, both the lesion recognition processing and the treatment tool recognition processing can be executed by a recognition model generated by machine learning (for example, a neural network or a support vector machine) or image analysis on the captured image.

[0038] The various kinds of processing described below performed by the processor **8**P may be performed by the processor **8**P alone, or may be performed by being shared between the processor **8**P and another processor. The other processor is, for example, a processor of a server in an examination system in which examination data generated by the endoscope system **200** is recorded, the processor **4**P, or the like. Alternatively, various kinds of processing performed by the processor **8**P can be performed by the processor **4**P.

[0039] FIG. **2** is a partial cross-sectional view illustrating a detailed configuration of the soft portion **10**A of the endoscope **1**. The soft portion **10**A, which forms most of a length of the insertion part **10**, has flexibility over substantially the entire length thereof, and has a structure in which, in particular, a portion to be inserted into a body cavity or the like is rich in flexibility.

[0040] The soft portion **10**A includes an outer skin layer **18** that constitutes a cylindrical member having an insulating property, and a tubular member **17** that is provided in the outer skin layer **18**. The outer skin layer **18** is coated with a coating layer **19**.

[0041] The tubular member **17** includes: a first member **14** that has a cylindrical shape, contains metal, and is covered with the outer skin layer **18**; and a second member **15** that has a cylindrical shape, contains metal, and is inserted into the first member **14**. In the example of FIG. **2**, the second member **15** is composed of a spiral tube formed by spirally winding a metal strip **15***a*. Further, the first member **14** is composed of a cylindrical-shaped net body formed by braiding a metal wire. The first member **14** and the second member **15** that continuously extend in the longitudinal direction X and have a thin structure are formed by plastic processing, and the metal constituting these members includes austenitic stainless steel. The austenitic stainless steel cannot be magnetized in a state in which the plastic processing is not performed, but can be magnetized by performing the plastic processing. As described above, each of the first member **14** and the second member **15** constitutes a member that extends in the longitudinal direction X and contains metal.

[0042] The outer skin layer **18** is composed of, for example, a resin such as an elastomer, and has a multi-layer structure of an inner resin layer **18**A and an outer resin layer **18**B. The outer skin layer **18** may have a monolayer structure. In the first member **14** and the second member **15**, a cap **16**A is fitted to an end part on the distal end part **10**C side, and a cap **16**B is fitted to an end part on the operating part **11** side. The cap **16**A and the cap **16**B are covered with the outer skin layer **18**. The soft portion **10**A is connected to the bendable part **10**B at the cap **16**A, and is connected to the operating part **11** at the cap **16**B.

[0043] The tubular member **17** of the soft portion **10**A is formed with a magnetic pattern along the longitudinal direction X. The magnetic pattern along the longitudinal direction X refers to a pattern in which two types of magnetic pole regions, which are a negative pole (S pole) and a positive pole (N pole), are arranged in a predetermined arrangement pattern in the longitudinal direction X. As illustrated in FIG. **2**, each of the first member **14** and the second member **15** is provided with a plurality of magnetic pole portions MA including the magnetic pole region. At least one of the two types of magnetic pole regions, which are the negative pole (S pole) and the positive pole (N pole), is formed on the magnetic pole portion MA. As described above, each of the first member **14** and the second member **15** constitutes the member that extends in the longitudinal direction X and has the magnetic pattern formed along the longitudinal direction X.

[0044] FIG. **3** is a schematic diagram illustrating details of the magnetic pattern formed on the tubular member **17**. FIG. **4** is a schematic cross-sectional view taken along each of an A-A arrow and a B-B arrow in FIG. **3**. As illustrated in FIGS. **3** and **4**, in the tubular member **17**, a magnetic pole portion MA**1** including a negative pole region **17**S formed in an annular shape along the circumferential direction of the tubular member **17**, and a magnetic pole portion MA**2** including a positive pole region **17**N formed in an annular shape along the circumferential direction of the tubular member **17** are provided to be alternately arranged in the longitudinal direction X. The total number of the magnetic pole portions MA**1** and the total number of the magnetic pole portions MA**2** are the same.

[0045] Here, an example of a manufacturing method of the endoscope **1** including the tubular member **17** having the magnetic pattern illustrated in FIG. **3** will be described. First, the endoscope **1** having the configuration illustrated in FIG. **1** is manufactured by a well-known method. Next, a magnetic field generation device **300** is prepared, which has a cylindrical coil, and can generate a magnetic field in the cylindrical coil by allowing a current to flow through the cylindrical coil. Next, as illustrated in FIG. **3**, the insertion part **10** of the endoscope **1** is inserted into the cylindrical coil of the magnetic field generation device **300** from the distal end side to relatively move the coil to a boundary portion between the operating part **11** and the soft portion **10**A. In this state, a step of allowing an alternating current to flow through the cylindrical coil of the magnetic field generation device **300** to form a magnetic field, and pulling out the insertion part **10** from the cylindrical coil of the magnetic field generation device **300** in the longitudinal direction X**2** at a constant speed is performed. In this step, a magnetic force of the tubular member **17** generated by the plastic processing is removed, and the tubular member **17** is demagnetized. In this step, it is preferable to pull out the insertion part **10** until the bendable part **10**B and the distal end part **10**C pass through the cylindrical coil, and to demagnetize the entire insertion part **10**. That is, in the insertion part **10** of the endoscope **1**, it is preferable that the bendable part **10**B and the distal end part **10**C are demagnetized. The demagnetization of a certain region means that a magnetic flux density detected from the region is equal to or less than the geomagnetism.

[0046] After the demagnetization of at least the tubular member **17** (soft portion **10**A) is performed, a work of forming a state in which the cylindrical coil of the magnetic field generation device **300** is disposed on an outer periphery of the soft portion **10**A at a predetermined position in the longitudinal direction X, and allowing the alternating current to flow through the cylindrical coil in that state to form the magnetic field is performed. By this work, the negative pole region **17**S and the positive pole region **17**N are formed over the entire circumferential direction of the tubular member **17** at positions in the vicinity of both ends of the cylindrical coil of the magnetic field generation device **300**. Thereafter, by repeating this work while shifting the position of the soft portion **10**A with respect to the cylindrical coil in the longitudinal direction X, the magnetic pattern illustrated in FIG. **3** can be formed on the tubular member **17**.

[0047] By adopting such a manufacturing method, any magnetic pattern can be easily formed on the tubular member **17** of the soft portion **10**A even in the endoscope **1** having the existing configuration or the endoscope **1** that has already been sold. In addition, by performing the demagnetization of the tubular member **17** of the soft portion **10**A and then forming the magnetic pattern on the tubular member **17**, the magnetic pattern having a desired magnetic force can be formed with high accuracy. Further, by forming the magnetic pole region by using the cylindrical coil, it is possible to form the magnetic pole region having a uniform magnetic force (magnetic flux density) over the entire outer periphery of the tubular member **17** in the magnetic pole portion MA. In FIG. **3**, a boundary line between each of the negative pole region **17**S and the positive pole region **17**N, and the other region in the tubular member **17** is illustrated, but this boundary line is illustrated for convenience, and is invisible. It is preferable that information on the magnetic pattern formed on the tubular member **17** is recorded in a memory (for example, a memory provided in the expansion device **8**) accessible by the processor **8**P. The information on the magnetic pattern includes information indicating positions of the two types of magnetic pole regions in the tubular member **17**, information indicating an arrangement pitch of the two types of magnetic pole regions in the tubular member **17**, information indicating a range in which the magnetic pole region is formed on the insertion part **10**, information indicating the position of the demagnetized region in the insertion part **10**, or the like. The demagnetized region in the insertion part **10** constitutes an adjacent region adjacent to the region in which the magnetic pattern is formed on the insertion part **10**. The bendable part **10**B and the distal end part **10**C are demagnetized regions in the insertion part **10**, but the bendable part **10**B and the distal end part **10**C need only be configured to be distinguishable from the region in which the magnetic pattern is formed, and it is not essential that the bendable part **10**B and the distal end part **10**C are demagnetized. For example, magnetization may be performed with a pattern or a magnetic force that is clearly different from the magnetic pattern.

[0048] FIG. **5** is an exploded perspective view illustrating a configuration example of the detection unit **40**. The detection unit **40** includes a housing **42** having the through-hole **41**; and a magnetic detection unit **43**, a magnetic detection unit **44**, a communication chip **45**, a storage battery **46**, and a power receiving coil **47** that are accommodated in the housing **42**.

[0049] The housing **42** includes: a body part **42**A including a flat plate portion **42***a* that has a rectangular flat plate shape and has a through-hole **41**A penetrating in a thickness direction, a side wall portion **42***b* that has a rectangular frame shape of rising from an outer peripheral edge portion of the flat plate portion **42***a* in the thickness direction of the flat plate portion **42***a*, and an inner wall portion **42***c* that has a cylindrical shape of rising from a peripheral edge portion of the through-hole **41**A in the flat plate portion **42***a* in the thickness direction of the flat plate portion **42***a*; and a lid portion **42**B that has a rectangular flat plate shape for closing an accommodation space surrounded by the flat plate portion **42***a*, the side wall portion **42***b*, and the inner wall portion **42***c*. The magnetic detection unit **43**, the magnetic detection unit **44**, the communication chip **45**, the storage battery **46**, and the power receiving coil **47** are accommodated in this accommodation space.

[0050] A through-hole **41**B penetrating in the thickness direction is formed on the lid portion **42**B, and in a state in which the lid portion **42**B closes the accommodation space, the through-hole **41**A and the through-hole **41**B communicate with each other through an inner peripheral portion of the inner wall portion **42***c* to form the through-hole **41** into which the endoscope **1** can be inserted. It is preferable that the through-hole **41** has a perfect circular shape as viewed from an axial direction of the inner wall portion **42***c* (direction in which the endoscope **1** is inserted). The housing **42** is preferably composed of a resin or the like in order to reduce the weight and the cost, and preferably has a structure that prevents moisture from entering the accommodation space.

[0051] Each of the magnetic detection unit **43** and the magnetic detection unit **44** is disposed close to the inner wall portion **42***c*, and is a three-axis magnetic sensor that can detect a magnetic flux density in a direction x (direction along the axis of the through-hole **41**) along the axis of the inner wall portion **42***c*, a magnetic flux density in a radial direction y of the through-hole **41**, and a magnetic flux density in a direction z orthogonal to the direction x and the radial direction y.

