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(54) APPARATUS, CONTROL DEVICE, METHOD, AND COMPUTER PROGRAM FOR MANAGING TEMPERATURE OF AN IMAGING UNIT

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(57) ABSTRACT

An apparatus including a temperature acquisition unit that acquires a temperature measured by a temperature sensor; a temperature determination unit that determines whether the temperature acquired by the temperature acquisition unit at the time of executing the detection operation for work is within an allowable range determined in advance in order to ensure the accuracy of the detection operation; and a temperature regulation unit that executes a warm-up operation for raising the temperature when the temperature determination unit determines that the temperature is lower than the lower limit of the allowable range, and executes a cooling operation for lowering the temperature when the temperature determination unit determines that the temperature is higher than the upper limit of the allowable range.

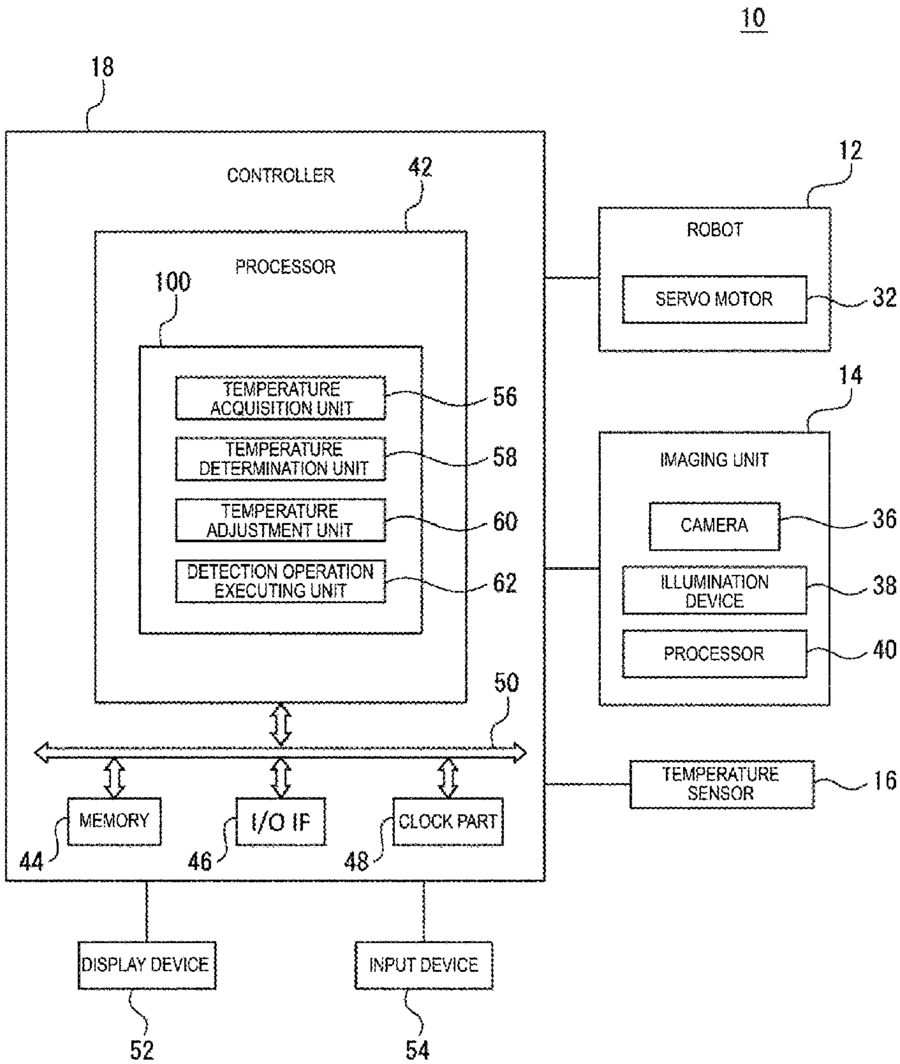


Fig. 1

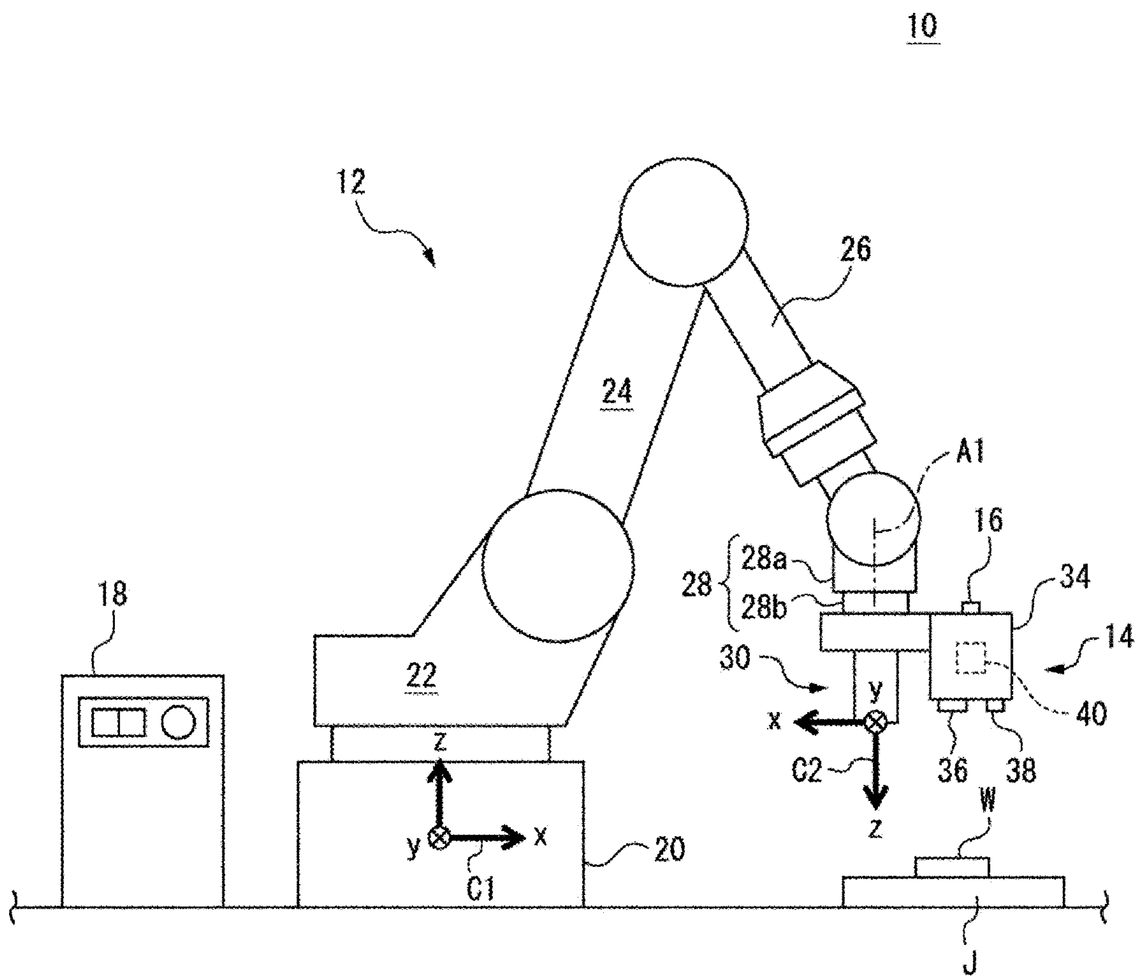

10
12
26
24
A1
16
28a
28
28b
34
14
18
30
22
y
x
40
z
C2
36
38
z
W
y
x
20
C1
J

Fig. 2

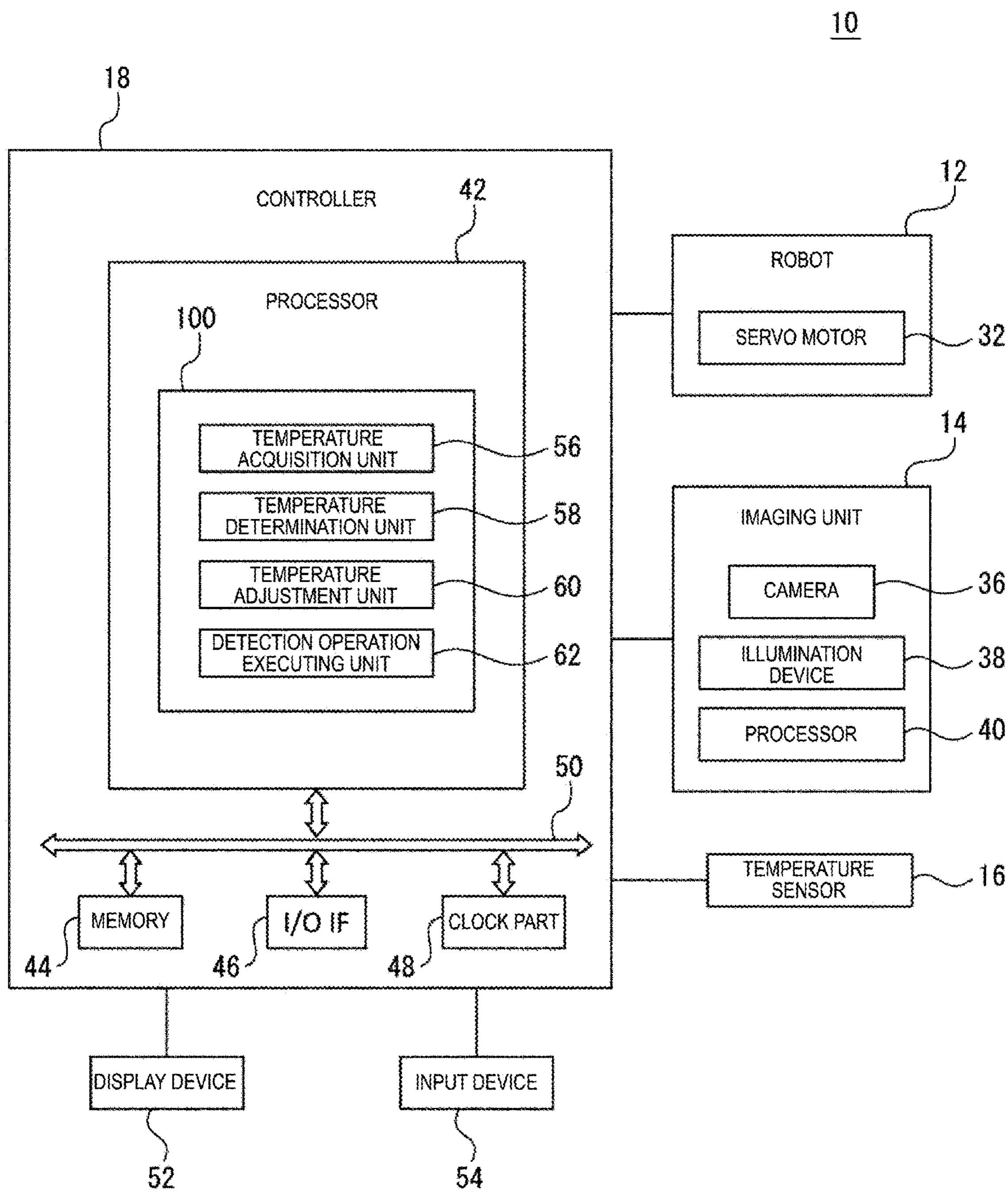

10
18
CONTROLLER
42
PROCESSOR
100
TEMPERATURE ACQUISITION UNIT
56
TEMPERATURE DETERMINATION UNIT
58
TEMPERATURE ADJUSTMENT UNIT
60
DETECTION OPERATION EXECUTING UNIT
62
50
MEMORY
44
I/O IF
46
CLOCK PART
48
12
ROBOT
SERVO MOTOR
32
14
IMAGING UNIT
CAMERA
36
ILLUMINATION DEVICE
38
PROCESSOR
40
TEMPERATURE SENSOR
16
DISPLAY DEVICE
52
INPUT DEVICE
54

