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(54) **MEDICAL SYSTEM AND CONTROL METHOD**

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(57) **ABSTRACT**

A medical system includes an endoscope that captures an image including an object, a moving device that includes a robot arm and that moves the endoscope in a body, and a controller that controls the moving device on the basis of the position of the object. The controller is configured to control the moving device in a first control mode in which the endoscope is caused to follow the object at a first speed and a second control mode in which the endoscope is caused to follow the object at a second speed lower than the first speed. The controller controls the moving device in the first control mode when the object is located outside a predetermined three-dimensional region set in a field of view of the endoscope. The controller controls the moving device in the second control mode when the object is located in the predetermined three-dimensional region.

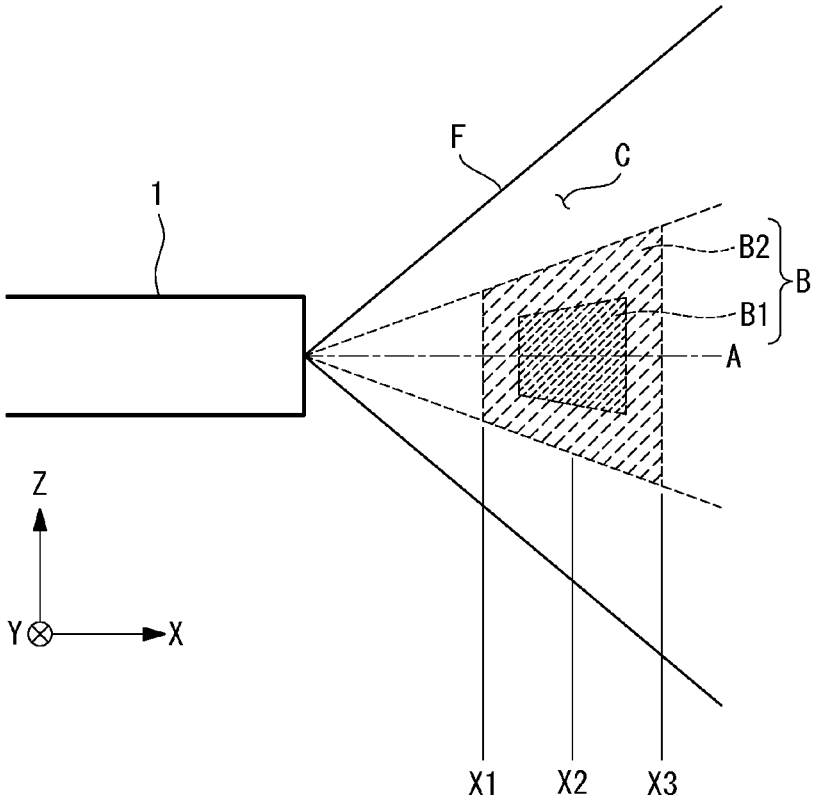


FIG. 1

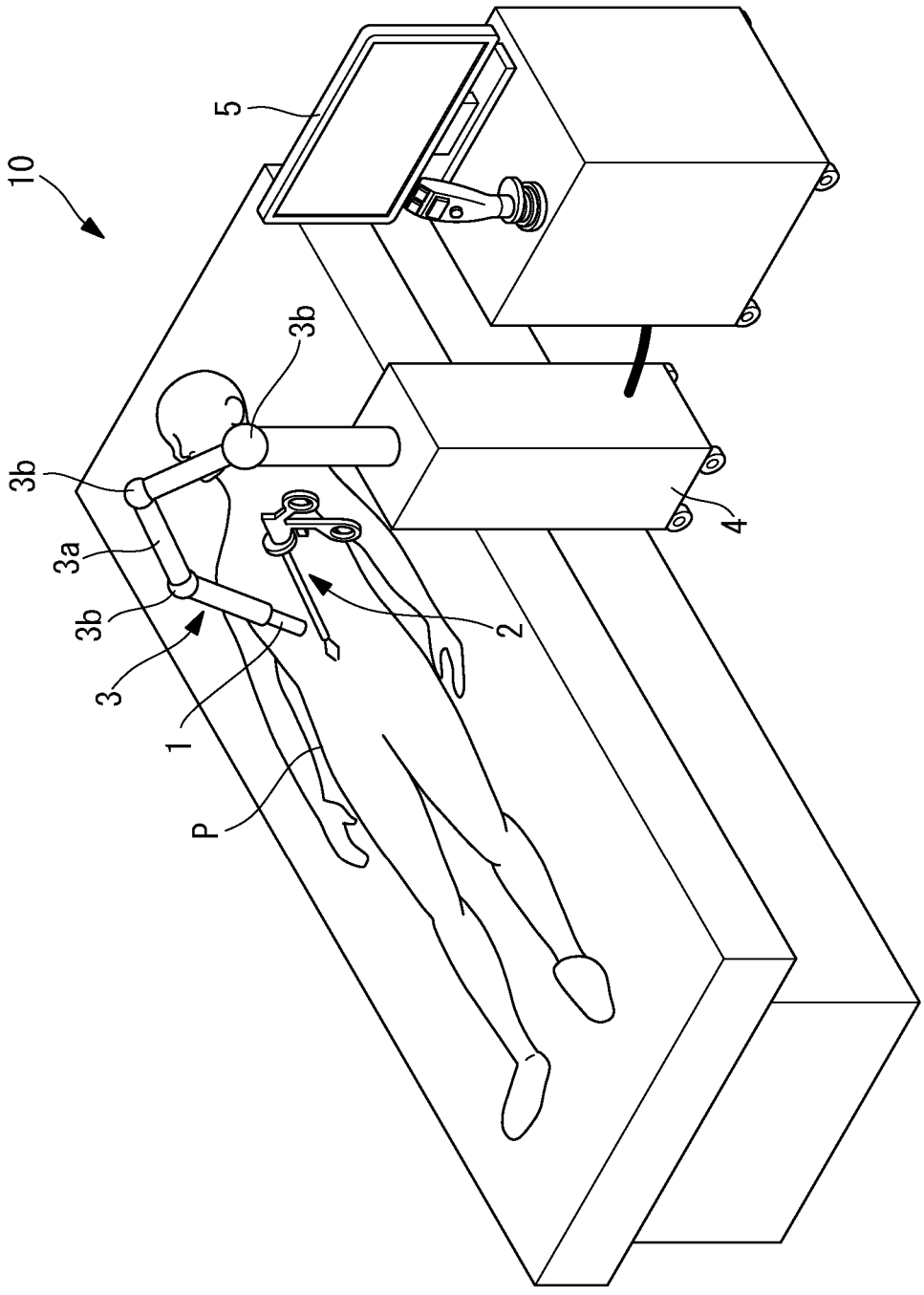


FIG. 2

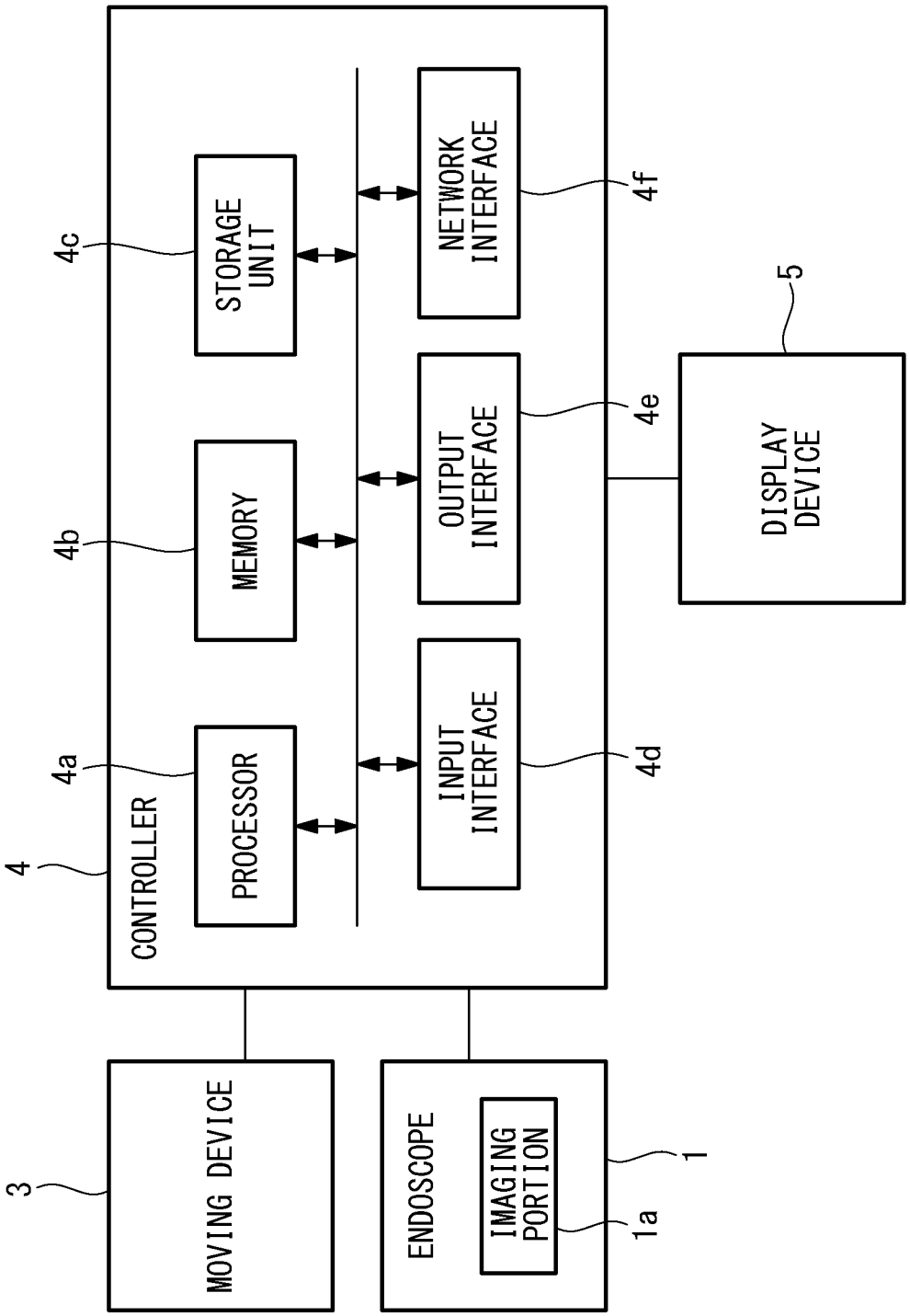

4
CONTROLLER
4a
PROCESSOR
4b
MEMORY
4c
STORAGE UNIT
4d
INPUT INTERFACE
4e
OUTPUT INTERFACE
4f
NETWORK INTERFACE
5
DISPLAY DEVICE
3
MOVING DEVICE
1
ENDOSCOPE
1a
IMAGING PORTION