[0052] In a state in which the insertion part **10** of the endoscope **1** is inserted into the through-hole **41**, the longitudinal direction X of the insertion part **10** and the direction x match each other, the radial direction Y of the insertion part **10** and the radial direction y match each other, and the circumferential direction Z of the insertion part **10** and the direction z match each other. Therefore, each of the magnetic detection unit **43** and the magnetic detection unit **44** is configured to detect a magnetic flux density BX in the longitudinal direction X of the insertion part **10**, a magnetic flux density BY in the radial direction Y of the insertion part **10**, and a magnetic flux density BZ in the circumferential direction Z of the insertion part **10**. Each of the magnetic detection unit **43** and the magnetic detection unit **44** may include three magnetic sensors, which are a uniaxial magnetic sensor that can detect the magnetic flux density BX, a uniaxial magnetic sensor that can detect the magnetic flux density BY, and a uniaxial magnetic sensor that can detect the magnetic flux density BZ. In the present specification, the magnetic flux density BX constitutes a first magnetic flux density, the magnetic flux density BY constitutes a second magnetic flux density, and the magnetic flux density BZ constitutes a third magnetic flux density.

[0053] Each of the magnetic detection unit **43** and the magnetic detection unit **44** need only be able to detect the magnetic flux density including a component in the longitudinal direction X, the magnetic flux density including a component in the radial direction Y, and the magnetic flux density including a component in the circumferential direction Z, and three detection axis directions may not exactly match the longitudinal direction X, the radial direction Y, and the circumferential direction Z, respectively. In the magnetic sensor, in a case in which a first detection axis direction is different from the radial direction Y and the circumferential direction Z, a second detection axis direction is different from the longitudinal direction X and the circumferential direction Z, and a third detection axis direction is different from the radial direction Y and the longitudinal direction X, the magnetic sensor can detect the magnetic flux density including the component in the longitudinal direction X, can detect the magnetic flux density including the component in the radial direction Y, and can detect the magnetic flux density including the component in the circumferential direction Z.

[0054] FIG. **6** is a schematic diagram of the body part **42**A of the detection unit **40** illustrated in FIG. **5** as viewed from the direction x. As illustrated in FIG. **6**, the magnetic detection unit **43** and the magnetic detection unit **44** are disposed at positions facing each other with a center CP of the through-hole **41** interposed therebetween as viewed in the direction x. That is, in a state of being viewed in the direction x, a midpoint of a line segment LL connecting the magnetic detection unit **43** and the magnetic detection unit **44** substantially matches the center CP of the through-hole **41**. In other words, a distance from the magnetic detection unit **43** to the center CP of the through-hole **41** and a distance from the magnetic detection unit **44** to the center CP of the through-hole **41** substantially match each other.

[0055] FIG. **7** is a diagram illustrating an example of a position at which the insertion part **10** can be located in the through-hole **41**. A state ST**1** of FIG. **7** illustrates a state in which the insertion part **10** is most distant from the magnetic detection unit **43** in the radial direction Y in the through-hole **41**. A state ST**2** of FIG. **7** illustrates a state in which the insertion part **10** is most distant from the magnetic detection unit **44** in the radial direction Y in the through-hole **41**. A detection range and an installation position of each of the magnetic detection unit **43** and the magnetic detection unit **44** are determined such that the magnetic flux density can be detected with high accuracy from the magnetic pattern formed on the tubular member **17** in any of the state ST**1** and the state ST**2** of FIG. **7**.

[0056] In the present embodiment, as illustrated in FIG. **6**, a thickness of a portion of the inner wall portion **42***c*, the portion being at the same position as the center CP in the direction z, is a thickness r**1**. The thickness r**1** is 0.5 mm, for example. In a case in which the magnetic force of the magnetic pole region formed on the tubular member **17** is defined by the magnetic flux density detected at a position distant from an outer surface of the insertion part **10** in the radial direction of the insertion part **10** by 0.5 mm, it is preferable that the magnetic force has a value that is sufficiently larger than the geomagnetism and is equal to or larger than a value (specifically, 500 microtesla) suitable for the performance of a general magnetic sensor. In addition, for example, in the state ST**1** or the state ST**2** of FIG. **7**, it is more preferable that the magnetic force of the magnetic pole region formed on the tubular member **17** is in a range of 1000 microtesla to 1500 microtesla such that the magnetic detection unit **43** and the magnetic detection unit **44** can detect the magnetic flux density with high accuracy. However, it is preferable that an upper limit value of the magnetic force of the magnetic pole region formed on the tubular member **17** is equal to or less than 20 millitesla such that the insertion part **10** does not adhere to another metal. In consideration of the maximum sensitivity of the general magnetic sensor, it is more preferable that the upper limit value of the magnetic force of the magnetic pole region formed on the tubular member **17** is equal to or less than 2 millitesla.

[0057] As illustrated in FIG. **7**, the position of the insertion part **10** in the through-hole **41** can be changed. However, by obtaining the arithmetic mean of the magnetic flux density BX detected from the tubular member **17** by the magnetic detection unit **43** and the magnetic flux density BX detected from the tubular member **17** by the magnetic detection unit **44**, it is possible to detect the magnetic flux density BX according to the magnetic pattern regardless of the position of the insertion part **10** in the through-hole **41**. Similarly, by obtaining the arithmetic mean of the magnetic flux density BY detected from the tubular member **17** by the magnetic detection unit **43** and the magnetic flux density BY detected from the tubular member **17** by the magnetic detection unit **44**, it is possible to detect the magnetic flux density BY according to the magnetic pattern regardless of the position of the insertion part **10** in the through-hole **41**. Similarly, by obtaining the arithmetic mean of the magnetic flux density BZ detected from the tubular member **17** by the magnetic detection unit **43** and the magnetic flux density BZ detected from the tubular member **17** by the magnetic detection unit **44**, it is possible to detect the magnetic flux density BZ according to the magnetic pattern regardless of the position of the insertion part **10** in the through-hole **41**.

[0058] The communication chip **45** illustrated in FIG. **5** transmits information on the magnetic flux density detected by each of the magnetic detection unit **43** and the magnetic detection unit **44** to the expansion device **8** by wireless communication. In the present specification, the communication chip **45** constitutes an output unit that outputs the information detected by the magnetic detection unit **43** and the magnetic detection unit **44** to the outside. This information on the magnetic flux density may be transmitted to the processor device **4**, and in this case, this information is transmitted by the processor **4**P to the processor **8**P of the expansion device **8**.

[0059] The storage battery **46** is charged by the power received by the power receiving coil **47** by the noncontact power supply. The magnetic detection unit **43**, the magnetic detection unit **44**, and the communication chip **45** are operated by the power supplied from the storage battery **46**. The detection unit **40** has a start-up switch (not illustrated). By performing an operation to turn on the start-up switch, the power supply from the storage battery **46** to the magnetic detection unit **43**, the magnetic detection unit **44**, and the communication chip **45** is started. The detection unit **40** may have a configuration in which the start-up switch is not provided and the power supply to the magnetic detection unit **43**, the magnetic detection unit **44**, and the communication chip **45** is started by receiving wireless power supply from the outside. In a case in which the start-up switch is not provided, a structure in which the accommodation space of the housing **42** is completely sealed can be easily realized.

[0060] FIG. **8** is a schematic diagram illustrating an example of the magnetic flux density detected by the magnetic detection unit **43**. Since the magnetic flux density detected by the magnetic detection unit **44** is the same as that in FIG. **8**, the illustration is omitted. Two graphs illustrated in FIG. **8** illustrate the magnetic flux density BX and the magnetic flux density BY that are detected by the magnetic detection unit **43** in a case where the soft portion **10**A is moved in the longitudinal direction X1 through the through-hole **41**. In FIG. **8**, a magnetic flux line from the positive pole region **17**N to the negative pole region **17**S adjacent to the positive pole region **17**N in the longitudinal direction X is indicated by a broken line arrow.

[0061] In a case in which the soft portion 10A (tubular member 17) is moved toward the through-hole 41 of the detection unit 40 illustrated in the upper left of FIG. 8, as illustrated in the graph of FIG. 8, the magnetic flux density BX detected by the magnetic detection unit 43 has a positive value between each positive pole region 17N and the negative pole region 17S adjacent to the positive pole region 17N in the longitudinal direction X1, and has a negative value between each positive pole region 17N and the negative pole region 17S adjacent to the positive pole region 17N in the longitudinal direction X2. In addition, the magnetic flux density BY detected by the magnetic detection unit 43 has a negative value and a large absolute value in the vicinity of the negative pole region 17S, has a positive value and a large absolute value in the vicinity of the positive pole region 17N, and has a value close to zero in the vicinity of an intermediate position between the negative pole region 17S and the positive pole region 17N.

[0062] Regarding the magnetic flux densities detected from the magnetic pattern formed on the tubular member 17 at a plurality of positions in the longitudinal direction X of the tubular member 17, each of the magnetic flux density BX and the magnetic flux density BY is periodically changed with positive and negative values, and the phases of the magnetic flux density BX and the magnetic flux density BY are shifted from each other in the longitudinal direction X. In the negative pole region 17S, an end (portion of a position P1 in FIG. 8) in the longitudinal direction X where the absolute value of the magnetic flux density BY is the maximum value is hereinafter referred to as a negative pole end. In the positive pole region 17N, an end (portion of a position P2 in FIG. 8) in the longitudinal direction X where the absolute value of the magnetic flux density BY is the maximum value is hereinafter referred to as a positive pole end.

[0063] As an example, by magnetizing the tubular member 17 using the method described above by setting a length of the cylindrical coil of the magnetic field generation device 300 in the axial direction to 60 mm, an inner diameter of the cylindrical coil of the magnetic field generation device 300 to 18 mm, and a movement pitch of the cylindrical coil in the longitudinal direction X to 144 mm, it is possible to form the magnetic pattern in which a distance between the negative pole end and the positive pole end is 72 mm. In the example of FIG. 8, for example, by disposing the cylindrical coil between the negative pole region 17S at the left end and the positive pole region 17N adjacent to the right side of the negative pole region 17S to form the magnetic field, it is possible to form these two magnetic pole regions. Then, from that state, by relatively moving the cylindrical coil by 144 mm in the longitudinal direction X2 to form the magnetic field in that state, it is possible to form the positive pole region 17N at the right end and the negative pole region 17S adjacent to the left side of the positive pole region 17N. In this manner, it is possible to form the magnetic pattern in which the distance (distance between the position P1 and the position P2) between the positive pole end and the negative pole end which are alternately formed in the longitudinal direction X is 72 mm.

[0064] In the endoscope system 200, the processor 8P of the expansion device 8 acquires the information on the magnetic flux densities detected by the magnetic detection unit 43 and the magnetic detection unit 44, from the detection unit 40, and determines the movement state of the insertion part 10 in the longitudinal direction X on the basis of the acquired magnetic flux density BX and magnetic flux density BY. The movement state of the insertion part 10 determined here includes: a movement direction indicating in which direction in the longitudinal direction X the insertion part 10 is moved with respect to the detection unit 40; and a movement amount (movement distance) indicating how much distance the insertion part 10 inserted into the through-hole 41 of the detection unit 40 has moved in the longitudinal direction X with respect to the detection unit 40. The processor 8P obtains the arithmetic mean of the magnetic flux densities BX respectively detected at the same timing by the magnetic detection unit 43 and the magnetic detection unit 44, obtains the arithmetic mean of the magnetic flux densities BY respectively detected at the same timing by the magnetic detection unit 43 and the magnetic detection unit 44, and determines the movement state of the insertion part 10 on the basis of the magnetic flux density BX and the magnetic flux density BY obtained by these arithmetic means.