Fig. 3

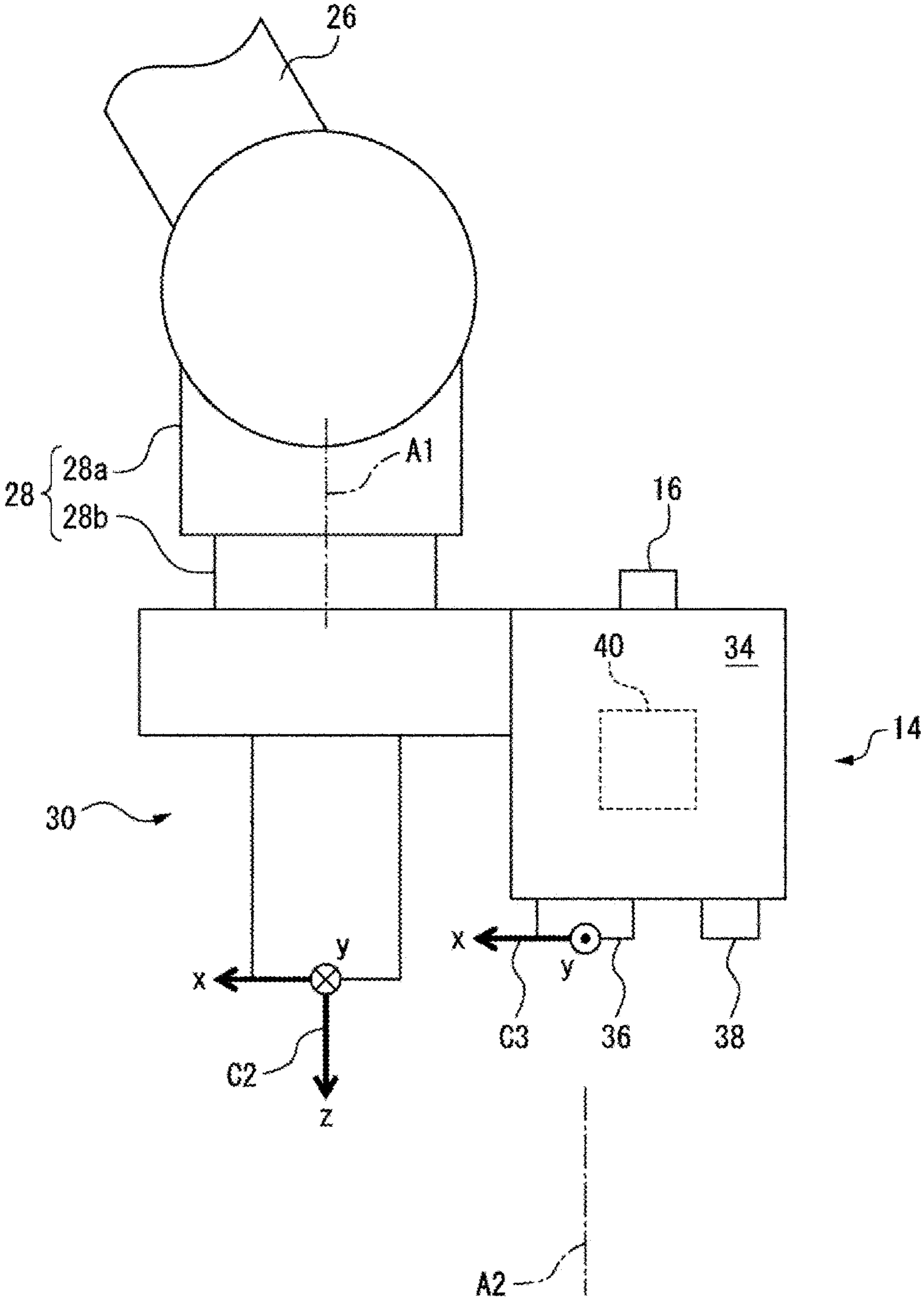


Fig. 4

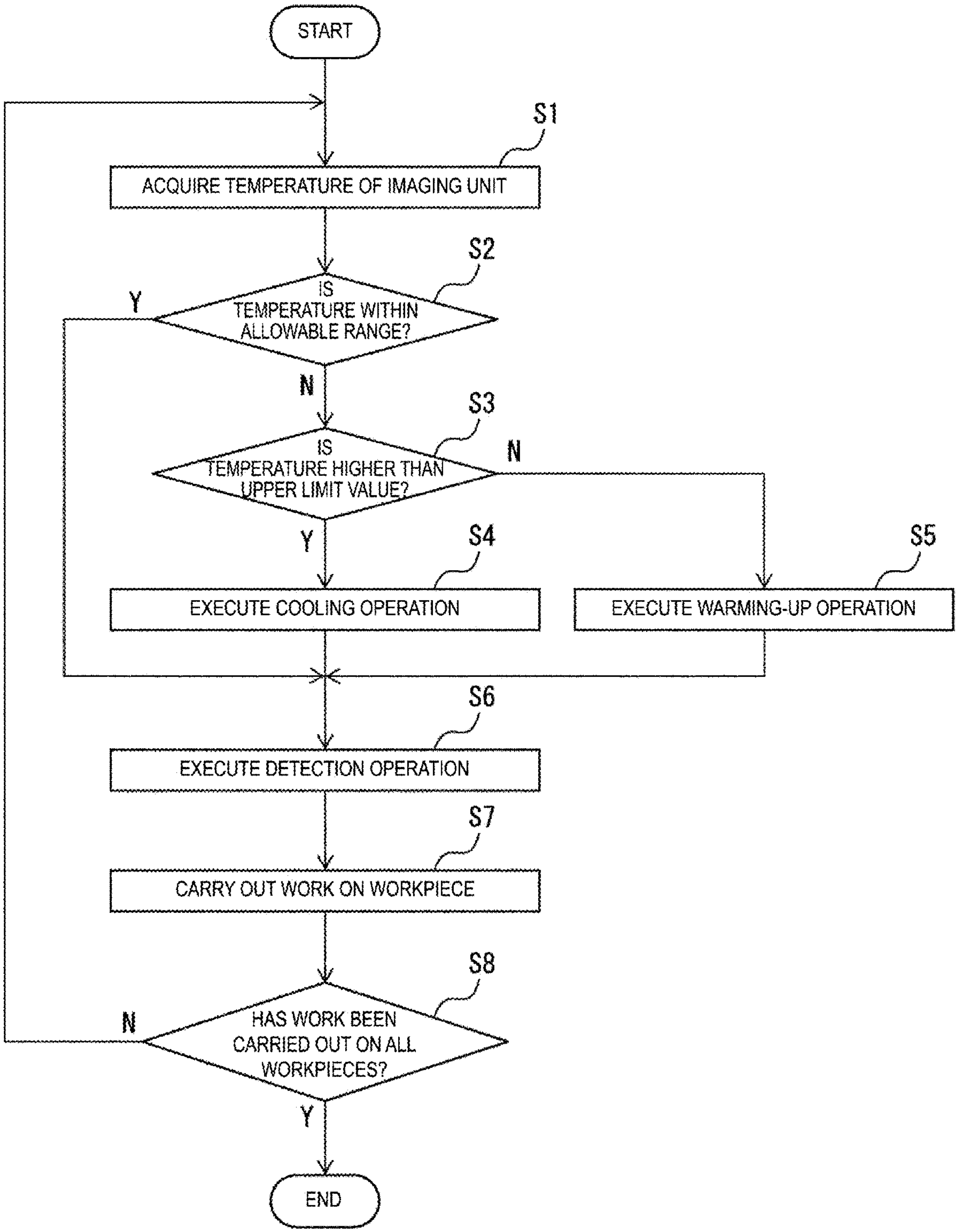

START
S1
ACQUIRE TEMPERATURE OF IMAGING UNIT
S2
IS TEMPERATURE WITHIN ALLOWABLE RANGE?
Y
N
S3
IS TEMPERATURE HIGHER THAN UPPER LIMIT VALUE?
N
Y
S4
EXECUTE COOLING OPERATION
S5
EXECUTE WARMING-UP OPERATION
S6
EXECUTE DETECTION OPERATION
S7
CARRY OUT WORK ON WORKPIECE
S8
HAS WORK BEEN CARRIED OUT ON ALL WORKPIECES?
N
Y
END