FIG. 3

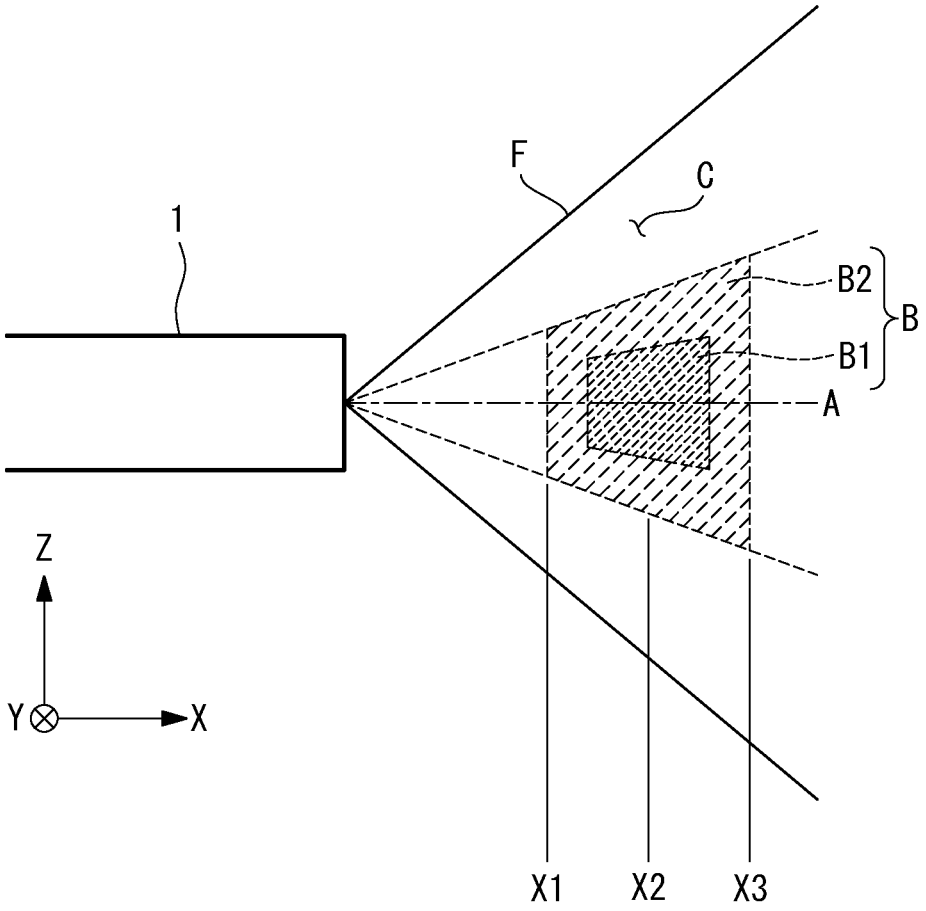


FIG. 4A

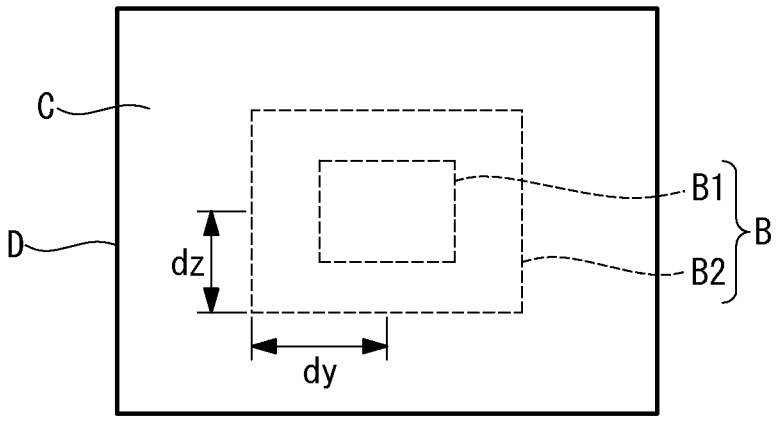


FIG. 4B

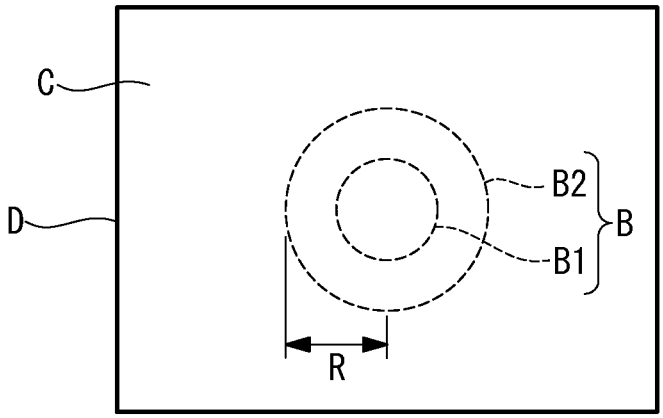


FIG. 4C

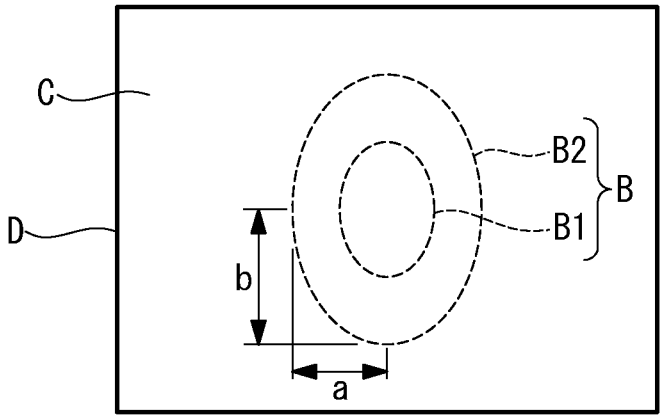


FIG. 5

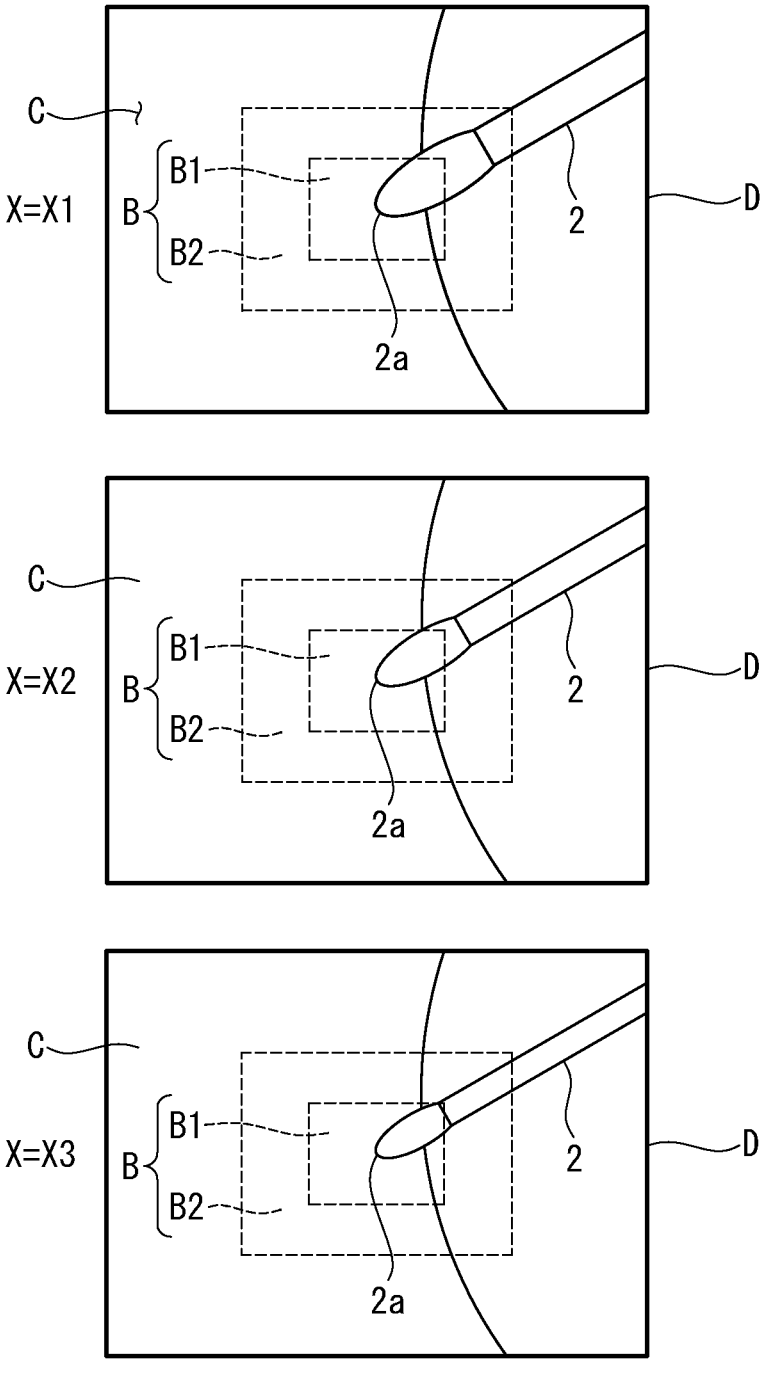


FIG. 6

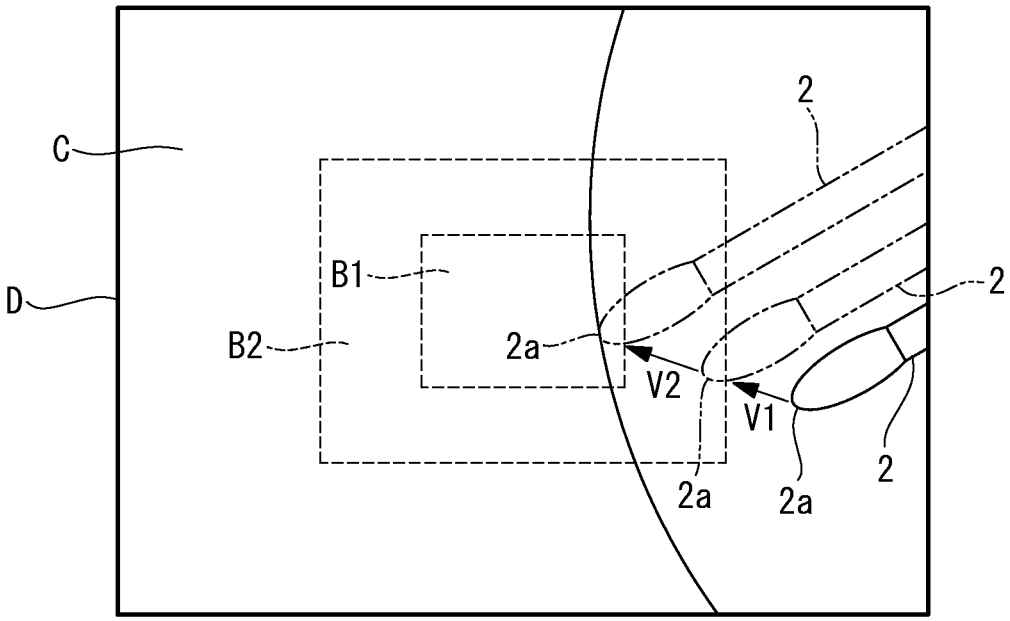


FIG. 7A

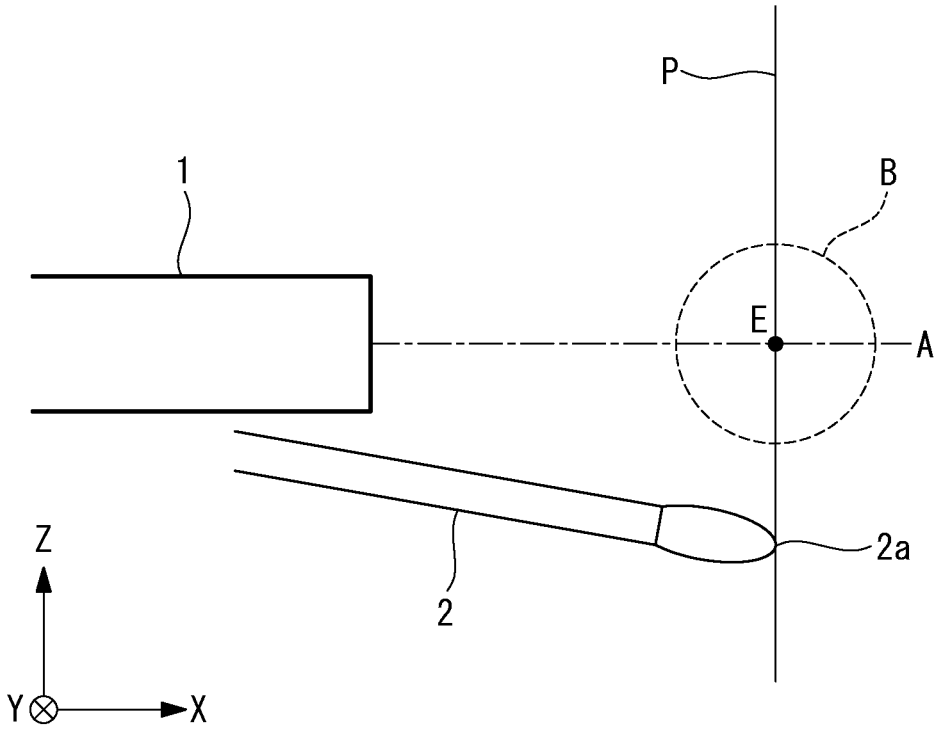


FIG. 7B

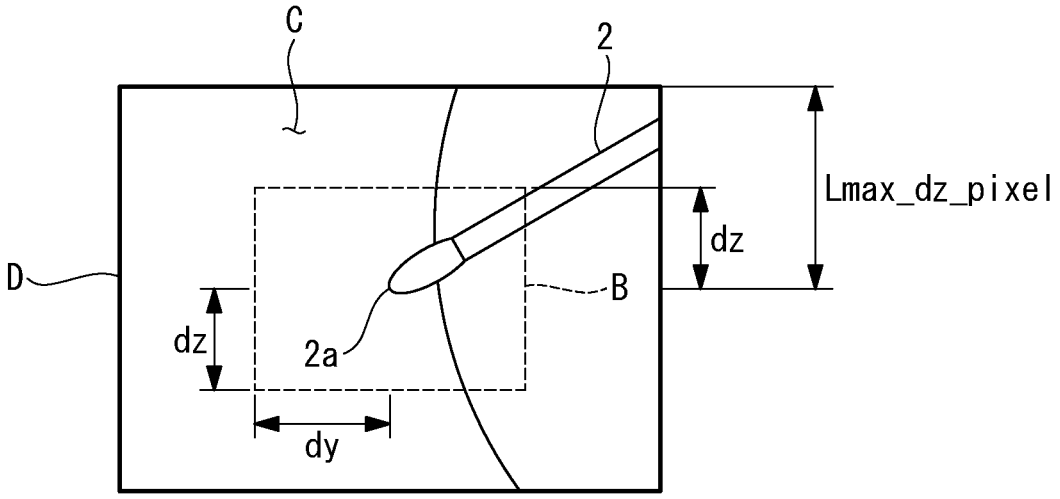


FIG. 7C

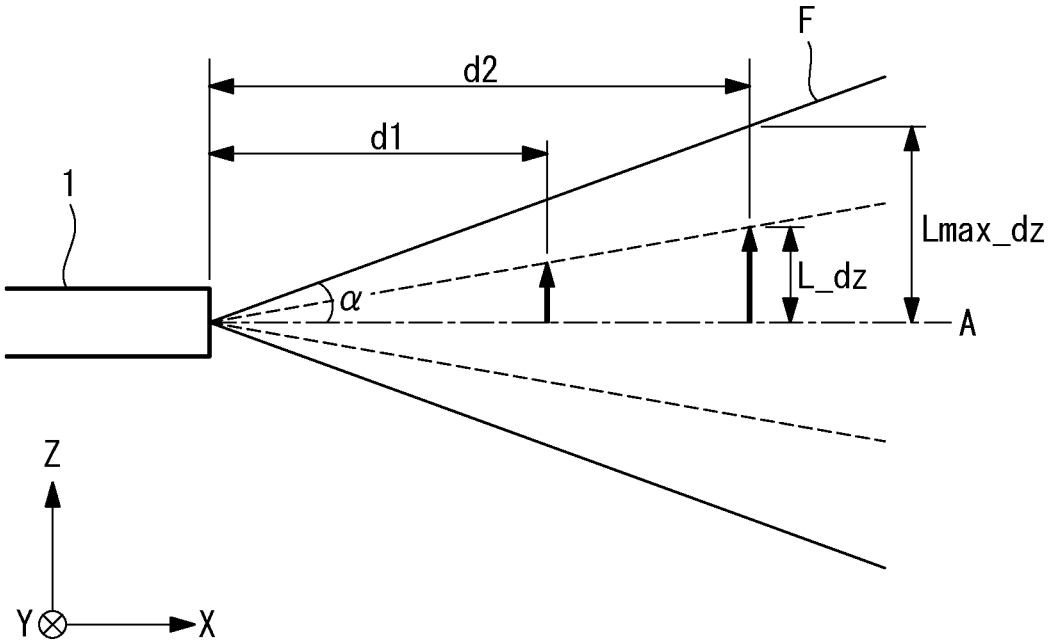


FIG. 7D