[0065] The processor 8P classifies the magnetic flux density BX into a plurality of pieces of information according to the magnitude thereof, classifies the magnetic flux density BY into a plurality of pieces of information according to the magnitude thereof, and determines the movement state of the insertion part 10 in the longitudinal direction X on the basis of a combination of any of the plurality of pieces of information obtained by classifying the magnetic flux density BX and any of the plurality of pieces of information obtained by classifying the magnetic flux density BY.

[0066] Specifically, the processor 8P sets a first threshold value th (for example, "0") as a threshold value for classifying the magnetic flux density BX into two levels, and sets a second threshold value th1 (positive value larger than 0) and a second threshold value th2 (negative value less than 0) as a threshold value for classifying the magnetic flux density BY into three levels. Moreover, the processor 8P classifies the magnetic flux density BX by setting a value larger than the first threshold value th as a high level H and setting a value less than the first threshold value th as a low level L. Further, the processor 8P classifies the magnetic flux density BY by setting a value larger than the second threshold value th1 as the high level H, setting a value between the second threshold value th1 and the second threshold value th2 as a middle level M, and setting a value less than the second threshold value th2 as the low level L. The result of classifying the magnetic flux density BX in this manner is also referred to as a classification level of the magnetic flux density BX, and the result of classifying the magnetic flux density BY in this manner is also referred to as a classification level of the magnetic flux density BY. In the present specification, among the classification levels of the magnetic flux density BX, the high level constitutes one of fourth information and fifth information, and the low level constitutes the other of the fourth information and the fifth information. In addition, among the classification levels of the magnetic flux density BY, the high level constitutes one of first information and second information, the low level constitutes the other of the first information and the second information, and the middle level constitutes third information.

[0067] In FIG. 9, the result (classification level) of classifying the magnetic flux density BX and the magnetic flux density BY in the graphs illustrated in FIG. 8 is indicated by a thick solid line. As illustrated in FIG. **9**, in the tubular member **17**, a range between two adjacent positions P**1** (between the negative pole ends) is divided into: a region R**1** in which the magnetic flux density BX is at the high level and the magnetic flux density BY is at the low level; a region R**2** in which the magnetic flux density BX is at the high level and the magnetic flux density BY is at the middle level; a region R**3** in which the magnetic flux density BX is at the high level and the magnetic flux density BY is at the high level; a region R**4** in which the magnetic flux density BX is at the low level and the magnetic flux density BY is at the high level; a region R**5** in which the magnetic flux density BX is at the low level and the magnetic flux density BY is at the middle level; and a region R**6** in which the magnetic flux density BX is at the low level and the magnetic flux density BY is at the low level. As described above, the range between the negative pole ends adjacent to each other in the longitudinal direction X can be divided into six regions R**1** to R**6** depending on the combination of the classification level of the magnetic flux density BX and the classification level of the magnetic flux density BY.

[0068] By monitoring the thick solid lines (classification levels of the magnetic flux densities BX and BY) illustrated in FIG. **9**, the processor **8**P determines the movement direction of the insertion part **10** with respect to the detection unit **40**, and the movement amount (movement distance) of the insertion part **10** in the longitudinal direction X starting from the position of the detection unit **40**.

[0069] For example, in a case in which the negative pole region **17**S provided on the most distal end side of the tubular member **17** passes through the through-hole **41**, the processor **8**P detects that the region R**1** at the most distal end of the tubular member **17** is located in the through-hole **41**, from the combination of the classification level of the magnetic flux density BX and the classification level of the magnetic flux density BY, and detects the position as a reference position. The distance (referred to as a distance Li) in the longitudinal direction X from the negative pole region **17**S provided on the most distal end side of the tubular member **17** to the distal end of the distal end part **10**C is known. Therefore, in a case in which this reference position is detected, the processor **8**P determines that the movement distance of the insertion part **10** with respect to the detection unit **40** is "0", and further determines that an insertion length (distance from the reference position (through-hole **41**) to the distal end of the insertion part **10**) of the insertion part **10** into the body of the subject **50** is the distance Li.

[0070] After the reference position is detected, in a case in which it is determined that the region of the tubular member **17** passing through the through-hole **41** is being changed in a direction from the region R**1** to the region R**6** according to the classification levels of the magnetic flux densities BX and BY, the processor **8**P determines that the insertion part **10** is being moved in the longitudinal direction X**1**. In addition, in a case in which it is determined that the insertion part **10** is being moved in the longitudinal direction X**1**, the processor **8**P increases the movement distance of the insertion part **10** in the longitudinal direction X**1** by a unit distance ΔL and increases the insertion length of the insertion part **10** into the body of the subject **50** by the unit distance ΔL, each time the region of the tubular member **17** passing through the through-hole **41** is changed by one (for example, a change from the region R**1** to the region R**2** or a change from the region R**2** to the region R**3**). The unit distance ΔL can be a value obtained by dividing an interval between the adjacent negative pole regions **17**S by **6**.

[0071] On the other hand, in a case in which it is determined that the region of the tubular member **17** passing through the through-hole **41** is being changed in a direction from the region R**6** to the region R**1** according to the classification levels of the magnetic flux densities BX and BY, the processor **8**P determines that the insertion part **10** is being moved in the longitudinal direction X**2**. In addition, in a case in which it is determined that the insertion part **10** is being moved in the longitudinal direction X**2**, the processor **8**P decreases the movement distance of the insertion part **10** in the longitudinal direction X**1** by a unit distance ΔL and decreases the insertion length of the insertion part **10** into the body of the subject **50** by the unit distance ΔL, each time the region of the tubular member **17** passing through the through-hole **41** is changed by one.

[0072] Depending on the movement speed of the insertion part **10**, it can also be determined that the region of the tubular member **17** passing through the through-hole **41** is changed from the region R**1** to the region R**3** or is changed from the region R**3** to the region R**1**. In a case in which it is determined that the region of the tubular member **17** passing through the through-hole **41** is changed by two in this manner, the processor **8**P need only increase or decrease the insertion length of the insertion part **10** by twice the unit distance ΔL.

[0073] The processor **8**P displays the information on the insertion length determined in this manner on the display device **7**, outputs the information by voice from a speaker (not illustrated), or transmits the information to an operator of the endoscope **1** by vibration of a vibrator provided in the operating part **11**. As a result, it is possible to accurately record an imaging position by the endoscope **1**, guide or evaluate the operation of the endoscope **1**, and the like.

[0074] As described above, by demagnetizing the distal end part **10**C and the bendable part **10**B in the insertion part **10**, the processor **8**P can easily detect the reference position. Specifically, in a case in which the insertion part **10** is inserted into the through-hole **41** from the distal end side and is moved in the longitudinal direction X**1**, both the magnetic flux density BX and the magnetic flux density BY are values in the vicinity of "0" while the distal end part **10**C and the bendable part **10**B pass through the through-hole **41**. Further, at a point in time at which the negative pole region **17**S on the most distal end side of the tubular member **17** reaches the through-hole **41**, the magnetic flux density BX and the magnetic flux density BY are a combination of the high level and the low level as illustrated in FIG. **9**, and therefore, it is possible to easily detect the reference position by the fluctuation of the magnetic flux density.

[0075] As described above, the processor **8**P classifies the magnetic flux density BX into two of the high level and the low level, classifies the magnetic flux density BY into three of the high level, the middle level, and the low level, and determines the movement state of the insertion part **10** in the longitudinal direction X on the basis of the combination thereof. In this way, by monitoring the change in the combination of the classification level of the magnetic flux density BX and the classification level of the magnetic flux density BY, the movement direction, the movement distance, and the insertion length of the insertion part **10** can be determined. With the endoscope system **200**, such an effect can be realized only by magnetizing the endoscope **1** having a general-purpose configuration and adding the detection unit **40**, so that a construction cost of the system can be reduced. In addition, since the movement direction, the movement distance, and the insertion length of the insertion part **10** are determined on the basis of the information on the magnetic flux density that can be acquired non-optically, even in a case in which the insertion part **10** is dirty, the determination accuracy is not reduced, and thus it is practical.

[0076] In addition, by using the combination of the classification level of the magnetic flux density BX and the classification level of the magnetic flux density BY, it is possible to determine the movement distance of the insertion part **10** with a resolution (for example, a unit of ⅓ of the interval) finer than the interval between the two types of adjacent magnetic pole regions (negative pole region **17**S and positive pole region **17**N). In this way, the movement distance can be finely determined, which can be useful for accurate recording of the imaging position by the endoscope **1**, guide or evaluation of the operation of the endoscope **1**, and the like.

[0077] In addition, the processor **8**P obtains the arithmetic mean of the magnetic flux density detected by the magnetic detection unit **43** and the magnetic flux density detected by the magnetic detection unit **44**, and determines the movement direction, the movement distance, and the insertion length of the insertion part **10** on the basis of the magnetic flux density of the arithmetic mean. Therefore, it is possible to obtain the change in the magnetic flux density according to the magnetic pattern regardless of the position of the insertion part **10** in the through-hole **41**. In addition, the magnetic flux densities detected by the magnetic detection unit **43** and the magnetic detection unit **44** can include a disturbance component caused by geomagnetism, a magnetic field generated by a steel frame of a building, a magnetic field generated by the steel furniture, and the like, in addition to a magnetic field generated by magnetization. However, as described above, by obtaining the arithmetic mean of the magnetic flux densities detected by the two magnetic detection units, it is possible to reduce an influence of the disturbance component.

[0078] In a case in which a difference between the inner diameter of the through-hole **41** and the outer diameter of the insertion part **10** is made as small as possible, any one of the magnetic detection unit **43** or the magnetic detection unit **44** provided in the detection unit **40** is not essential and can be omitted. In this case, the processor **8**P need only determine the movement direction, the movement distance, and the insertion length of the insertion part **10** on the basis of the magnetic flux densities BX and BY detected by the magnetic detection unit **43** or the magnetic detection unit **44**.

[0079] In addition, in the present embodiment, each of the negative pole region **17**S and the positive pole region **17**N formed on the tubular member **17** is formed in an annular shape along the outer periphery of the tubular member **17**. Therefore, even in a case in which the insertion part **10** is rotated in the circumferential direction thereof in the through-hole **41**, it is possible to substantially eliminate the change in the magnetic flux densities detected by the magnetic detection unit **43** and the magnetic detection unit **44**. Therefore, the movement direction, the movement distance, and the insertion length of the insertion part **10** can be determined regardless of the posture of the insertion part **10**.