Fig. 5

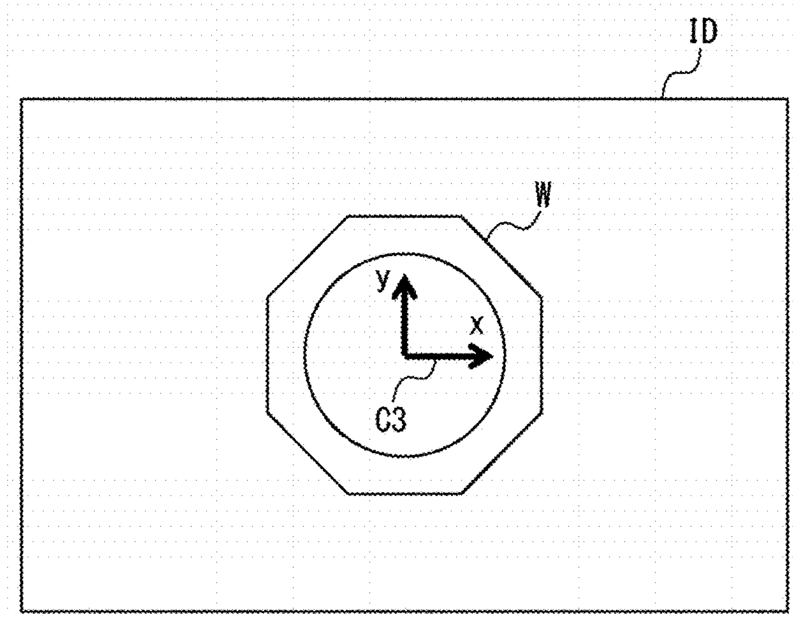


Fig. 6

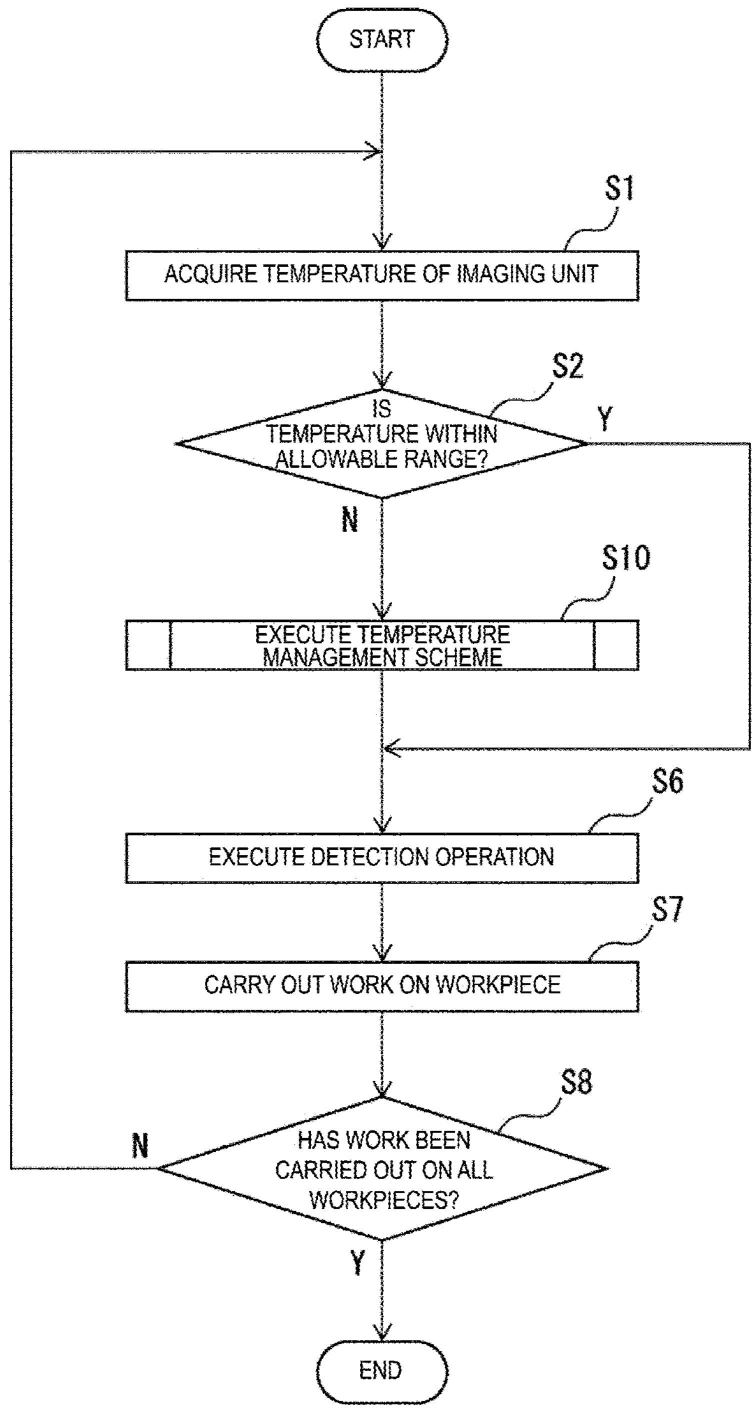

START
S1
ACQUIRE TEMPERATURE OF IMAGING UNIT
S2
IS TEMPERATURE WITHIN ALLOWABLE RANGE?
Y
N
S10
EXECUTE TEMPERATURE MANAGEMENT SCHEME
S6
EXECUTE DETECTION OPERATION
S7
CARRY OUT WORK ON WORKPIECE
S8
HAS WORK BEEN CARRIED OUT ON ALL WORKPIECES?
N
Y
END