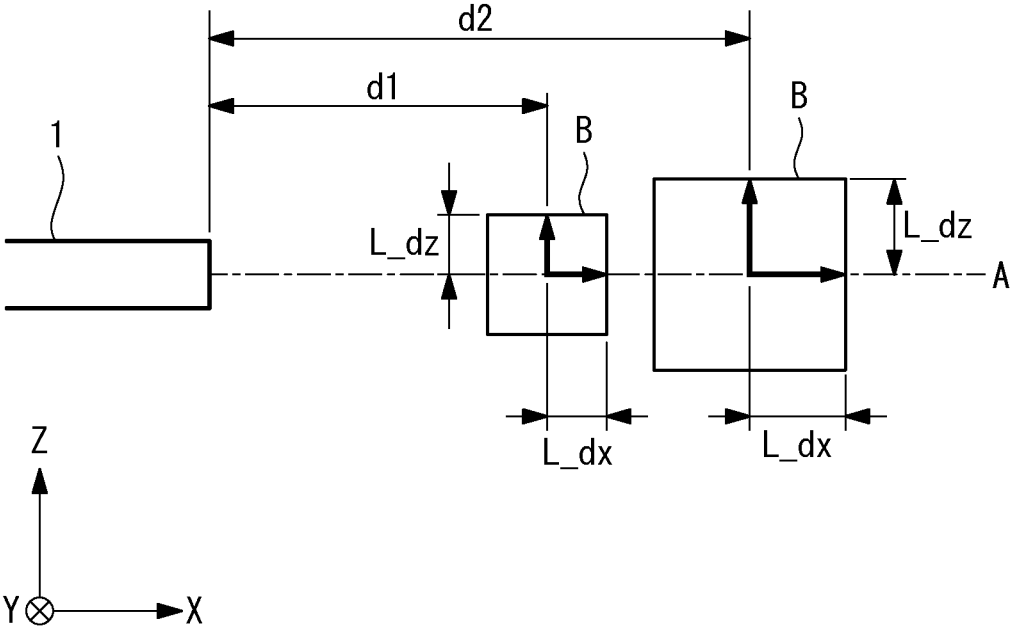


FIG. 8A

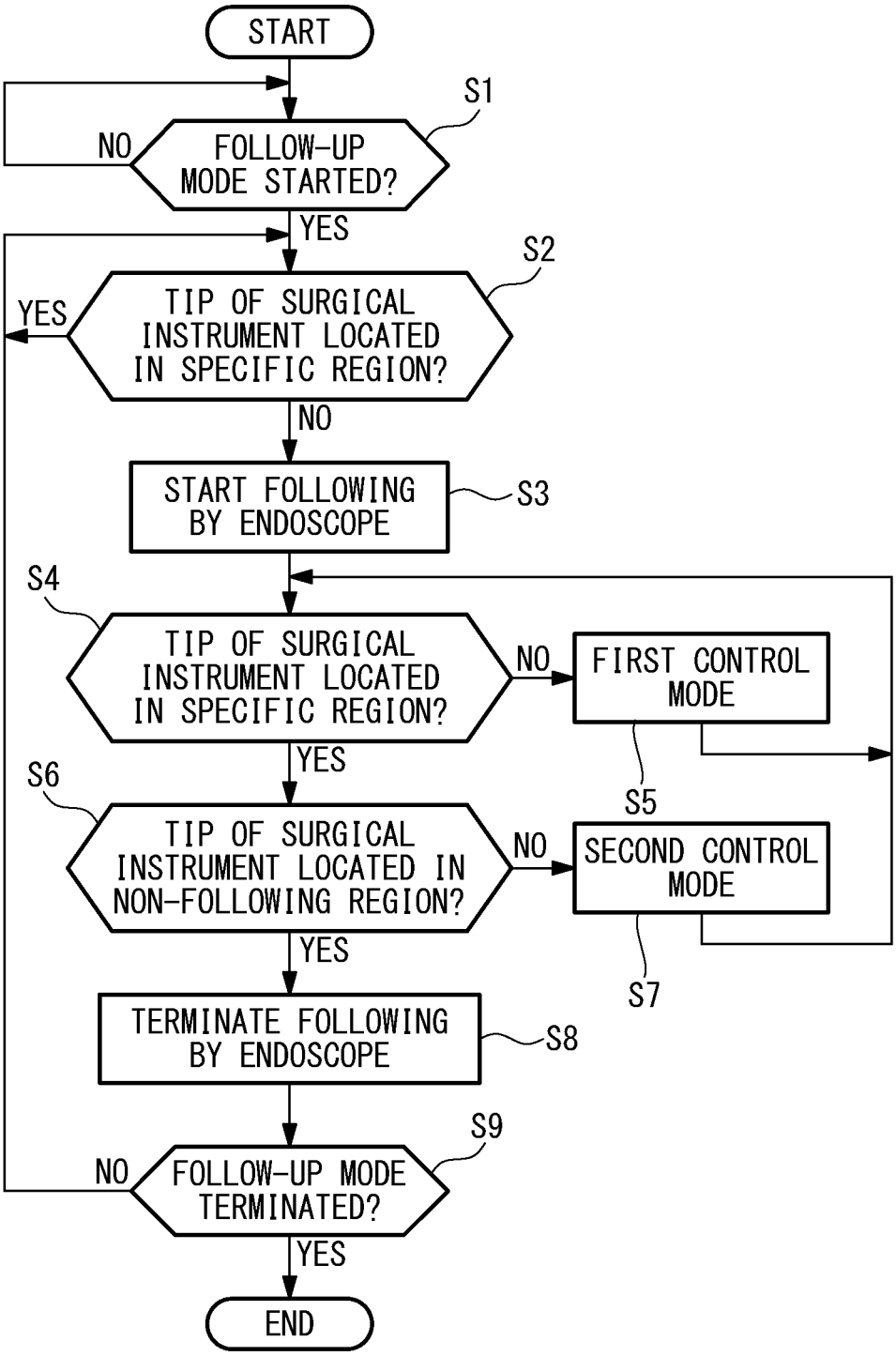

START
S1
NO
FOLLOW-UP MODE STARTED?
YES
S2
YES
TIP OF SURGICAL INSTRUMENT LOCATED IN SPECIFIC REGION?
NO
START FOLLOWING BY ENDOSCOPE
S3
S4
TIP OF SURGICAL INSTRUMENT LOCATED IN SPECIFIC REGION?
NO
FIRST CONTROL MODE
S5
YES
S6
TIP OF SURGICAL INSTRUMENT LOCATED IN NON-FOLLOWING REGION?
NO
SECOND CONTROL MODE
S7
YES
TERMINATE FOLLOWING BY ENDOSCOPE
S8
S9
NO
FOLLOW-UP MODE TERMINATED?