[0080] The disturbance component can be included in the magnetic flux densities detected by the magnetic detection unit **43** and the magnetic detection unit **44**. In addition, the orientation of the disturbance component is also changed depending on the posture of the detection unit **40**. Therefore, the influence of the disturbance component can be eliminated by classifying the magnetic flux density BX into two of the high level and the low level, classifying the magnetic flux density BY into three of the high level, the middle level, and the low level, and determining the movement state of the insertion part **10** in the longitudinal direction X on the basis of the combination of the classification levels as described above, rather than determining the movement state of the insertion part **10** in the longitudinal direction X using raw data of the magnetic flux density BX and the magnetic flux density BY as they are.

[0081] In the above description, the processor **8**P classifies the magnetic flux density BX into two of the high level and the low level, classifies the magnetic flux density BY into three of the high level, the middle level, and the low level, and determines the movement state of the insertion part **10** in the longitudinal direction X on the basis of the combination of the classification levels. As a modification example, the processor **8**P may classify the magnetic flux density BX into two of the high level and the low level, may classify the magnetic flux density BY into two of the high level and the low level, and may determine the movement state of the insertion part **10** in the longitudinal direction X on the basis of the combination of the classification levels.

[0082] Specifically, the processor **8**P sets the "first threshold value th (for example, 0)" as the threshold value for classifying the magnetic flux density BX into two levels, and sets a "second threshold value th**3** (for example, 0)" as the threshold value for classifying the magnetic flux density BY into two levels. Moreover, the processor **8**P classifies the magnetic flux density BX by setting a value larger than the first threshold value th as the high level and setting a value less than the first threshold value th as the low level. Further, the processor **8**P classifies the magnetic flux density BY by setting a value larger than the second threshold value th**3** as the high level and setting a value less than the second threshold value th**3** as the low level.

[0083] In FIG. **10**, the result (classification level) of classifying the magnetic flux density BX and the magnetic flux density BY in the graphs illustrated in FIG. **8** is indicated by a thick solid line. As illustrated in FIG. **10**, in the tubular member **17**, a range between two adjacent positions P**1** is divided into a region R**1** in which the magnetic flux density BX is at the high level and the magnetic flux density BY is at the low level, a region R**2** in which the magnetic flux density BX is at the high level and the magnetic flux density BY is at the high level, a region R**3** in which the magnetic flux density BX is at the low level and the magnetic flux density BY is at the high level, and a region R**4** in which the magnetic flux density BX is at the low level and the magnetic flux density BY is at the low level. As described above, the range between the negative pole ends adjacent to each other in the longitudinal direction X can be divided into four regions R**1** to R**4** depending on the combination of the classification level of the magnetic flux density BX and the classification level of the magnetic flux density BY. By monitoring the thick solid lines (classification levels of the magnetic flux densities BX and BY) illustrated in FIG. **10**, the processor **8**P can determine the movement direction of the insertion part **10** and the movement amount (movement distance) of the insertion part **10** in the longitudinal direction X.

[0084] In the description above, the processor **8**P classifies the magnetic flux density into the plurality of pieces of information according to the magnitude thereof. However, a configuration may be adopted in which this classification is performed by a processor provided in the communication chip of the detection unit **40**. That is, a configuration may be adopted in which the detection unit **40** transmits information on the classification level indicated by the thick solid line illustrated in FIG. **9** or FIG. **10** to the processor **8**P. In addition, the processor **8**P performs the determination of the movement state of the insertion part **10**, but a configuration may be adopted in which the processor provided in the communication chip of the detection unit **40** performs the determination to transmit the determination result to the processor **8**P. Further, a configuration may be adopted in which a processor such as a personal computer connected to the expansion device **8** via a network acquires the information on the magnetic flux density from the detection unit **40**, performs the determination, and transmits the determination result to the processor **8**P. Also, a processor separate from the processor **8**P may perform the determination of the movement state of the insertion part **10**. Further, a configuration may be adopted in which a processor provided outside the endoscope device **100** performs the determination of the movement state of the insertion part **10** to transmit the determination result to the processor **8**P.

[0085] The threshold value used in a case of classifying each of the magnetic flux density BX and the magnetic flux density BY according to the magnitude thereof may be a predetermined fixed value, but the threshold value is preferably a variable value to be determined on the basis of the magnetic flux densities detected by the magnetic detection unit **43** and the magnetic detection unit **44** after the insertion of the insertion part **10** into the through-hole **41** is started.

[0086] For example, in a case in which the start-up switch of the detection unit **40** is turned on, the insertion part **10** is inserted into the through-hole **41**, and the third magnetic pole region from the most distal end side of the tubular member **17** passes through the through-hole **41**, the processor **8**P can acquire each of the maximum value and the minimum value of the magnetic flux density BX detected by the magnetic detection unit **43**, and the maximum value and the minimum value of the magnetic flux density BY detected by the magnetic detection unit **43**. In a case where the maximum value and the minimum value of the magnetic flux density BX are acquired, the processor **8**P obtains an average value of the maximum value and the minimum value, and sets the average value as the first threshold value th. Further, in a case in which the maximum value and the minimum value of the magnetic flux density BY are acquired, the processor **8**P obtains an average value of the maximum value and the minimum value, sets a value obtained by adding a predetermined value to the average value as the second threshold value th**1**, and sets a value obtained by subtracting a predetermined value from the average value as the second threshold value th**2**. The predetermined value is a value that is larger than a value assumed as the disturbance component and is less than the absolute value of each of the maximum value and the minimum value of the magnetic flux density BY. The first to third magnetic pole regions from the most distal end side of the tubular member **17** constitute a base end part on the demagnetized region (adjacent region) side in the region in which the magnetic pattern is formed.

[0087] Hereinafter, the processor **8**P need only classify the magnetic flux density BX and the magnetic flux density BY by using the threshold values set in this manner. In this way, it is possible to perform the determination of the movement state of the insertion part **10** with higher accuracy by setting the threshold values on the basis of the magnetic flux densities detected by the magnetic detection unit **43** and the magnetic detection unit **44**.

[0088] In this way, in a case in which the threshold value is set on the basis of the magnetic flux densities detected by the magnetic detection unit **43** and the magnetic detection unit **44**, it is preferable that, in a period until the third magnetic pole region from the most distal end side of the tubular member **17** passes through the through-hole **41**, the processor **8**P sets the first threshold value th, the second threshold value th**1**, and the second threshold value th**2** to the predetermined values, performs the detection of the reference position and the determination of the movement state of the insertion part **10**, and then updates the first threshold value th, the second threshold value th**1**, and the second threshold value th**2** by the method described above to perform the determination of the movement state of the insertion part **10**.

[0089] As described above, in the endoscope system **200**, the magnetic pattern is formed on the tubular member **17** such that the magnetic flux densities BX and BY detected by each of the magnetic detection unit **43** and the magnetic detection unit **44** are changed periodically between the positive side and the negative side and phases thereof are shifted in a case in which the insertion part **10** passes through the through-hole **41**, so that it is possible to perform the determination of the movement state of the insertion part **10**. Such a magnetic pattern is not limited to the configurations of the magnetic pole portions MA**1** and MA**2** illustrated in FIGS. **3** and **4**, and can be variously modified.

[0090] FIG. **11** is a schematic cross-sectional view illustrating a modification example of the magnetic pole portions MA**1** and MA**2** illustrated in FIG. **3** taken along the A-A arrow and the B-B arrow. In the modification example illustrated in FIG. **11**, the magnetic pole portion MA**1** has a configuration in which the negative pole region **17**S and the positive pole region **17**N are formed alternately with an interval therebetween along the circumferential direction of the tubular member **17**. Similarly, the magnetic pole portion MA**2** has a configuration in which the negative pole region **17**S and the positive pole region **17**N are formed alternately with an interval therebetween along the circumferential direction of the tubular member **17**. The magnetic pole portion MA**2** has a configuration in which the magnetic pole portion MA**1** is rotated by 90 degrees around an axis center of the tubular member **17**.

[0091] As illustrated in FIG. **11**, in a state of being viewed in the longitudinal direction X, the positive pole region **17**N in the magnetic pole portion MA**1** and the negative pole region **17**S in the magnetic pole portion MA**2** are present at the same position in the circumferential direction of the tubular member **17**. That is, in the tubular member **17**, all the magnetic pole regions at the same position in the circumferential direction have a configuration in which the negative pole region **17**S and the positive pole region **17**N are alternately arranged in the longitudinal direction X. That is, in the tubular member **17**, a first magnetic pattern in which the negative pole region **17**S and the positive pole region **17**N are alternately arranged along the longitudinal direction X with the negative pole region **17**S at the beginning, and a second magnetic pattern in which the negative pole region **17**S and the positive pole region **17**N are alternately arranged along the longitudinal direction X with the positive pole region **17**N at the beginning are alternately arranged with an interval therebetween in the circumferential direction of the tubular member **17**.

[0092] FIG. **12** is a diagram schematically illustrating a magnetic flux line generated in the magnetic pole portion MA**1** having the configuration illustrated in FIG. **11**. FIG. **12** illustrates the positions of the magnetic detection units **43** and **44** with respect to the soft portion **10**A in a case in which the soft portion **10**A passes through the through-hole **41**.

[0093] In a state illustrated in FIG. **12**, the magnetic flux density BY detected by the magnetic detection unit **43** has a large negative value. In a case in which the soft portion **10**A is rotated by 45 degrees counterclockwise from the state illustrated in FIG. **12**, the magnetic flux density BY detected by the magnetic detection unit **43** has a value close to zero. In a case in which the soft portion **10**A is rotated by 90 degrees counterclockwise from the state illustrated in FIG. **12**, the magnetic flux density BY detected by the magnetic detection unit **43** has a large positive value. In a case in which the soft portion **10**A is rotated by 135 degrees counterclockwise from the state illustrated in FIG. **12**, the magnetic flux density BY detected by the magnetic detection unit **43** has a value close to zero. In a case in which the soft portion **10**A is rotated by 180 degrees counterclockwise from the state illustrated in FIG. **12**, the magnetic flux density BY detected by the magnetic detection unit **43** has a large negative value. In a case in which the soft portion **10**A is rotated in the circumferential direction thereof in the through-hole **41** in this manner, the magnetic flux density BY detected by the magnetic detection unit **43** is equivalent to the magnetic flux density BY illustrated in FIG. **8**. Similarly, in a case in which the soft portion **10**A is rotated in the circumferential direction thereof in the through-hole **41**, the magnetic flux density BZ detected by the magnetic detection unit **43** is equivalent to the magnetic flux density BY illustrated in FIG. **8** and has a phase shifted by 90 degrees. Therefore, in a case in which the magnetic flux densities BY and BZ detected by the magnetic detection unit **43** are classified into the high level and the low level, respectively, these classification levels are equivalent to the thick solid lines of the magnetic flux density BY illustrated in FIG. **10** (it should be noted that the phases of the magnetic flux density BY and the magnetic flux density BZ are shifted by 90 degrees). Therefore, it is possible to derive a rotation direction and a rotation amount of the insertion part **10** by the combination of the classification levels.