Fig. 7

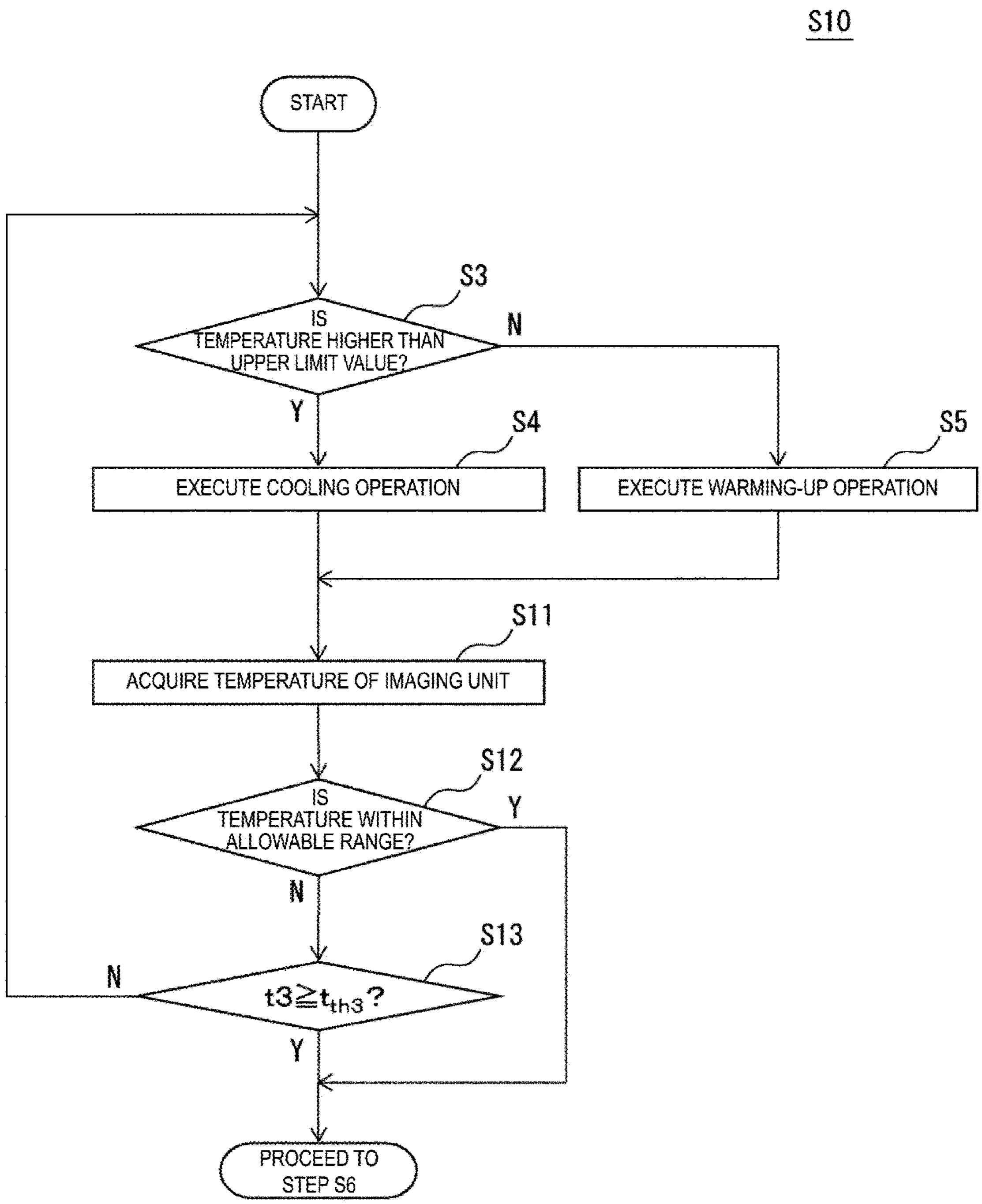

S10
START
S3
IS TEMPERATURE HIGHER THAN UPPER LIMIT VALUE?
N
Y
S4
EXECUTE COOLING OPERATION
S5
EXECUTE WARMING-UP OPERATION
S11
ACQUIRE TEMPERATURE OF IMAGING UNIT
S12
IS TEMPERATURE WITHIN ALLOWABLE RANGE?
Y
N
S13
$t3 \geqq t_{th3}$?
N
Y
PROCEED TO STEP S6