YES
END

FIG. 8B

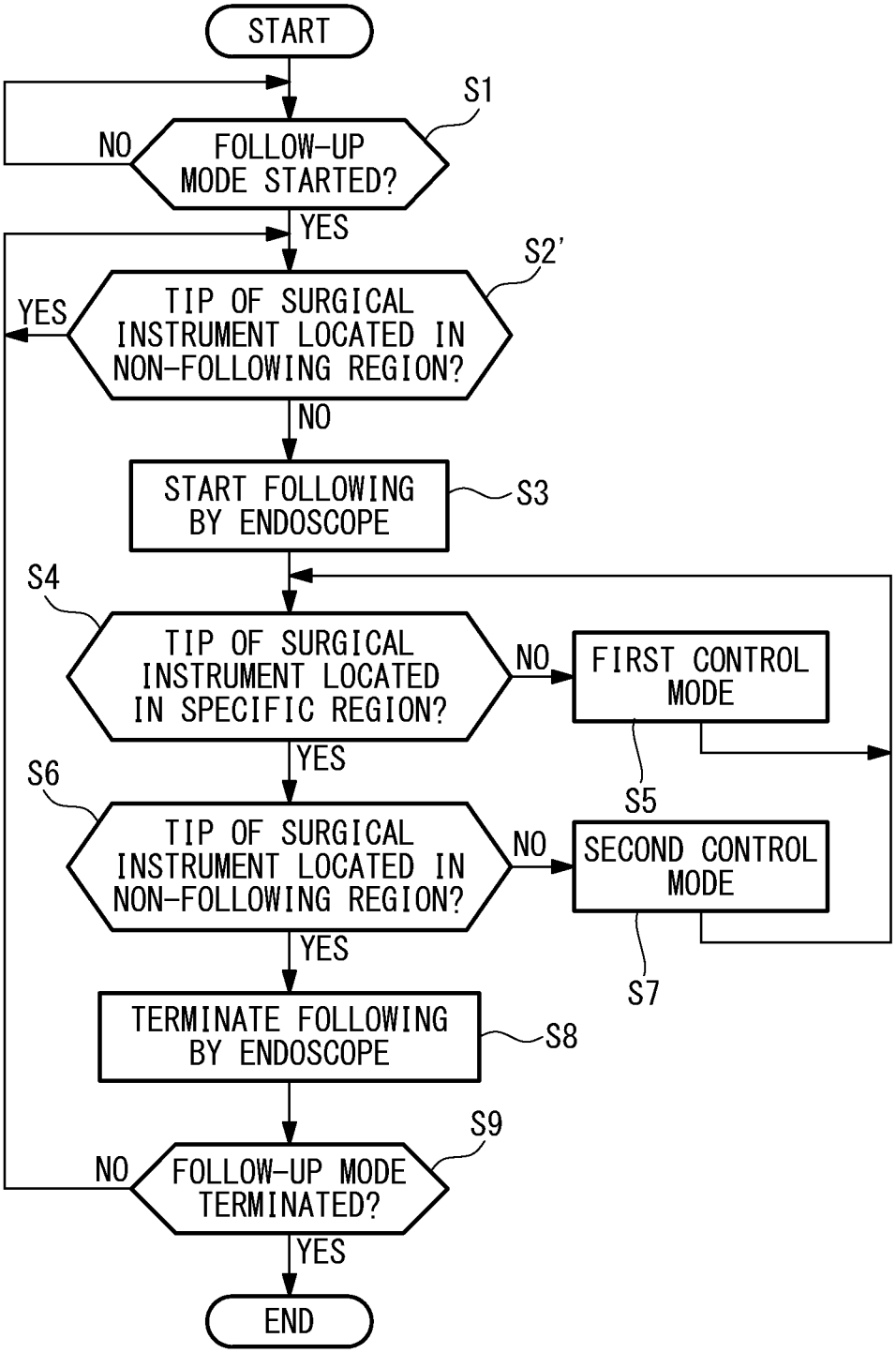

START
S1
FOLLOW-UP MODE STARTED?
NO
YES
S2'
TIP OF SURGICAL INSTRUMENT LOCATED IN NON-FOLLOWING REGION?
YES
NO
START FOLLOWING BY ENDOSCOPE
S3
S4
TIP OF SURGICAL INSTRUMENT LOCATED IN SPECIFIC REGION?
NO
FIRST CONTROL MODE
S5
YES
S6
TIP OF SURGICAL INSTRUMENT LOCATED IN NON-FOLLOWING REGION?
NO
SECOND CONTROL MODE
S7
YES
TERMINATE FOLLOWING BY ENDOSCOPE
S8
S9
FOLLOW-UP MODE TERMINATED?
NO
YES
END