[0094] In a case in which the endoscope **1** having the magnetic pattern having such a configuration is used, the processor **8**P can determine a rotation state (rotation direction and rotation amount (rotation angle)) of the insertion part **10** in the circumferential direction in the same manner as the determination method of the movement state of the insertion part **10**, by classifying each of the magnetic flux density BZ and the magnetic flux density BY into the plurality of pieces of information and monitoring the change in the combination of these pieces of information. In the configuration illustrated in FIG. **11**, since the first magnetic pattern and the second magnetic pattern extending in the longitudinal direction X are formed on the tubular member **17**, it is possible to determine the movement state of the insertion part **10** on the basis of the magnetic flux density BX and the magnetic flux density BY, as described above. In FIG. **11**, each of the magnetic pole portions MA**1** and the magnetic pole portions MA**2** includes four magnetic pole regions arranged in the circumferential direction. However, each of the magnetic pole portion MA**1** and the magnetic pole portion MA**2** may have a configuration of including two magnetic pole regions, or have a configuration of including an even number (six or more) of magnetic pole regions.

[0095] Even in the configuration illustrated in FIG. **11**, it is preferable that the arithmetic means of the magnetic flux densities BY and BZ detected by the magnetic detection unit **43** and the magnetic flux densities BY and BZ detected by the magnetic detection unit **44** are obtained, each of the values of these two arithmetic means is classified into the high level and the low level, and the rotation direction and the rotation amount of the insertion part **10** are derived by the combination of the classification levels.

<Processing of Processor **8**P>

[0096] Next, details of various kinds of processing executed by the processor **8**P will be described. In order to describe these various kinds of processing, the movement path of the insertion part **10** of the endoscope **1** will be described. FIG. **13** is a schematic diagram illustrating the movement path of the insertion part **10** in an examination (hereinafter, referred to as endoscopy) performed using the endoscope **1**.

[0097] The endoscopy includes an endoscopy that examines an upper digestive organ such as a stomach, an endoscopy that examines a lower digestive organ such as a large intestine. In addition, the endoscopy includes a first examination in which the insertion part **10** is inserted into the subject in order to examine whether or not a lesion region is present in the subject, and a second examination in which the insertion part **10** is inserted into the subject in order to excise the already known lesion region.

(Movement Path of Endoscope)

[0098] FIG. **13** illustrates a large intestine **51** of the subject (subject **50**). In the endoscopy of the large intestine, the insertion part **10** is moved along a movement path **10**X indicated by the broken line in the drawing. The movement path **10**X is a tubular path from the through-hole **41** of the detection unit **40** disposed in the vicinity of the anus **50**A outside the subject through the anus **50**A to a rectum **53**, and further from the rectum **53** through a sigmoid colon **54**, a descending colon **55**, a transverse colon **56**, and an ascending colon **57** to an ileocecum **58**.

[0099] In the endoscopy and the first examination of the large intestine, the operator of the endoscope **1** inserts the insertion part **10** into the anus **50**A through the through-hole **41**, causes the insertion part **10** to reach the ileocecum **58** which is a turnaround point of the examination, and then pulls out the insertion part **10** from the ileocecum **58** toward the outside of the subject. Hereinafter, a step of moving the distal end of the insertion part **10** from the through-hole **41** to the ileocecum **58** will be described as an insertion step, and a step of moving the distal end of the insertion part **10**

from the ileocecum **58** to the through-hole **41** will be referred to as a pulling-out step. The first examination is composed of a set of the insertion step and the pulling-out step. The endoscopy and the second examination of the large intestine are the same as the first examination except that the turnaround point of the examination is changed to the presence position of the lesion region found in the first examination in advance.

[0100] In the endoscopy of the stomach, the turnaround point of the first examination is the duodenum, and the turnaround point of the second examination is the presence position of the lesion region found in the first examination in advance.

(Processing During Endoscopy)

[0101] In a case where the endoscopy is started, the power of the detection unit **40** is turned on. As described above, the processor **8**P derives a first distance (the insertion length described above) from the reference position (position of the through-hole **41**) on the movement path **10**X to the distal end of the insertion part **10** on the basis of the magnetic flux densities BX and BY detected by the detection unit **40**.

(Determination of Reaching Site)

[0102] In a case in which the endoscope **1** is activated, the processor **8**P performs reaching site determination processing of sequentially acquiring the captured images captured by the endoscope **1**, and determining the site (the anus, the rectum, the sigmoid colon, the top part of the sigmoid colon (S-top), the transition part between the sigmoid colon and the descending colon (SDJ), the descending colon, the splenic flexure, the transverse colon, the hepatic curvature, the ascending colon, the ileocecum, or the outside of the body and the like) in the subject that the distal end of the insertion part **10** has reached on the basis of the acquired captured images and the derived first distance. The processor **8**P performs the reaching site determination processing using, for example, a recognition model (machine learning model) generated by machine learning, and the first distance.

(First Determination Example of Reaching Site)

[0103] FIG. **14** is a schematic diagram for describing a first determination example of a reaching site. FIG. **14** illustrates a recognition model **81**. The recognition model **81** comprises an input layer, at least one intermediate layer (two intermediate layers, a first intermediate layer and a second intermediate layer in the example illustrated in FIG. **14**), and an output layer, and a fully connected layer that connects these layers. The recognition model **81** is generated by being trained, for example, using a set of a captured image of a specific site acquired in a past endoscopy and an image based on a first distance in a case of reaching the specific site acquired in the past endoscopy (hereinafter, also referred to as a distance image) as training data, to output answer data indicating that the reaching site is the specific site. The combination of the training data and the answer data is prepared for each site in the subject, and learning is performed for each site.

[0104] As the first distance that is a source of the distance image used for the training data, a value measured by the endoscope device **100** (for example, a measured value of the first distance in a case where the operator determines that the endoscope device **100** has reached a specific site) may be used, or a value statistically determined from anatomical knowledge (for example, information indicating that the ileocecum is at a distance of several cm from the position of the detection unit **40**) may be used. The distance image is, for example, an image obtained by converting the first distance into an image of characters or the like, or an image obtained by converting a reaching site in the subject, which is statistically determined from the first distance, into an image of characters or the like.

[0105] In a case where the endoscope **1** is activated, the processor **8**P sequentially acquires the captured image obtained by imaging with the endoscope **1**, and inputs the acquired captured image and the image based on the derived first distance to the recognition model **81**. The recognition model **81** that has received this input outputs a recognition result (the recognition site and the correct answer rate thereof) of the reaching site. In a case where the correct answer rate is equal to or greater than the threshold value, the processor **8**P determines that the site in the subject reached by the distal end of the insertion part **10** is the recognition site included in the recognition result.

(Second Determination Example of Reaching Site)

[0106] FIG. **15** is a schematic diagram for describing a second determination example of a reaching site. The recognition model **82** illustrated in FIG. **15** is generated by learning a combination of the training data and the answer data in the same manner as the recognition model **81**, but is different from the recognition model **81** in that an input destination of the distance image as the training data is the second intermediate layer instead of the input layer. In the recognition model **82**, the first intermediate layer extracts, for example, a feature amount from the captured image of the training data. The recognition model **82** is trained by the feature amount and the distance image being input to the second intermediate layer as training data. The combination of the training data and the answer data is prepared for each site in the subject, and learning is performed for each site.

[0107] In a case where the endoscope **1** is activated, the processor **8**P sequentially acquires the captured image obtained by imaging with the endoscope **1**, inputs the acquired captured image to the input layer of the recognition model **82**, and inputs the image based on the derived first distance to the second intermediate layer of the recognition model **82**. The recognition model **82** that has received this input outputs a recognition result (the recognition site and the correct answer rate thereof) of the reaching site. In a case where the correct answer rate is equal to or greater than the threshold value, the processor **8**P determines that the site in the subject reached by the distal end of the insertion part **10** is the recognition site included in the recognition result.

(Third Determination Example of Reaching Site)

[0108] FIG. **16** is a schematic diagram for describing a third determination example of a reaching site. The recognition model **83** illustrated in the FIG. **16** comprises an input layer, at least one intermediate layer (two intermediate layers, a first intermediate layer and a second intermediate layer in the example illustrated in FIG. **16**), and an output layer, and a fully connected layer that connects these layers. The recognition model **83** is generated by being trained, for example, using a captured image of a specific site acquired in a past endoscopy as training data, to output answer data indicating that the reaching site is the specific site. The combination of the training data and the answer data is prepared for each site in the subject, and learning is performed for each site.

[0109] The determination unit **83**A illustrated in FIG. **16** is a functional block of the processor **8**P. The determination unit **83**A acquires the recognition result (the recognition site and the correct answer rate thereof) by the recognition model **83**, and determines where the reaching site is based on the recognition result and the first distance derived in a state in which the recognition result is obtained. For example, in a case where information on a reaching site corresponding to the first distance is acquired from table data in which a correspondence relationship between the first distance and the reaching site is statistically obtained, and the information and the recognition site included in the recognition result match and the correct answer rate included in the recognition result is equal to or higher than a threshold value, it is determined that the site in the subject reached by the distal end of the insertion part **10** is the recognition site included in the recognition result.

[0110] The processor **8**P may perform the reaching site determination processing only in a case where a predetermined condition is satisfied, instead of sequentially performing the reaching site determination processing after the endoscope **1** is activated. The predetermined condition is, for example, that a specific recognition result is obtained by the recognition processing related to the endoscopy (the lesion recognition processing, the treatment tool recognition processing, or the like described above), that a recording instruction of the captured image is given, and the like.

[0111] For example, in a case where the lesion region is detected based on the captured image, the processor **8**P performs the above-described reaching site determination processing based on the captured image and the first distance derived at that time to determine where the site in the subject in which the lesion region is detected is. In addition, for example, in a case where the treatment tool is detected based on the captured image, the processor **8**P performs the above-described reaching site determination processing based on the captured image and the first distance derived at that time to determine which site in the subject has been treated. In this case, it is preferable that the processor **8**P stores the result of the lesion recognition processing or the treatment tool recognition processing (the result of detecting the lesion region or the result of performing the treatment), the reaching site determined by the reaching site determination processing, and the first distance used in the reaching site determination processing in the memory in association with each other. In this way, it is possible to check the position of the lesion region or the position where the treatment is performed after the examination.