Fig. 8

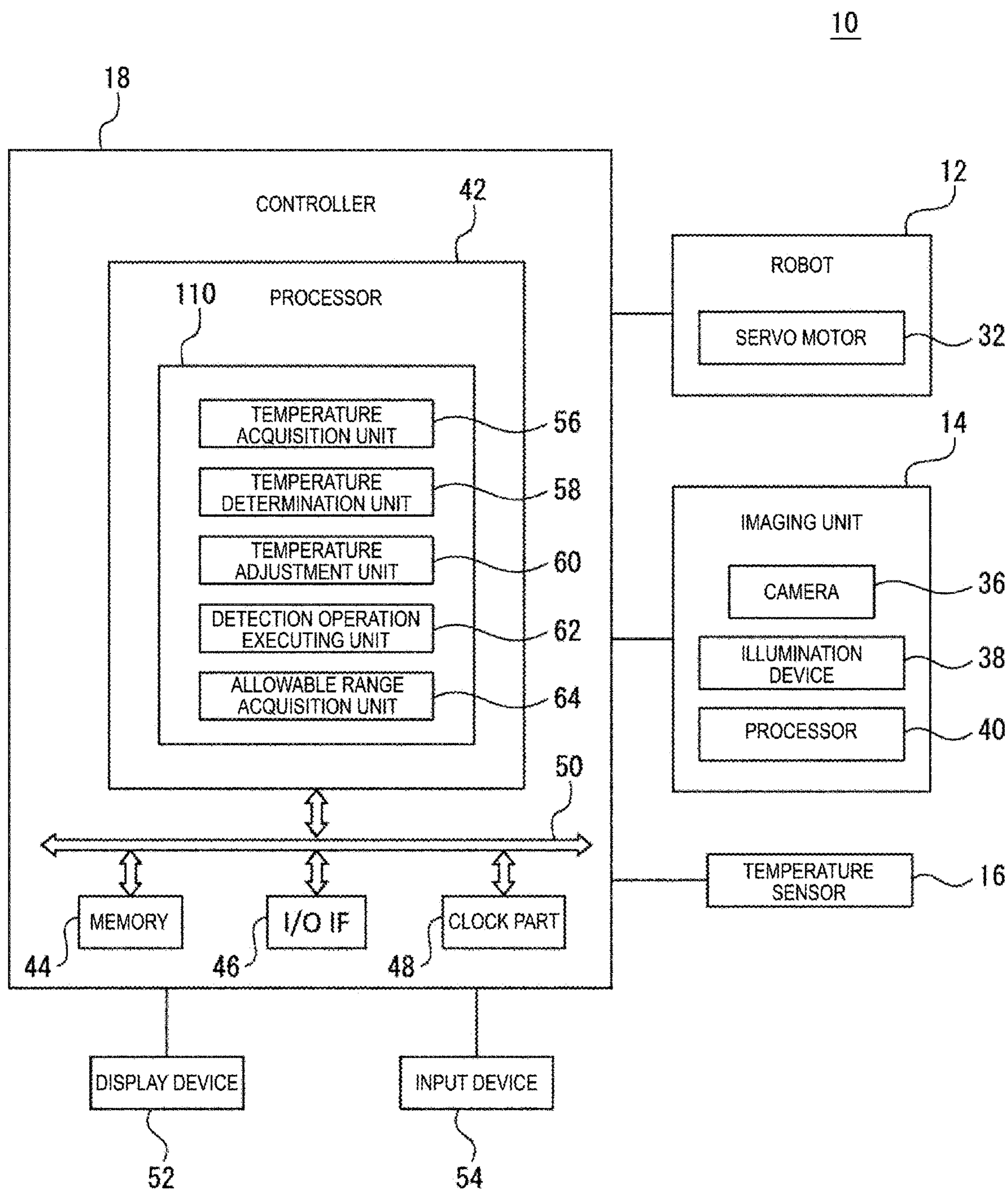

10
18
CONTROLLER
42
PROCESSOR
110
TEMPERATURE ACQUISITION UNIT
56
TEMPERATURE DETERMINATION UNIT
58
TEMPERATURE ADJUSTMENT UNIT
60
DETECTION OPERATION EXECUTING UNIT
62
ALLOWABLE RANGE ACQUISITION UNIT
64
50
MEMORY
44
I/O IF
46
CLOCK PART
48
12
ROBOT
SERVO MOTOR
32
14
IMAGING UNIT
CAMERA
36
ILLUMINATION DEVICE
38
PROCESSOR
40
TEMPERATURE SENSOR
16
DISPLAY DEVICE
52
INPUT DEVICE
54