FIG. 9A

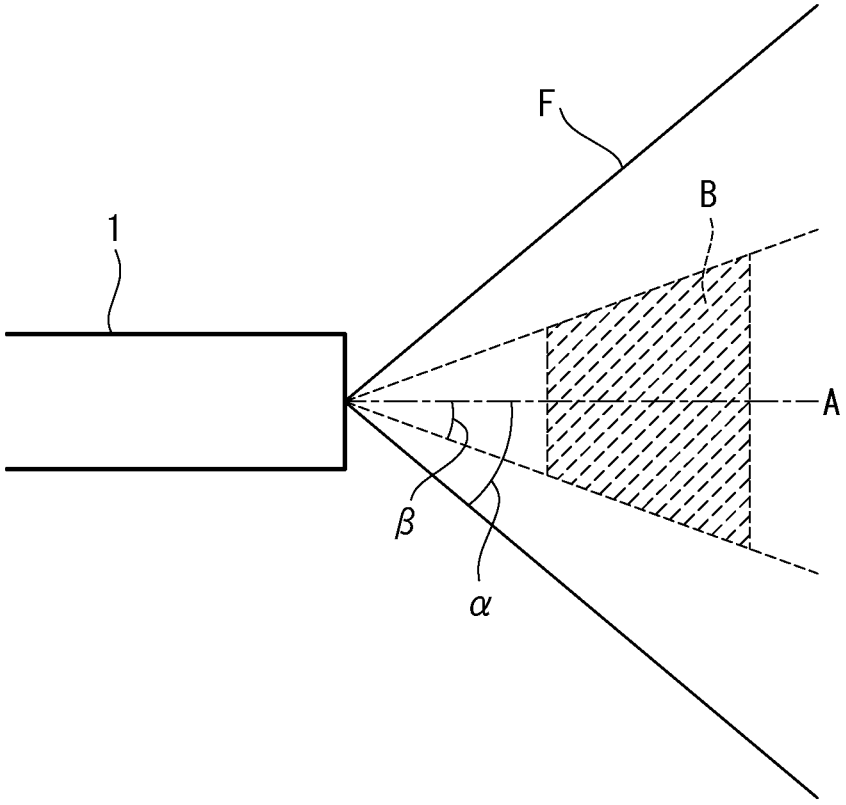


FIG. 9B

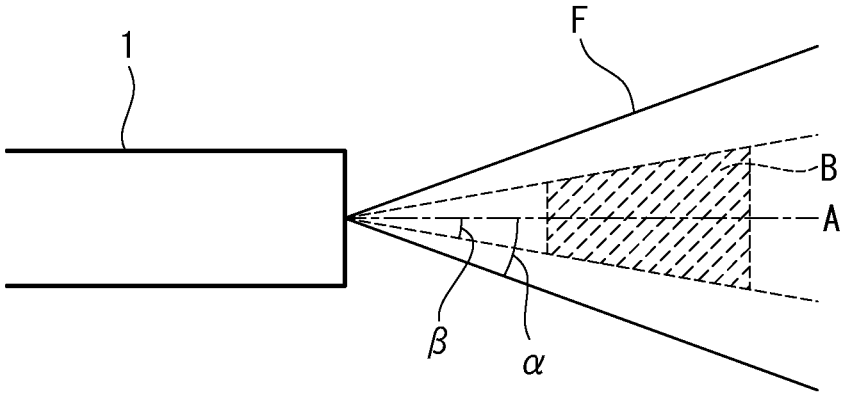


FIG. 10

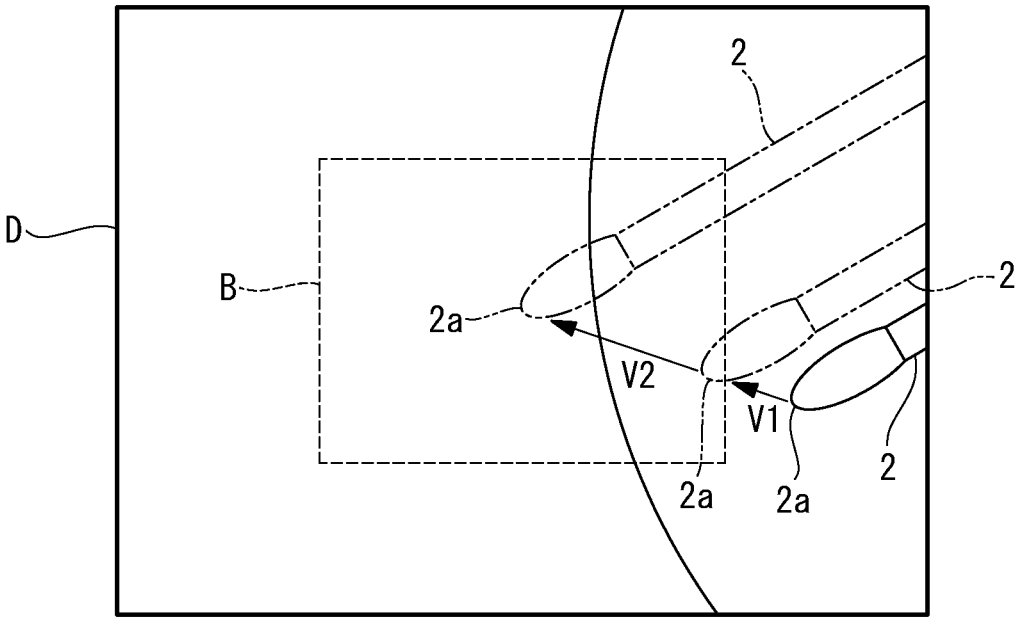
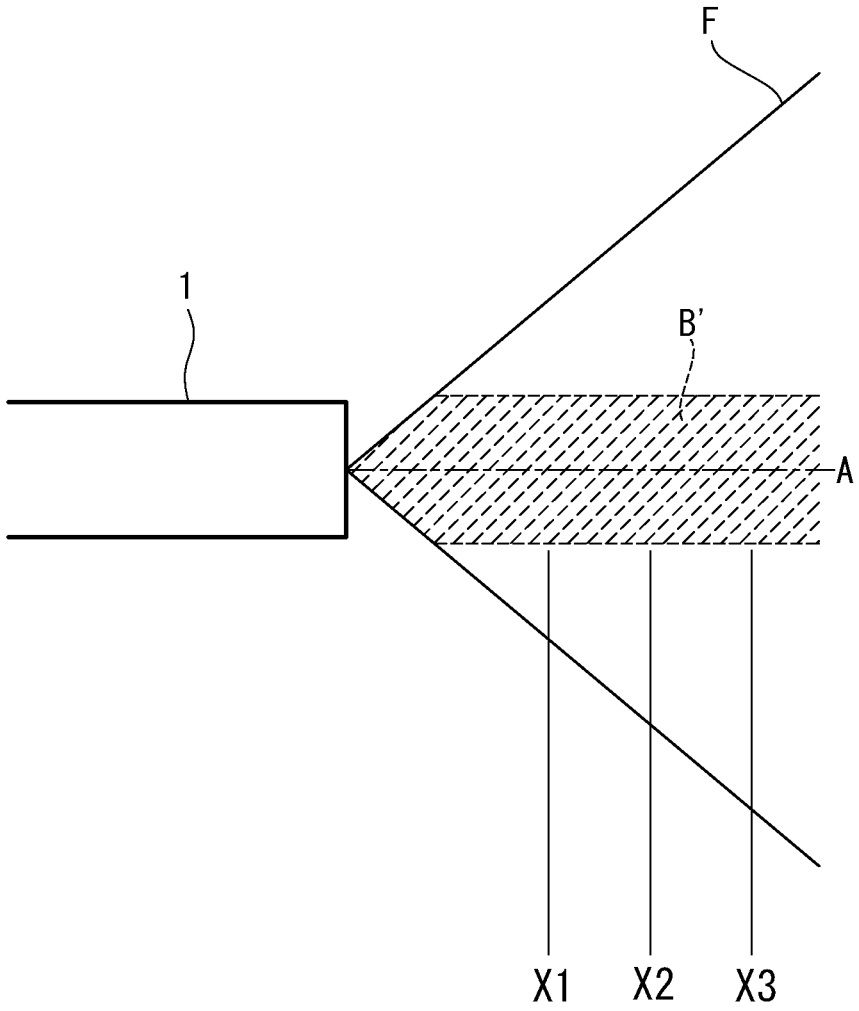


FIG. 11



MEDICAL SYSTEM AND CONTROL METHOD

TECHNICAL FIELD

[0001] The present invention relates to a medical system and a control method and particularly relates to a medical system having the function of causing an endoscope to follow an object, and a control method thereof. The present application claims priority under the provisional U.S. Pat. Application No. 63/076408 filed on Sep. 10, 2020, which is incorporated herein by reference. This is a continuation of International Application PCT/JP2021/027564 which is hereby incorporated by reference herein in its entirety.

BACKGROUND ART

[0002] Conventionally, a system has been proposed to move the field of view of an endoscope in a semiautonomous manner by causing the endoscope to follow an object, e.g., a surgical instrument (for example, see PTL 1).

[0003] To allow a surgeon to follow an object with ease of operation, it is desirable to suppress excessive following motion of an endoscope so that an excessive movement of the field of view is prevented. Specifically, if an endoscope follows all the movements of an object, the field of view may become unstable and cause a surgeon to feel stress. Moreover, the field of view desirably stays stationary during procedures such as blunt dissection and thus a movement of the field of view may interfere with the procedure.

[0004] In PTL 1, a permissible region is set in an image so as to extend around the central region of the image, an endoscope follows a surgical instrument to place the surgical instrument back to the central region when the surgical instrument moves out of the permissible region, and the following is terminated when the surgical instrument moves into the central region. This configuration prevents the endoscope from following the surgical instrument insofar as the surgical instrument stays in the permissible region and the central region, thereby suppressing an excessive movement of the field of view.

CITATION LIST

Patent Literature

[0005] {PTL 1} U.S. Pat. application publication No. 2002/0156345

SUMMARY OF INVENTION

[0006] An aspect of the present invention is a medical system including an endoscope that captures an image including an object, a moving device that includes a robot arm and that moves the endoscope in a body, and a controller that controls the moving device on the basis of the position of the object, wherein the controller is configured to control the moving device in a first control mode in which the endoscope is caused to follow the object at a first speed and a second control mode in which the endoscope is caused to follow the object at a second speed lower than the first speed, the controller controls the moving device in the first control mode when the object is located outside a predetermined three-dimensional region set in the field of view of the endoscope, and the controller controls the moving device in the second control mode when the object is located in the predetermined three-dimensional region.

[0007] Another aspect of the present invention is a control method for controlling a movement of an endoscope on the basis of the position of an object, the endoscope capturing an image including the object, the control method including: controlling the movement of the endoscope in a first control mode in which the endoscope is caused to follow the object at a first speed, when the object is located outside a predetermined three-dimensional region set in a field of view of the endoscope; and controlling the movement of the endoscope in a second control mode in which the endoscope is caused to follow the object at a second speed lower than the first speed, when the object is located in the predetermined three-dimensional region.

BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. **1** illustrates an appearance of a medical system according to an embodiment of the present invention.