(Modification Example of Recognition Model)

[0112] The training data used for each of the generation of the recognition model **81** and the recognition model **82** may be a set of a plurality of captured images (a plurality of captured images arranged in time series) continuously obtained for a predetermined period of time in a case where a specific site is reached in a past endoscopy, and an image based on each of a plurality of first distances (a plurality of first distances arranged in time series) continuously derived for a predetermined period of time in a case where the specific site is reached, instead of a set of single captured image and single distance image. The training data used for generating the recognition model **83** may be a plurality of captured images continuously obtained for a predetermined period of time (a plurality of captured images arranged in time series) instead of a single captured image. In such a case, in the example of FIGS. **14** and **15**, the processor **8**P may input, for example, after the endoscope **1** is activated, the captured image acquired at the first timing, the captured image acquired at the second timing after the first timing, the image based on the first distance derived at the first timing, and the image based on the first distance acquired at the second timing, to the recognition model, and may determine the reaching site based on the output of the recognition model.

[0113] The training data used for generating each of the recognition model **81** and the recognition model **82** may further include a change amount per unit time of the first distance (in other words, the movement speed of the endoscope **1**).

[0114] For example, the recognition model **81** may be generated by being trained using a set of the captured image of the specific site acquired in the past endoscopy, the image based on the first distance in a case of reaching the specific site acquired in the past endoscopy, and the change amount per unit time of the first distance derived in a case of reaching the specific site in the past endoscopy as training data, to output the answer data indicating that the reaching site is the specific site. In such a case, for example, after the endoscope **1** is activated, the processor **8**P may input the captured image acquired at the first timing, the captured image acquired at the second timing after the first timing, the image based on the first distance derived at the first timing, the image based on the first distance acquired at the second timing, and the change amount in the first distance in the time from the second timing to the first timing, to the recognition model **81**, and determine the reaching site based on the output of the recognition model.

[0115] In the insertion step, the movement speed of the endoscope **1** may greatly change depending on the reaching site. By learning this movement speed and recognizing the reaching site, it is possible to improve the recognition accuracy. In a case where the distal end of the endoscope **1** has reached the ileocecum, the endoscope **1** is sufficiently inserted to the inside, and thus the movement speed of the endoscope **1** tends to decrease. Therefore, by considering the movement speed, it is possible to recognize that the reaching site is the ileocecum with high accuracy. For example, in a case where it is estimated that the reaching site is the ileocecum from the captured image, it is estimated that the reaching site is the ileocecum from the first distance, and it is further estimated that the reaching site is the vicinity of the ileocecum from the movement speed, the determination result that the reaching site is the ileocecum can be output.

[0116] The processor **8**P can also determine, for example, whether any of the insertion step or the pulling-out step is performed by using the result of the reaching site determination processing. As an example, the processor **8**P determines a period after the determination result that the reaching site is the anus **50**A or the rectum **53** is obtained until the determination result that the reaching site is the ileocecum **58** is obtained, as a period (first period) of the insertion step in which the endoscope **1** is moved from a starting point toward an ending point of the movement path **10**X, and determines a period after the determination result that the reaching site is the ileocecum **58** is obtained until the determination result that the reaching site is the outside of the subject is obtained, as a period (second period) of the pulling-out step in which the endoscope **1** is moved from the ending point toward the starting point of the movement path lox.

[0117] The processor **8**P can determine the movement direction of the insertion part **10** on the movement path **10**X on the basis of a time change of the first distance derived on the basis of the magnetic flux densities BX and BY detected by the detection unit **40**, and can discriminate the period of the insertion step and the period of the pulling-out step from the movement direction. For example, in a case where the first distance tends to be increased, the processor **8**P determines that the insertion part **10** is being moved in a direction from the outside of the body of the subject toward the ileocecum **58**, and determines the period of the insertion step (first period). On the other hand, in a case where the first distance tends to be decreased, the processor **8**P determines that the insertion part **10** is being moved from the ileocecum **58** toward the outside of the body of the subject, and determines the period of the pulling-out step (second period).

[0118] The recognition model **83** described above is generated by machine learning, but a method of recognizing a site by general image processing may be employed.

(Detection of Event)

[0119] The processor **8**P can detect the occurrence of various events related to the endoscopy by using, for example, the result of the above-described reaching site determination processing and the result of the above-described lesion recognition processing and treatment tool recognition processing to acquire event information which is information on the event.

[0120] For example, the processor **8**P can detect an event that the insertion step is started, an event that the pulling-out step is started, an event that the endoscopy is ended, an event that the distal end of the endoscope **1** reaches a specific site in the subject, an event that a specific operation (for example, operation of the treatment tool) of the endoscope **1** is performed, an event that the lesion region is detected from the subject, or the like.

[0121] Specifically, in a case where the determination result that the reaching site is the anus **50**A is obtained by the reaching site determination processing, the processor **8**P detects the occurrence of the event that the endoscopy is started (insertion step is started) (examination start event). In a case where, after the examination start event is detected, the recognition result that the reaching site is the ileocecum **58** is obtained by the reaching site determination processing, the processor **8**P detects the occurrence of the event that the pulling-out step is started (pulling-out start event). In a case where, after the pulling-out start event, the recognition result that the reaching site is not inside the subject is obtained, the processor **8**P detects the occurrence of the event that the endoscopy is ended (examination end event).

[0122] In a case where the lesion region is detected by the lesion recognition processing, the processor **8**P detects the occurrence of the event that the lesion region is detected (lesion detection event). In a case where the treatment tool is detected by the treatment tool recognition processing, the processor **8**P detects the occurrence of the event that the treatment (operation of the treatment tool) is performed (treatment event). In a case where the determination result that a predetermined specific site is reached is obtained by the reaching site determination processing, the processor **8**P detects the event that the distal end of the insertion part **10** reaches the specific site (specific site reaching event).

(Derivation of Second Distance)

[0123] The processor **8**P may derive a second distance, which is a distance of the distal end of the insertion part **10** from the predetermined site in the subject, based on the result of the above-described reaching site determination processing and the first distance derived based on the magnetic flux densities BX and BY.

[0124] First, in a case where the endoscopy of the large intestine is started, in the initial stage of the insertion step, the processor **8**P obtains the determination result that the reaching site of the distal end of the insertion part **10** is the anus **50**A or the rectum **53**. In a case where such a determination result is obtained, the processor **8**P sets the first distance derived in a state in which the determination result is obtained as the first correction value. Then, after the determination result is obtained, the processor **8**P performs processing of subtracting the first correction value from the first distance derived based on the magnetic flux densities BX and BY to obtain the specific insertion length (a distance from the reference position to the distal end of the insertion part **10** in a case where the anus **50**A or the rectum **53** on the starting point side of the movement path **10**X is used as the reference position). By this processing, in the insertion step, the second distance in a case where the anus **50**A or the rectum **53** is the predetermined site (first predetermined site) is sequentially derived as the specific insertion length. For example, as illustrated in FIG. **13**, a case is assumed in which the determination result that the reaching site is the rectum **53** in a state where the distal end of the insertion part **10** reaches a position PO**1** is obtained. In this case, in a case where the distal end of the insertion part **10** slightly advances from the rectum **53** to be moved to a position PO**2**, a value (=D2) obtained by subtracting the first distance (=D0, first correction value) derived in a state where the distal end of the insertion part **10** is at the position PO**1**, from the first distance (=D1) derived at a point in time when the distal end of the insertion part **10** is moved to the position PO**2**, is derived as the specific insertion length.

[0125] After that, in a case where the insertion step is continued and the distal end of the insertion part **10** is moved to a turnaround point (that is, the ileocecum **58**) at which the insertion step is switched to the pulling-out step, the processor **8**P obtains the determination result that the reaching site of the distal end of the insertion part **10** is the ileocecum **58**. In a case where the determination result that the reaching site is the ileocecum **58** is obtained, the processor **8**P sets the first distance derived in a state in which the determination result is obtained, as the second correction value. Then, after the determination result is obtained, the processor **8**P performs processing of obtaining the pulling-out length (a distance from the reference position to the distal end of the insertion part **10** in a case where the ileocecum **58** at the ending point of the movement path **10**X is set as the reference position) by subtracting the first distance derived based on the magnetic flux densities BX and BY from the second correction value. By this processing, in the pulling-out step, the second distance in a case where the ileocecum

58 is the predetermined site (second predetermined site) is sequentially derived as the pulling-out length.

[0126] In the insertion step of the endoscopy of the large intestine, the insertion part **10** may be inserted while the large intestine is folded, or the insertion part **10** may be inserted while the large intestine is stretched. On the other hand, in the pulling-out step of the endoscopy of the large intestine, the insertion part **10** is pulled out in a state where the large intestine has returned to a steady state. Therefore, in the endoscopy of the large intestine, even in a case where the first distances derived on the basis of the magnetic flux densities BX and BY are the same in the insertion step and the pulling-out step, the positions at which the distal end of the insertion part **10** is present in the large intestine **51** are different in some cases. In the present embodiment, in the insertion step, the front end position of the insertion part **10** can be managed by the specific insertion length, and in the pulling-out step, the front end position of the insertion part **10** can be managed by the pulling-out length. Therefore, the insertion state of the insertion part **10** can be managed with high accuracy.

[0127] The specific insertion length constitutes a distance from the reference position (position of the anus **50**A or the rectum **53**) on the starting point side of the movement path **10**X to the distal end of the endoscope **1** moved along the movement path **10**X. The pulling-out length constitutes a distance from the ending point position (the position of the ileocecum **58**) on the movement path **10**X to the distal end of the endoscope **1** moved along the movement path **10**X.

[0128] The first distance constitutes a distance from the reference position (position of the through-hole **41**) on the starting point side of the movement path **10**X to the distal end of the endoscope **1** moved along the movement path **10**X. The first distance, the specific insertion length, or the pulling-out length will also be referred to distance information below.

[0129] The recognition model **81** illustrated in FIG. **14** is generated by training the first distance as training data. The specific insertion length or pulling-out length may be used instead of the first distance as the training data for generating the recognition model **81**. A recognition model generated using the specific insertion length instead of the first distance as the training data for generating the recognition model **81** will be referred to as a recognition model **81**A below. A recognition model generated using the pulling-out length instead of the first distance as the training data for generating the recognition model **81** will be referred to as a recognition model **81**B below.

[0130] In a case where the endoscope **1** is activated, the processor **8**P first determines the reaching site of the distal end of the endoscope **1** by using the recognition model **81**, the captured image, and the first distance. In a case where it is determined that the reaching site is the anus or the rectum, the processor **8**P determines the reaching site of the distal end of the endoscope **1** using the recognition model **81**A, the captured image, and the specific insertion length. Thereafter, in a case where the processor **8**P determines that the reaching site is the ileocecum, the processor **8**P determines the reaching site of the distal end of the endoscope **1** using the recognition model **81**B, the captured image, and the pulling-out length. As described above, by performing the determination of the reaching portion using different recognition models in the insertion step and the pulling-out step, it is possible to improve the determination accuracy of the reaching site in the insertion step and the determination accuracy of the reaching site in the removal step.