Fig. 9

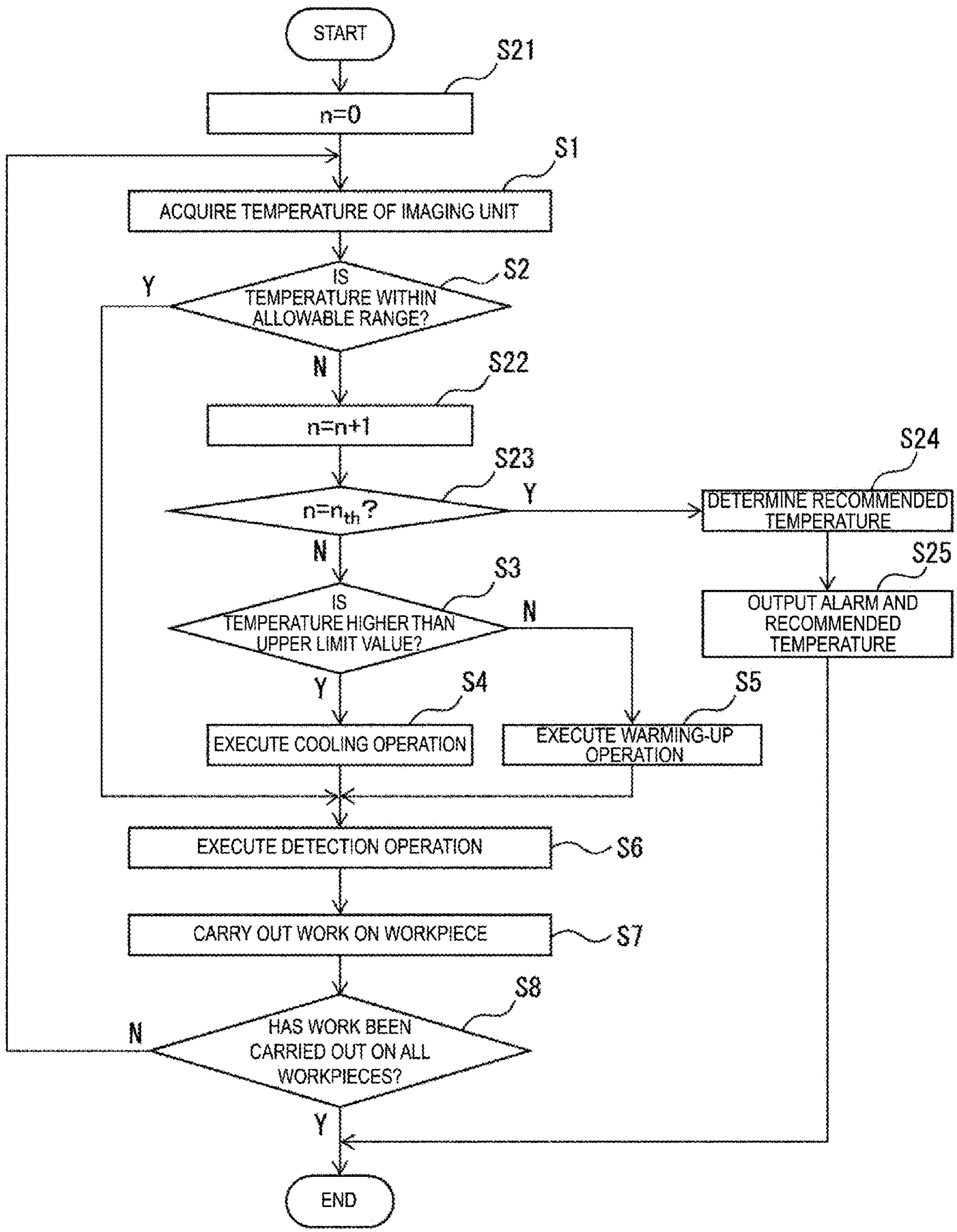

START
S21
n=0
S1
ACQUIRE TEMPERATURE OF IMAGING UNIT
S2
IS TEMPERATURE WITHIN ALLOWABLE RANGE?
Y
N
S22
n=n+1
S23
n=n_th?
Y
N
S24
DETERMINE RECOMMENDED TEMPERATURE
S25
OUTPUT ALARM AND RECOMMENDED TEMPERATURE
S3
IS TEMPERATURE HIGHER THAN UPPER LIMIT VALUE?
N
Y
S4
EXECUTE COOLING OPERATION
S5
EXECUTE WARMING-UP OPERATION
EXECUTE DETECTION OPERATION
S6
CARRY OUT WORK ON WORKPIECE
S7
S8
HAS WORK BEEN CARRIED OUT ON ALL WORKPIECES?