[0009] FIG. **2** is a block diagram of the medical system illustrated in FIG. **1**.

[0010] FIG. **3** illustrates a three-dimensional specific region set in the field of view of an endoscope.

[0011] FIG. **4**A is an endoscope image illustrating an example of a cross section of the specific region.

[0012] FIG. **4**B is an endoscope image illustrating another example of a cross section of the specific region.

[0013] FIG. **4**C is an endoscope image illustrating another example of a cross section of the specific region.

[0014] FIG. **5** is an explanatory drawing of a size on the endoscope image of the specific region at depth positions X1, X2, and X3 in FIG. **3**.

[0015] FIG. **6** is an explanatory drawing of a movement of a surgical instrument followed by the endoscope in the endoscope image.

[0016] FIG. **7**A is an explanatory drawing of a specific example of a method for calculating the specific region.

[0017] FIG. **7**B is an explanatory drawing of the specific example of the method for calculating the specific region.

[0018] FIG. **7**C is an explanatory drawing of the specific example of the method for calculating the specific region.

[0019] FIG. **7**D is an explanatory drawing of the specific example of the method for calculating the specific region.

[0020] FIG. **8**A is a flowchart of a control method performed by a controller in FIG. **1**.

[0021] FIG. **8**B is a flowchart of a modification of the control method performed by the controller in FIG. **1**.

[0022] FIG. **9**A is an explanatory drawing of a method for setting the size of the specific region according to the viewing angle of the endoscope.

[0023] FIG. **9**B is an explanatory drawing of the method for setting the size of the specific region according to the viewing angle of the endoscope.

[0024] FIG. **10** is an explanatory drawing of a modification of a movement of the surgical instrument followed by the endoscope in the endoscope image.

[0025] FIG. **11** illustrates a three-dimensional specific region in a reference example.

DESCRIPTION OF EMBODIMENT

[0026] A medical system and a control method according to an embodiment of the present invention will be described below with reference to the accompanying drawings.

[0027] As illustrated in FIG. **1**, a medical system **10** according to the present embodiment includes an endoscope **1** and a surgical instrument **2** that are inserted into the body of a patient, a moving device **3** that holds the endoscope **1** and moves the endoscope **1** in the body, a controller **4** that is connected to the endoscope **1** and the moving device **3** and controls the moving device **3**, and a display device **5** that displays an endoscope image.

[0028] The endoscope **1** is, for example, a rigid endoscope and includes an imaging portion **1***a* that has an image sensor and captures an endoscope image (see FIG. **2**). The endoscope **1** captures an endoscope image D (see FIGS. **5** and **6**), which includes a tip **2***a* of the surgical instrument **2**, through the imaging portion **1***a* and transmits the endoscope image D to the controller **4**. The imaging portion **1***a* is, for example, a three-dimensional camera provided at the tip portion of the endoscope **1** and captures a stereo image, which includes information on the three-dimensional position of the tip **2***a* of the surgical instrument **2**, as the endoscope image D.

[0029] The moving device **3** includes a robot arm **3***a* having a plurality of joints **3***b* and holds the proximal portion of the endoscope **1** at the tip portion of the robot arm **3***a*. In an example, the robot arm **3***a* has three degrees of freedom of movement: a back-and-forth linear motion along the X axis, a rotation (pitch) about the Y axis, and a rotation (yaw) about the Z axis. A rotation (roll) about the X axis is preferably added as a degree of freedom of movement. The X axis is an axis on the same straight line as an optical axis A of the endoscope **1**, and the Y and Z axes are axes that are orthogonal to the optical axis A and extend in respective directions corresponding to the lateral direction and the longitudinal direction of the endoscope image D.

[0030] As illustrated in FIG. **2**, the controller **4** includes at least one processor **4***a* like a central processing unit, a memory **4***b*, a storage unit **4***c*, an input interface **4***d*, an output interface **4***e*, and a network interface **4***f*.

[0031] The endoscope images D transmitted from the endoscope **1** are sequentially inputted to the controller **4** through the input interface **4***d*, are sequentially outputted to the display device **5** through the output interface **4***e*, and are displayed on the display device **5**. A surgeon operates the surgical instrument **2** inserted into a body while observing the endoscope image D displayed on the display device **5**, and performs an operation on an affected area in the body by using the surgical instrument **2**.

[0032] The storage unit **4***c* is a ROM (read-only memory) or a nonvolatile recording medium such as a hard disk and stores a program and data necessary for causing the processor **4***a* to perform processing. The program is read in the memory **4***b* and is executed by the processor **4***a*, thereby implementing the functions of the controller **4**. The functions will be described later. Some of the functions of the controller **4** may be implemented by dedicated logic circuits or the like.

[0033] The controller **4** has a manual mode or a follow-up mode. The manual mode is a mode in which an operator, e.g., a surgeon manually operates the endoscope **1**, whereas the follow-up mode is a mode in which the controller **4** causes the endoscope **1** to automatically follow the tip **2***a* of the surgical instrument (object) **2**.

[0034] The controller **4** switches the manual mode and the follow-up mode on the basis of an instruction from the operator. For example, the controller **4** has AI capable of recognizing a human voice. When recognizing a voice of "manual mode," the controller **4** switches to the manual mode. When recognizing a voice of "follow-up mode," the controller **4** switches to the follow-up mode. The controller **4** may switch the manual mode and the follow-up mode in response to turn-on or turn-off of a manual operation switch (not illustrated) provided on the endoscope **1**.

[0035] In the manual mode, for example, an operator, e.g., a surgeon can remotely operate the robot arm **3***a* by operating an operating device (not illustrated) connected to the controller **4**.

[0036] In the follow-up mode, the controller **4** controls the moving device **3** on the basis of the three-dimensional position of the tip **2***a* of the surgical instrument **2**, so that the endoscope **1** is caused to three-dimensionally follow the tip **2***a* so as to move the tip **2***a* toward the center of the endoscope image D and to a predetermined depth of the endoscope image D. Specifically, the controller **4** recognizes the surgical instrument **2** in the endoscope image D and calculates the three-dimensional position of the tip **2***a* by using the endoscope image D. The controller **4** then operates the joints **3***b* such that the optical axis A of the endoscope **1** moves to the tip **2***a* in a direction that crosses the optical axis A and the tip of the endoscope **1** moves to a position at a predetermined observation distance from the tip **2***a* in the depth direction extending along the optical axis A.

[0037] In this case, the follow-up mode includes a first control mode in which the endoscope **1** is caused to follow the tip **2***a* of the surgical instrument **2** at a first speed and a second control mode in which the endoscope **1** is caused to follow the tip **2***a* of the surgical instrument **2** at a second speed lower than the first speed. As illustrated in FIG. **3**, the controller **4** controls the moving device **3** in the first control mode when the tip **2***a* is located outside a predetermined specific region B, and the controller **4** controls the moving device **3** in the second control mode when the tip **2***a* is located in the specific region B. Thus, when the tip **2***a* is located in the specific region B, sensitivity for following a movement of the tip **2***a* by the endoscope **1** decreases, thereby suppressing excessive following motion of the endoscope **1** with respective to the tip **2***a*.

[0038] The specific region B is a predetermined three-dimensional region that is set in a field of view F of the endoscope **1** and has dimensions in the X direction, the Y direction, and the Z direction that are orthogonal to one another. The X direction is a depth direction parallel to the optical axis A of the endoscope **1**. The Y direction and the Z direction are directions that are orthogonal to the optical axis A and are parallel respectively to the lateral direction and the longitudinal direction of the endoscope image D.

[0039] The specific region B is separated from the tip of the endoscope **1** in the X direction and is set in a part of the range of the field of view F in the X direction. Moreover, the specific region B includes the optical axis A and has a three-dimensional shape that decreases in size in cross section toward the tip of the endoscope **1**. Hence, the specific region B on the endoscope image D is a central region including the center of the endoscope image D. As illustrated in FIGS. **4**A to **4**C, the specific region B orthogonal to the optical axis A may be rectangular, circular, or oval in cross section and may have any other shapes such as a polygon. The specific region B may be superimposed on the endoscope image D or may be hidden.

[0040] In an example, the specific region B and the endoscope image D are identical in shape in cross section. For example, when the endoscope image D is rectangular, the specific region B is also rectangular in cross section. The specific region B displayed on the endoscope image D may interfere with an observation of the endoscope image D and thus is preferably hidden. When the specific region B and the endoscope image D are identical in shape, the surgeon easily recognizes the position of the hidden specific region B.

[0041] The field of view F of the endoscope **1** is typically shaped like a cone having the vertex at or near the tip of the endoscope **1**. The specific region B is preferably a frustum with the vertex shared with the field of view F of the endoscope **1**. As illustrated in FIG. **5**, the size and position of the displayed specific region B are fixed on the endoscope image D regardless of positions X1, X2, and X**3** in the X direction.

[0042] The size of the specific region B on the endoscope image D (that is, the size of the specific region B relative to the field of view F in cross section) is preferably 25% to 55% of the size of the endoscope image D. In the case of the specific region B like a frustum, a vertex angle β of the specific region B is preferably 25% to 55% of a viewing angle α of the endoscope **1**. This configuration can place the tip **2***a* of the surgical instrument **2** at the center of the endoscope image D and suppress excessive following motion of the endoscope **1** with respective to the tip **2***a*.

[0043] When the size of the specific region B is less than 25% of the size of the endoscope image D, the effect of suppressing excessive following motion of the endoscope **1** relative to a movement of the tip **2***a* may become insufficient, leading to frequent movements of the field of view F. When the size of the specific region B is larger than 55% of the size of the endoscope image D, the tip **2***a* is frequently disposed at a position remote from the center of the endoscope image D, leading to difficulty in placing the tip **2***a* at the center.

[0044] As illustrated in FIGS. **3** to **5**, the specific region B includes a non-following region B**1** and a following region B**2**. The non-following region B**1** is a central region of the specific region B including the optical axis A. The following region B**2** is an outer region of the specific region B and surrounds the non-following region B**1**. Like the specific region B, the non-following region B**1** has a three-dimensional shape that decreases in size in cross section toward the tip of the endoscope **1**. The non-following region B**1** is preferably a frustum.