(Display and Recording During Endoscopy)

[0131] In the period of the insertion step, it is preferable that the processor **8**P performs control to display at least one of the specific insertion length (second distance) or the first distance derived as described above on the display device **7**, or performs control to record the specific insertion length or the first distance in association with the information regarding the endoscopy (hereinafter, referred to as examination association information) in the recording medium (for example, the memory of the expansion device **8**). The examination association information refers to the captured image captured by the endoscope **1**, various kinds of event information described above, an elapsed time (examination time) from the start of the endoscopy (examination start event), and the like. For example, each time the first distance and the specific insertion length are derived, the processor **8**P performs control to record which derived value is associated with the elapsed time (examination time). In a case where there is an instruction to record the captured image, the processor **8**P performs control to record the captured image further in association with the elapsed time at that time. In a case where the event information is acquired, the processor **8**P performs control to record the event information in association with the elapsed time at that time.

[0132] In the period of the pulling-out step, it is preferable that the processor **8**P performs control to display at least one of the pulling-out length (the second distance) or the first distance derived as described above on the display device **7**, or performs control to record the pulling-out length or the first distance in association with the examination association information in the recording medium.

[0133] The processor **8**P may perform control of outputting the operation support information based on the reaching site determined by the reaching site determination processing. For example, in the insertion step, depending on the position of the distal end of the insertion part **10**, the hardness adjustment of the insertion part **10** of the endoscope **1** or the manual compression may be required in order to smoothly insert the insertion part **10**. For example, in a case where it is determined that the reaching site is a site where the hardness adjustment or manual compression is required, the processor **8**P performs control of displaying information (operation support information) for instructing the hardness adjustment or manual compression on the display device **7**, or performs control of outputting the information by voice from the speaker. In this manner, it is possible to smoothly insert the endoscope **1**. The processor **8**P may perform control of outputting the operation support information only in the insertion step of the insertion step and the removal step based on the result of the reaching site determination processing, and may not perform the control in the pulling-out step. In the pulling-out step of the endoscopy of the large intestine, it is often not difficult to pull out the endoscope **1**, and therefore, it is possible to reduce the processing load of the processor **8**P by doing in this manner.

[0134] The examination data including the examination association information (the captured image, the event information, or the examination time) and the distance information (the first distance, the specific insertion length, or the pulling-out length) associated by the processor **8**P is transmitted to a server (not illustrated) and stored. After the endoscopy is ended, an examination report creation support device that can access the server creates a draft of an examination report on the basis of the examination data. A doctor can efficiently perform work by creating a final examination report using the draft.

(Display Example of Examination Data)

[0135] FIG. **17** is a graph illustrating a display example of the examination data associated and recorded by the processor **8**P. The processor **8**P performs control to display the graph illustrated in FIG. **17** on, for example, the display device **7** or another display. With the graph displayed in this way, the operator of the endoscope **1** or an instructor thereof can evaluate the procedure of the endoscopy.

[0136] In the graph illustrated in FIG. **17**, the first distance is plotted for each elapsed time of the endoscopy. In the graph illustrated in FIG. **17**, characters (S-top, SDJ, splenic flexure, hepatic curvature, and ileocecum) indicating the content (reaching site) of the specific site reaching event are attached to the timing when the specific site reaching event is detected. In addition, characters (pulling-out start, treatment, lesion detection, examination end) indicating the content of another event are attached to the timing at which the event is detected. The period from the start of the insertion step (elapsed time=0) to the pulling-out start event is the period of the insertion step, and the period from the pulling-out start event to the examination end event is the period of the pulling-out step.

[0137] In a case where an arbitrary position in the plot waveform in FIG. **17** is designated and a captured image associated with the elapsed time of the arbitrary position is recorded, the processor **8**P may display the captured image on the display device **7**.

<Main Effects of Endoscope System **200**>

[0138] According to the endoscope system **200**, since the reaching site of the distal end of the endoscope **1** is determined based on the captured image and the distance information, it is possible to improve the determination accuracy.

[0139] With the endoscope system **200**, not only the insertion length (first distance) of the insertion part **10** into the subject with the position of the detection unit **40** installed outside the subject as the starting point, but also the specific insertion length of the insertion part **10** into the subject with the first predetermined site (anus or rectum) in the subject as the starting point and the pulling-out length of the insertion part **10** to the outside of the subject with the second predetermined site (ileocecum) in the subject as the starting point can be derived. In a case of performing the endoscopy of the stomach, it is possible to obtain the specific insertion length and the pulling-out length by setting the first predetermined site as, for example, a cardia, and the second predetermined site as, for example, a duodenum.

[0140] With the endoscope system **200**, since the specific insertion length and the pulling-out length are derived by using the result of the reaching site recognition processing using the captured image obtained through the imaging by the endoscope **1** actually inserted into the subject, it is possible to eliminate the influence of individual differences for each subject, and manage the front end position of the insertion part **10** with high accuracy by using the specific insertion length and the pulling-out length. As a result, it is possible to perform the operation support of the endoscope **1** with high accuracy during the endoscopy. In addition, it is possible to determine the recording position of the captured image with high accuracy, which can be used for later creation of an examination report or can improve the diagnosis accuracy. In particular, since the specific insertion length and the pulling-out length can be derived separately, these effects can be further enhanced.

[0141] As described above, the detection unit **40** can also be integrally configured with an insertion assisting member of the endoscope **1**. For example, the detection unit **40** may be integrally formed with the insertion assisting member to be inserted into the anus, or may be integrally formed with a mouthpiece-type insertion assisting member that is held in the mouth. In addition, the detection unit **40** may be integrally formed with the pants for endoscopy, or may be configured to be attachable to and detachable from the pants for endoscopy.

[0142] The technology of the present disclosure is not limited to the above description, and can be appropriately changed as described below.

[0143] For example, the endoscope **1** may be inserted into the body through the mouth or the nose of the subject **50**. In this case, the detection unit **40** need only have a shape to be attachable to the mouth or the nose of the subject **50**.

[0144] The tubular member **17** has the configuration in which the first member **14** and the second member **15** are provided, and each of the first member **14** and the second member **15** contains the magnetizable austenitic stainless steel, but one of the first member **14** or the second member **15** may be made of a non-magnetizable material. That is, the magnetic pattern may not be formed on one of the first member **14** or the second member **15**. Even in such a case, since the magnetic flux densities BX, BY, and BZ described above can be detected from the tubular member **17**, it is possible to determine the movement state and the rotation state of the insertion part **10**.

[0145] In the above description, in the tubular member **17**, the two types of magnetic pole regions are alternately arranged in the longitudinal direction to form the magnetic pattern, and the movement state of the insertion part **10** in the longitudinal direction is determined on the basis of the combination of the classification levels of the magnetic information in the two directions detected from the magnetic pattern. However, the two types of magnetic pole regions formed on the tubular member **17** may not be alternately arranged in the longitudinal direction. Even in such a case, the movement state of the insertion part **10** in the longitudinal direction can be determined on the basis of the combination of the classification levels of the magnetic information in the two directions detected from the magnetic pattern.

[0146] In addition, as a modification example, the movement state of the insertion part **10** in the longitudinal direction may be determined by forming a pattern more complicated than the magnetic pattern described above on the tubular member **17** and detecting the pattern by the magnetic detection units **43** and **44**. Specifically, a table in which each position of the tubular member **17** in the longitudinal direction and the magnetic flux density BX or the magnetic flux density BY (classification level) detected at each position are associated with each other may be recorded in a memory, and the processor **8**P may classify the magnetic flux density BX or the magnetic flux density BY detected by the magnetic detection unit **43** to acquire the classification level, and may acquire the information on the position corresponding to the classification level from the table to determine the insertion length of the insertion part **10**. As a result, the insertion length of the insertion part **10** can be finely determined. In addition, the magnetic detection units **43** and **44** can detect the magnetic flux densities in one direction, so that the cost can be reduced.

[0147] As described above, at least the following matters are described in the present specification.

(1)

[0148] A processing device comprising:

[0149] a processor configured to:

[0150] acquire a distance from a reference position on a movement path of an endoscope to a distal end of the endoscope that is moved along the movement path;

[0151] acquire a captured image that is captured by the endoscope; and

[0152] determine a reaching site of the distal end of the endoscope inserted into a subject, based on the captured image and the distance.

(2)

[0153] The processing device according to (1),

[0154] wherein the processor is configured to determine the reaching site further based on a change amount in the distance per unit time.

(3)

[0155] The processing device according to (2),

[0156] wherein the processor is configured to determine whether or not the reaching site is a turnaround point of the distal end of the endoscope in an examination using the endoscope, based on the captured image, the distance in a case where the reference position is a position on the movement path on a starting point side, and the change amount.

(4)

[0157] The processing device according to (3),

[0158] wherein the turnaround point includes an ileocecum.

(5)

[0159] The processing device according to any of (1) to (4),

[0160] wherein the processor is configured to acquire the distance using different reference positions in a first period in which the endoscope is moving from a starting point to an ending point of the movement path and in a second period in which the endoscope is moving from the ending point to the starting point of the movement path.

(6)

[0161] The processing device according to (5),

[0162] wherein the reference position used in the second period is an ending point position of the movement path, and

[0163] the reference position used in the first period is a position on a starting point side of the movement path.

(7)

The processing device according to (5) or (6),

[0164] wherein the processor is configured to determine the reaching site with different processing contents between the first period and the second period.

(8)

[0165] The processing device according to any of (1) to (7),

[0166] wherein the processor is configured to:

[0167] perform recognition processing related to an examination of the endoscope based on the captured image; and

[0168] perform determination of the reaching site based on the captured image used in the recognition processing and the distance in a case where a specific recognition result is obtained by the recognition processing.

(9)

[0169] The processing device according to (8),

[0170] wherein the processor is configured to store the specific recognition result, a determination result of the reaching site, and the distance in association with one another.

(10)

[0171] The processing device according to any of (1) to (9),

[0172] wherein the processor is configured to determine the reaching site based on an output of a machine learning model obtained by inputting an image based on the distance and the captured image to the machine learning model.

(11)

[0173] The processing device according to any of (1) to (9),

[0174] wherein the processor is configured to determine the reaching site based on an output of a machine learning model obtained by inputting the captured image to the machine learning model and inputting an image based on the distance to an intermediate layer of the machine learning model.

(12)

[0175] The processing device according to any of (1) to (9),

[0176] wherein the processor is configured to determine the reaching site based on an output of a machine learning model obtained by inputting the captured image to the machine learning model, and the distance.