[0045] As illustrated in FIG. **6**, when the tip **2***a* of the surgical instrument **2** is disposed outside the following region B**2**, the controller **4** rotates, for example, the robot arm **3***a* about the Y axis and the Z axis so as to cause the endoscope **1** to follow the tip **2***a* at a first speed V**1**.

[0046] When the tip **2***a* is disposed in the non-following region B**1**, the controller **4** keeps the position of the endoscope **1** without causing the endoscope **1** to follow the tip **2***a*. Specifically, the controller **4** controls the angular velocities of the joints **3***b* to zero. Thus, the second speed in the non-following region B**1** is zero.

[0047] When the tip **2***a* is disposed in the following region B**2**, the controller **4** continues the operation of the endoscope **1** in the previous control cycle. Specifically, when the position of the endoscope **1** is kept in the previous control cycle, the controller **4** keeps the position of the endoscope **1** also in the current control cycle. When the endoscope **1** is caused to follow the tip **2***a* in the previous control cycle, the controller **4** causes the endoscope **1** to follow the tip **2***a* also in the current control cycle. At this point, the speed of following is a second speed V**2** higher than zero.

[0048] In the foregoing control, the following region B**2** acts as a trigger for starting following of the tip **2***a* by the endoscope **1**, and the non-following region B**1** acts as a trigger for terminating following of the tip **2***a* by the endoscope **1**. Specifically, when the tip **2***a* moves from the following region B**2** to an outer region C, the endoscope **1** starts following the tip **2***a*. When the tip **2***a* enters the non-following region B**1** from the outer region C through the following region B**2**, following of the tip **2***a* by the endoscope **1** is terminated.

[0049] The first speed V**1** and the second speed V**2** are each kept constant, whereas the following speed of the endoscope **1** may be changed in two steps.

[0050] Alternatively, the first speed V**1** and the second speed V**2** may change according to a distance from the center of the endoscope image D to the tip **2***a*. For example, the controller **4** may calculate distances from the optical axis A of the endoscope **1** to the tip **2***a* in the Y direction and the Z direction and increase the speeds V**1** and V**2** according to the distances. In this case, the following speeds V**1** and V**2** of the endoscope **1** may continuously decrease from the outer region C to the non-following region B**1**.

[0051] FIGS. **7**A to **7**D are explanatory drawings of a method for calculating the specific region B.

[0052] As illustrated in FIG. **7**A, the controller **4** sets, as a fiducial point E, an intersection point of the optical axis A and a YZ plane P that passes through the tip **2***a* of the surgical instrument **2** and is perpendicular to the optical axis A. The controller **4** then defines, as the specific region B, a region like a rectangular solid or a sphere that is centered around the fiducial point E.

[0053] FIGS. **7**B and **7**C are explanatory drawings of a method for calculating an actual size [mm] of the specific region B.

[0054] A size Lmax_dz[mm] of the endoscope image D (the size of the field of view F in the Z direction) at an observation distance di (i = 1, 2, ...) in the Z direction (longitudinal direction) is expressed by the following formula according to the geometric relationship of FIG. **7**C.

$$Lmax_dz = di*\tan\alpha$$

[0055] where α[deg] is the viewing angle (half angle of view) of the endoscope **1**. A pixel size Lmax_dz_pixel [px] of the endoscope image D in the Z direction is known and is expressed by, for example, the following formula:

$$Lmax_dz_pixel = 1080/2[pixel]$$

[0056] Thus, an actual size L_dz[mm] of the specific region B in the Z direction is calculated from the following formula by using a pixel size[dx] of the specific region B in the Z direction.

$$L_dz = Lmax_dz*(dz/Lmax_dz_pixel)$$

[0057] An actual size L_dy[mm] of the specific region B in the Y direction is also calculated by the same method as L_dz.

[0058] An actual size L_dx of the specific region B in the X direction is also set. For example, the actual size L_dx may be set at a fixed value regardless of the observation distance di. Alternatively, as illustrated in FIG. **7**D, an actual size L_dx at a reference observation distance di (e.g., d1) may be preset and L_dx at another observation distance di (e.g., d2) may be set at a value proportionate to a change of the observation distance.

[0059] The operation of the medical system **10** will be described below.

[0060] A surgeon performs a procedure by operating the surgical instrument **2** inserted into a body while observing the endoscope image D displayed on the display device **5**. During the procedure, the surgeon switches from the manual mode to the follow-up mode or from the follow-up mode to the manual mode in response to, for example, a voice.

[0061] As indicated in FIG. **8**A, when switching to the follow-up mode in step S**1**, the controller **4** performs the control method of steps S**2** to S**8** and controls the moving device **3** in the follow-up mode.

[0062] The control method includes step S**2** of determining whether the tip **2***a* of the surgical instrument **2** is located in the specific region B and steps S**3** to S**8** of causing, when the position of the tip **2***a* is located outside the specific region B, the endoscope **1** to follow the surgical instrument **2** until the tip **2***a* of the surgical instrument **2** reaches the non-following region B**1**.

[0063] After the start of the follow-up mode (YES at step S**1**), the controller **4** calculates the three-dimensional position of the tip **2***a* by using the endoscope image D, which is a stereo image, and determines whether the tip **2***a* is located in the predetermined specific region B (step S**2**). When the tip **2***a* is located in the specific region B (YES at step S**2**), the controller **4** keeps the position of the endoscope **1** without causing the endoscope **1** to follow the surgical instrument **2**. When the tip **2***a* is located outside the specific region B (NO at step S**2**), the controller **4** starts following of the surgical instrument **2** by the endoscope **1** (step S**3**).

[0064] In following of the surgical instrument **2**, the controller **4** selects one of the first control mode and the second control mode on the basis of the position of the tip **2***a*. As illustrated in FIG. **6**, the tip **2***a* is located outside the specific region B at the start of following (NO at step S**4**) and thus the controller **4** controls the moving device **3** in the first control mode, so that the endoscope **1** is caused to follow the tip **2***a* of the surgical instrument **2** at the first speed V**1** so as to move the tip **2***a* of the surgical instrument **2** toward the center of the endoscope image D (step S**5**). The controller **4** controls the moving device **3** in the first control mode until the tip **2***a* enters the specific region B.

[0065] After the tip **2***a* enters the specific region B (YES at step S**4**), the controller **4** then controls the moving device **3** in the second control mode, so that the endoscope **1** is caused to follow the tip **2***a* of the surgical instrument **2** at the second speed V**2** so as to move the tip **2***a* of the surgical instrument **2** toward the center of the endoscope image D. Since the second speed V**2** is lower than the first speed V**1**, the responsivity for following a movement of the tip **2***a* by the endoscope **1** decreases. In other words, after the tip **2***a* returns to the specific region B from the outer region C, the endoscope **1** is prevented from excessively following a movement of the surgical instrument **2**. The controller **4** controls the moving device **3** in the second control mode until the tip **2***a* enters the non-following region B**1**.

[0066] When the tip **2***a* of the surgical instrument **2** enters the non-following region B**1** (YES at step S**6**), the controller **4** causes the endoscope **1** to finish following the surgical instrument **2** (step S**8**).

[0067] While the follow-up mode continues (NO at step S**9**), the controller **4** repeats steps S**1** to S**8**.

[0068] To allow a surgeon to follow an object through the endoscope **1** with ease of operation, it is desirable to cause the endoscope **1** to follow the surgical instrument **2** so as to satisfy three conditions: suppressing excessive following motion, bringing the tip **2***a* of the surgical instrument **2** at the center of the endoscope image D, and bringing the tip **2***a* of the surgical instrument **2** at a proper distance in the X direction.

[0069] According to the present embodiment, the specific region B is a three-dimensional region set in the field of view F and thus can be properly designed. For example, a distance between the tip of the endoscope **1** and the specific region B in the X direction and a size of the specific region B in cross section at each position in the X direction are designed to satisfy the three conditions. This allows the endoscope **1** to follow the surgical instrument **2** with ease of operation.

[0070] Moreover, the specific region B is shaped to decrease in size in cross section toward the tip of the endoscope **1**, thereby suppressing a difference in the size of the displayed specific region B on the endoscope image D between positions in the X direction. The specific region B is preferably displayed with a fixed size regardless of the position in the X direction. This can suppress excessive following motion of the endoscope **1** and place the tip **2***a* at the center regardless of the position of the tip **2***a* in the X direction.

[0071] FIG. **11** illustrates a specific region B′ as a reference example. As illustrated in FIG. **11**, when the specific region B′ is formed by simply extending a two-dimensional region on the image plane of the endoscope image D, the specific region B′ extends from the tip of the endoscope **1** in the X direction. Thus, the endoscope **1** cannot be caused to follow the surgical instrument **2** such that the tip **2***a* is brought at a proper distance in the X direction.

[0072] Moreover, the size of the specific region B′ is fixed in cross section and thus the displayed specific region B′ on the endoscope image D changes in size according to the position in the X direction. This leads to difficulty in suppressing excessive following motion of the endoscope **1** with respective to the surgical instrument **2** while placing the tip **2***a* at the center. Specifically, the displayed specific region B′ decreases in size at a position X**3** remote from the tip of the endoscope **1** in the X direction, so that excessive following motion of the endoscope **1** cannot be suppressed, though the tip **2***a* can be placed at the center. The size of the displayed specific region B′ increases at a position X1 close to the tip of the endoscope **1** in the X direction. This can suppress excessive following motion of the endoscope **1** but leads to difficulty in placing the tip **2***a* at the center.

[0073] In the foregoing embodiment, when the tip **2***a* is located in the following region B**2**, the controller **4** continues the operation of the endoscope **1** in the previous control cycle. Alternatively, the endoscope **1** may be caused to always follow the tip **2***a* at the second speed V**2** larger than

zero. In other words, the controller **4** may control the moving device **3** in the second control mode in either of the following cases: where the tip **2***a* enters the following region B**2** from the outer region C, and where the tip **2***a* enters the following region B**2** from the non-following region B**1**.

[0074] In this case, as indicated in FIG. **8**B, the controller **4** determines whether the tip **2***a* is located in the non-following region B**1** (step S**2**′). When the tip **2***a* moves from the non-following region B**1** into the following region B**2** (NO at step S**2**′), the controller **4** starts following the surgical instrument **2** by the endoscope **1** (step S**3**).

[0075] The tip **2***a* is located in the following region B**2** at the start of following (YES at step S**4** and NO at step S**6**) and thus the controller **4** controls the moving device **3** in the second control mode, so that the endoscope **1** is caused to follow the tip **2***a* of the surgical instrument **2** at the second speed V**2** so as to move the tip **2***a* of the surgical instrument **2** toward the center of the endoscope image D (step S**7**). The controller **4** controls the moving device **3** in the second control mode until the tip **2***a* enters the non-following region B**1**. As described above, since the second speed V**2** is lower than the first speed V**1**, the endoscope **1** is prevented from excessively following a movement of the surgical instrument **2** while the tip **2***a* moves in the following region B**2**.

[0076] When the tip **2***a* moves out of the specific region B while being followed by the endoscope **1** in the second control mode (NO at step S**4**), the controller **4** switches from the second control mode to the first control mode (step S**5**) and controls the moving device **3** in the first control mode until the tip **2***a* returns to the specific region B.

[0077] In the foregoing embodiment, as illustrated in FIGS. **9**A and **9**B, the controller **4** may change the size of the specific region B in cross section according to the viewing angle α of the endoscope **1**.

[0078] For example, in the storage unit **4***c*, a value of the viewing angle α is stored for each type of the endoscope **1**. The controller **4** recognizes the type of the endoscope **1** held by the robot arm **3***a*, reads the value of the viewing angle α of the recognized type from the storage unit **4***c*, and sets the vertex angle βof the specific region B at a predetermined rate of the viewing angle α. For example, the vertex angle β is calculated by multiplying the value of the viewing angle α by a predetermined rate k selected from 25% to 55%. Thus, the specific region B increases in size in cross section in proportion to the viewing angle α.

[0079] With this configuration, the area ratio of the cross section of the specific region B to the cross section of the field of view F is kept constant regardless of a difference in the viewing angle α of the used endoscope **1**. Hence, the displayed specific region B on the endoscope image D displayed on the display device **5** can have the same size regardless of the viewing angle α of the endoscope **1**.

[0080] In the foregoing embodiment, the specific region B includes the non-following region B**1** where the endoscope **1** is not caused to follow the surgical instrument **2**. Alternatively, as illustrated in FIG. **10**, the non-following region B**1** may be absent in the specific region B. In this modification, the controller **4** causes the endoscope **1** to follow the surgical instrument **2** at the second speed V**2** until the tip **2***a* of the surgical instrument **2** is located at the center of the endoscope image D. When the tip **2***a* is located at the center of the endoscope image D, the controller **4** causes the endoscope **1** to finish following the surgical instrument **2**.

[0081] In the case of FIG. **6**, the endoscope **1** finishes following the tip **2***a* when the tip **2***a* reaches the end of the following region B**2** remote from the center of the endoscope image D. In contrast, in FIG. **10**, the endoscope **1** is caused to follow the tip **2***a* until the tip **2***a* reaches the center of the endoscope image D. Thus, a procedure can be performed with the tip **2***a* located at the center of the endoscope image D.

[0082] In the modification of FIG. **10**, the second speed V**2** is preferably 50% or less of the first speed V**1**. The second speed V**2** may remain constant or gradually decrease as the tip **2***a* of the surgical instrument **2** moves close to the center of the endoscope image D. If the second speed V**2** is higher than 50% of the first speed V**1**, it is difficult to sufficiently obtain the effect of suppressing excessive following motion of the endoscope **1**.

[0083] In the foregoing embodiment, the shape of the specific region B may be changed in cross section. For example, the cross-sectional shape can be selected from a rectangle, a circle, and an ellipse in FIGS. **4**A to **4**C, and parameters dy, dz, R, a, and b can be set to determine the size of each shape in cross section. The selection of the shape and the setting of the parameters may be manual operations performed by the surgeon or automatic operations performed by the controller **4**.

[0084] With this configuration, the shape and size of the specific region B in cross section can be set according to, for example, the technique, the contents of the procedure, or the preferences of the surgeon.

[0085] In an example, in a procedure where the tip **2***a* frequently makes large movements in the longitudinal direction of the endoscope image D, the cross section is set as a vertically oriented ellipse in FIG. **4**C. This can prevent the field of view F from excessively reacting to a longitudinal movement of the tip **2***a* and vibrating in the longitudinal direction, thereby stopping the field of view F regardless of a longitudinal movement of the tip **2***a* during the procedure.

[0086] The controller **4** may recognize the type of the surgical instrument **2** or a procedure and automatically change at least one of the shape of the specific region B, the sizes of the specific region B in the X, Y, and Z directions, and the position of the specific region B according to the type of the surgical instrument **2** or the procedure. Furthermore, the controller **4** may automatically change the first speed and the second speed according to the type of the surgical instrument **2** or the procedure. For example, the controller **4** recognizes the type of the surgical instrument **2** on the basis of the endoscope image D and recognizes the type of the procedure according to the type of the surgical instrument **2**.

[0087] The proper shape, size, and position of the specific region B change according to the type of the surgical instrument **2** or the procedure. With this configuration, the shape, size, and position of the specific region B can be automatically set to be suitable for the type of the surgical instrument **2** and the procedure.

[0088] In an example, when the type of the surgical instrument **2** is gripping forceps, the specific region B having a larger size in the X direction is set to be located at a larger distance from the tip of the endoscope **1**. For example, a range of 90 mm to 190 mm from the tip of the endoscope **1** is set as the specific region B.

[0089] In another example, when the type of the surgical instrument **2** is an energy treatment tool, the specific region B is set to be located at a shorter distance from the tip of the endoscope **1** in order to perform an elaborate procedure. For example, a range of 60 mm to 90 mm from the tip of the endoscope **1** is set as the specific region B. Moreover, in order to prevent a movement of the field of view F during a blunt dissection operation, the size of the specific region B may be increased in cross section or the second speed may be reduced.

[0090] In still another example, the controller **4** may learn a movement of the tip **2***a* during a procedure and change the shape and size of the specific region B such that the motion range of the tip **2***a* is included in the specific region B during the procedure.

[0091] In the foregoing embodiment, a definite border may be absent between the specific region B and the outer region C. In other words, the controller **4** may continuously change the following speed according to a distance from the center of the endoscope image D to the tip **2***a*.

[0092] For example, the controller **4** may calculate an angular velocity Vp of a rotation about the Y axis and an angular velocity Vy of a rotation about the Z axis according to the formula below, and rotate the robot arm **3***a* at the calculated angular velocities Vp and Vy. py is a distance from the center of the endoscope image D to the tip **2***a* in the Y direction, pz is a distance from the center of the endoscope image D to the tip **2***a* in the Z direction, and Gy and Gz are predetermined coefficients of proportionality.

$$Vp = Gz*pz$$

$$Vy = Gy*py$$

[0093] In the foregoing embodiment, the endoscope **1** captures a three-dimensional stereo image as the endoscope image D. Alternatively, a two-dimensional endoscope image D may be captured. In this case, for example, the position of the tip **2***a* of the surgical instrument **2** in the X direction may be measured by another distance-measuring means, e.g., a distance sensor provided at the tip of the endoscope **1**.

[0094] In the foregoing embodiment, an object to be followed by the endoscope **1** is the surgical instrument **2** but is not limited thereto. The endoscope **1** may follow any object in the endoscope image D during a surgical operation. For example, an object may be a lesion, an organ, a blood vessel, a marker, a biomedical material such as gauze, or a medical instrument other than the surgical instrument **2**.

REFERENCE SIGNS LIST

1	Endoscope
1*a*	Imaging portion
2	Surgical instrument (object)
3	Moving device
3*a*	Robot arm
3*b*	Joint
4	Controller
5	Display device
10	Medical system
A	Optical axis
B	Specific region (predetermined three-dimensional region)
B**1**	Non-following region (specific region)
B**2**	Following region (specific region)
C	Outer region
D	Endoscope image
F	Field of view
α	Viewing angle

1. A medical system comprising:
an endoscope that captures an image including an object;
a moving device that comprises a robot arm and that moves the endoscope in a body; and
a controller that controls the moving device on a basis of a position of the object,
wherein the controller is configured to control the moving device in a first control mode in which the endoscope is caused to follow the object at a first speed and a second control mode in which the endoscope is caused to follow the object at a second speed lower than the first speed,
the controller controls the moving device in the first control mode when the object is located outside a predetermined three-dimensional region set in a field of view of the endoscope, and
the controller controls the moving device in the second control mode when the object is located in the predetermined three-dimensional region.

2. The medical system according to claim **1**, wherein the three-dimensional region orthogonal to an optical axis of the endoscope is shaped to decrease in size in cross section toward a tip of the endoscope.

3. The medical system according to claim **1**, wherein the endoscope is configured to capture a stereo image, and
the controller calculates a three-dimensional position of the object by using the stereo image.

4. The medical system according to claim **1**, wherein the object is a surgical instrument, and
the controller recognizes a type of the surgical instrument and
the controller changes at least one of a size and a shape of the three-dimensional region orthogonal to an optical axis of the endoscope in cross section according to the type of the surgical instrument.

5. The medical system according to claim **1**, wherein the controller controls the moving device in the first control mode and the second control mode so as to move the object toward a center of the image.

6. The medical system according to claim **1**, wherein the controller controls the moving device in the first control mode until the object enters the three-dimensional region.

7. The medical system according to claim **1**, wherein the controller recognizes a type of a procedure, and
the controller changes at least one of a size and a shape of the three-dimensional region according to the type of the procedure.

8. The medical system according to claim **1**, wherein the controller changes a size of the three-dimensional region orthogonal to an optical axis of the endoscope in cross section according to a viewing angle of the endoscope.

9. A control method for controlling a movement of an endoscope on a basis of a position of an object, the endoscope capturing an image including the object,
the control method comprising:

controlling the movement of the endoscope in a first control mode in which the endoscope is caused to follow the object at a first speed, when the object is located outside a predetermined three-dimensional region set in a field of view of the endoscope; and

controlling the movement of the endoscope in a second control mode in which the endoscope is caused to follow the object at a second speed lower than the first speed, when the object is located in the predetermined three-dimensional region.

* * * * *