(13)

[0177] The processing device according to any of (1) to (12),

[0178] wherein the processor is configured to store information related to an examination of the subject performed using the endoscope and a determination result of the reaching site in association with each other.

(14)

[0179] The processing device according to any of (1) to (13),

[0180] wherein the processor in configured to output operation support information of the endoscope based on a determination result of the reaching site.

(15)

[0181] The processing device according to any of (1) to (14),

[0182] wherein a magnetic pattern is formed along a longitudinal direction on an insertion part of the endoscope, and

[0183] the processor acquires the distance based on a magnetic field from the magnetic pattern, which is detected by a magnetic detection unit installed outside a subject.

(16)

[0184] An endoscope device comprising: the processing device according to any of (1) to (15); and the endoscope.

(17)

[0185] The endoscope device according to (16), further comprising:

[0186] a magnetic detection unit disposed on the movement path,

[0187] wherein an insertion part of the endoscope has a member containing metal, which extends in a longitudinal direction and has a magnetic pattern integrally formed along the longitudinal direction,

[0188] the magnetic detection unit detects a magnetic field from the member, and

[0189] the processor derives the distance based on the magnetic field detected by the magnetic detection unit.

(18)

[0190] The endoscope device according to (17),

[0191] wherein the insertion part includes a soft portion of the endoscope.

(19)

[0192] The endoscope device according to (18),

[0193] wherein the soft portion has a cylindrical member having an insulating property, a cylindrical first member that contains metal and is inserted into the cylindrical member, and a cylindrical second member that contains metal and is inserted into the first member, and

[0194] the member includes at least one of the first member or the second member.

(20)

[0195] The endoscope device according to (19),

[0196] wherein at least one of the first member or the second member is made of magnetizable austenitic stainless steel.

(21)

[0197] The endoscope device according to (16), further comprising:

[0198] a magnetic detection unit disposed on the movement path,

[0199] wherein an insertion part of the endoscope has a member containing metal, which extends in a longitudinal direction and has a magnetic pattern formed along the longitudinal direction,

[0200] the magnetic detection unit detects a magnetic field from the member,

[0201] the processor derives the distance based on the magnetic field detected by the magnetic detection unit,

[0202] the insertion part has a cylindrical member having an insulating property, a cylindrical first member that contains metal and is inserted into the cylindrical member, and a cylindrical second member that contains metal and is inserted into the first member,

[0203] the member includes at least one of the first member or the second member,

[0204] the first member is a spiral tube, and

[0205] the second member is a net body.

(22)

[0206] The endoscope device according to any of (17) to (21),

[0207] wherein the magnetic detection unit detects a first magnetic flux density in a first direction and a second magnetic flux density in a second direction intersecting the first direction, at a plurality of positions along the longitudinal direction of the member.

(23)

[0208] A processing method comprising:

[0209] acquiring a distance from a reference position on a movement path of an endoscope to a distal end of the endoscope that is moved along the movement path;

[0210] acquiring a captured image that is captured by the endoscope; and

[0211] determining a reaching site of the distal end of the endoscope inserted into a subject, based on the captured image and the distance.

[0212] Although various embodiments have been described above, it goes without saying that the present invention is not limited to these examples. It is apparent that those skilled in the art may perceive various modification examples or correction examples within the scope disclosed in the claims, and those examples are also understood as falling within the technical scope of the present invention. In addition, each constituent in the embodiment may be used in any combination without departing from the gist of the invention.

[0213] The present application is based on Japanese Patent Application (JP2022-174971) filed on Oct. 31, 2022, the content of which is incorporated in the present application by reference.

EXPLANATION OF REFERENCES

[0214] **1**: endoscope
[0215] MA, MA**1**, MA**2**: magnetic pole portion
[0216] **4**P: processor
[0217] **4**: processor device
[0218] **5**: light source device
[0219] **6**: input unit
[0220] **7**: display device
[0221] **8**: expansion device
[0222] **8**P: processor
[0223] **10**A: soft portion
[0224] **10**B: bendable part
[0225] **10**C: distal end part
[0226] **10**: insertion part
[0227] **11**: operating part
[0228] **12**: angle knob
[0229] **13**A, **13**B: connector portion
[0230] **13**: universal cord
[0231] **14**: first member
[0232] **15***a*: metal strip
[0233] **15**: second member
[0234] **16**A, **16**B: cap
[0235] **17**N: positive pole region
[0236] **17**S: negative pole region
[0237] **17**: tubular member
[0238] **18**A: inner resin layer
[0239] **18**B: outer resin layer
[0240] **18**: outer skin layer
[0241] **19**: coating layer
[0242] **40**: detection unit
[0243] **42**: housing

[0244] **42**A: body part
[0245] **42**B: lid portion
[0246] **42***a*: flat plate portion
[0247] **42***b*: side wall portion
[0248] **42***c*: inner wall portion
[0249] **41**A, **41**B, **41**: through-hole
[0250] **43**, **44**: magnetic detection unit
[0251] **45**: communication chip
[0252] **46**: storage battery
[0253] **47**: power receiving coil
[0254] **50**A: anus
[0255] **53**: rectum
[0256] **54**: sigmoid colon
[0257] **55**: descending colon
[0258] **56**: transverse colon
[0259] **57**: ascending colon
[0260] **58**: ileocecum
[0261] **50**: subject
[0262] **81**, **82**, **83**: recognition model
[0263] **83**A: determination unit
[0264] **100**: endoscope device
[0265] **200**: endoscope system
[0266] **300**: magnetic field generation device
[0267] PO**1**, PO**2**: position

What is claimed is:

1. A processing device comprising:
a processor configured to:
acquire a distance from a reference position on a movement path of an endoscope to a distal end of the endoscope that is moved along the movement path;
acquire a captured image that is captured by the endoscope; and
determine a reaching site of the distal end of the endoscope inserted into a subject, based on the captured image and the distance,
wherein the reference position with which the processor is configured to acquire the distance in a first period in which the endoscope is moving from a starting point to an ending point of the movement path, and the reference position with which the processor is configured to acquire the distance in a second period in which the endoscope is moving from the ending point to the starting point of the movement path are different.

2. The processing device according to claim **1**,
wherein the processor is configured to determine the reaching site further based on a change amount in the distance per unit time.

3. The processing device according to claim **2**,
wherein the processor is configured to determine whether or not the reaching site is a turnaround point of the distal end of the endoscope in an examination using the endoscope, based on the captured image, the distance in a case where the reference position is a position on the movement path at a starting point side, and the change amount.

4. The processing device according to claim **3**,
wherein the turnaround point includes an ileocecum.

5. The processing device according to claim **1**,
wherein the reference position with which the processor is configured to acquire the distance in the second period is an ending point position of the movement path, and
the reference position with which the processor is configured to acquire the distance in the first period is a position at a starting point side of the movement path.

6. The processing device according to claim **1**,
wherein the processor is configured to determine the reaching site with different processing contents between the first period and the second period.

7. The processing device according to claim **1**,
wherein the processor is configured to:
perform recognition processing related to an examination using the endoscope based on the captured image; and
perform, in a case where a specific recognition result is obtained by the recognition processing, determination of the reaching site based on the captured image used in the recognition processing and the distance.

8. The processing device according to claim **7**,
wherein the processor is configured to store the specific recognition result, a determination result of the reaching site, and the distance in association with one another.

9. The processing device according to claim **1**,
wherein the processor is configured to determine the reaching site based on an output of a machine learning model obtained by inputting an image based on the distance and the captured image to the machine learning model.

10. The processing device according to claim **1**,
wherein the processor is configured to determine the reaching site based on an output of a machine learning model obtained by inputting the captured image to the machine learning model and inputting an image based on the distance to an intermediate layer of the machine learning model.

11. The processing device according to claim **1**,
wherein the processor is configured to determine the reaching site based on the distance and an output of a machine learning model obtained by inputting the captured image to the machine learning model.

12. The processing device according to claim **1**,
wherein the processor is configured to store information related to an examination of the subject performed using the endoscope and a determination result of the reaching site in association with each other.

13. The processing device according to claim **1**,
wherein the processor in configured to output operation support information of the endoscope based on a determination result of the reaching site.

14. The processing device according to claim **1**,
wherein a magnetic pattern is formed along a longitudinal direction on an insertion part of the endoscope, and
the processor is configured to acquire the distance based on a magnetic field from the magnetic pattern, which is detected by a magnetic detector positioned outside a subject.

15. An endoscope device comprising:
the processing device according to claim **1**; and
the endoscope.

16. The endoscope device according to claim **15**, further comprising:
a magnetic detector disposed on the movement path,
wherein an insertion part of the endoscope has a member containing metal, which extends in a longitudinal direction and has a magnetic pattern integrally formed along the longitudinal direction,
the magnetic detector detects a magnetic field from the member, and

the processor is configured to derive the distance based on the magnetic field detected by the magnetic detector.

17. The endoscope device according to claim **16**,

wherein the insertion part includes a soft portion of the endoscope.

18. The endoscope device according to claim **17**,

wherein the soft portion has a cylindrical member having an insulating property, a cylindrical first member that contains metal and is inserted into the cylindrical member, and a cylindrical second member that contains metal and is inserted into the first member, and

the member containing metal includes at least one of the first member or the second member.

19. The endoscope device according to claim **18**,

wherein at least one of the first member or the second member is made from magnetizable austenitic stainless steel.

20. The endoscope device according to claim **15**, further comprising:

a magnetic detector disposed on the movement path,

wherein an insertion part of the endoscope has a member containing metal, which extends in a longitudinal direction and has a magnetic pattern formed along the longitudinal direction,

the magnetic detector detects a magnetic field from the member,

the processor is configured to derive the distance based on the magnetic field detected by the magnetic detector,

the insertion part has a cylindrical member having an insulating property, a cylindrical first member that contains metal and is inserted into the cylindrical member, and a cylindrical second member that contains metal and is inserted into the first member,

the member containing metal includes at least one of the first member or the second member,

the first member is a spiral tube, and

the second member is a net body.

21. The endoscope device according to claim **16**,

wherein the magnetic detector detects a first magnetic flux density in a first direction and a second magnetic flux density in a second direction intersecting the first direction, at a plurality of positions along the longitudinal direction of the member.

22. A processing method comprising:

acquiring a distance from a reference position on a movement path of an endoscope to a distal end of the endoscope that is moved along the movement path;

acquiring a captured image that is captured by the endoscope; and

determining a reaching site of the distal end of the endoscope inserted into a subject, based on the captured image and the distance,

wherein the reference position with which the acquiring of the distance is performed in a first period in which the endoscope is moving from a starting point to an ending point of the movement path, and the reference position with which the acquiring of the distance is performed in a second period in which the endoscope is moving from the ending point to the starting point of the movement path are different.

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