N
Y
END

Fig. 10

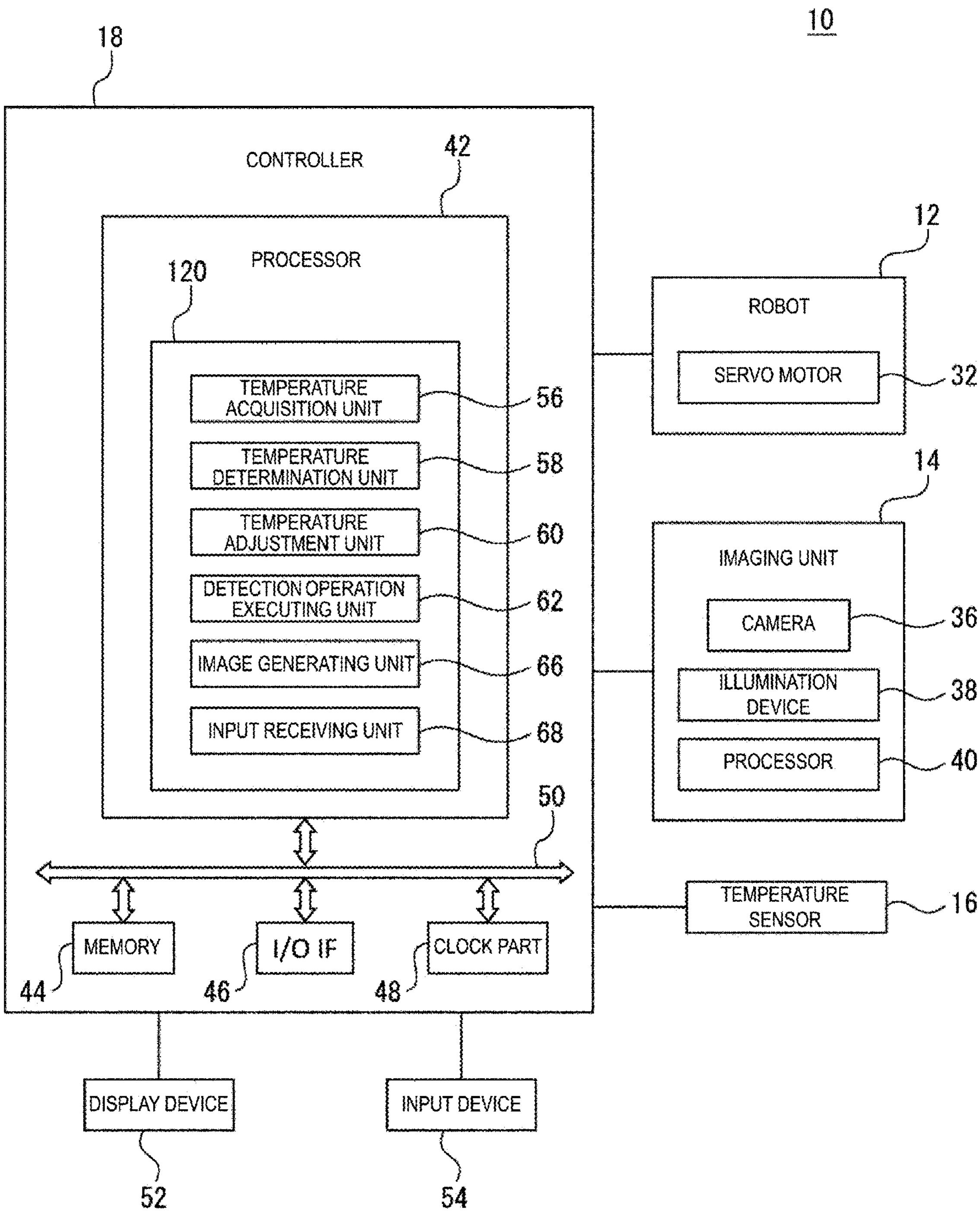

10
18
CONTROLLER
42
PROCESSOR
120
TEMPERATURE ACQUISITION UNIT
56
TEMPERATURE DETERMINATION UNIT
58
TEMPERATURE ADJUSTMENT UNIT
60
DETECTION OPERATION EXECUTING UNIT
62
IMAGE GENERATING UNIT
66
INPUT RECEIVING UNIT
68
50
MEMORY
44
I/O IF
46
CLOCK PART
48
12
ROBOT
SERVO MOTOR
32
14
IMAGING UNIT
CAMERA
36
ILLUMINATION DEVICE
38
PROCESSOR
40
TEMPERATURE SENSOR
16
DISPLAY DEVICE
52
INPUT DEVICE
54

Fig. 11

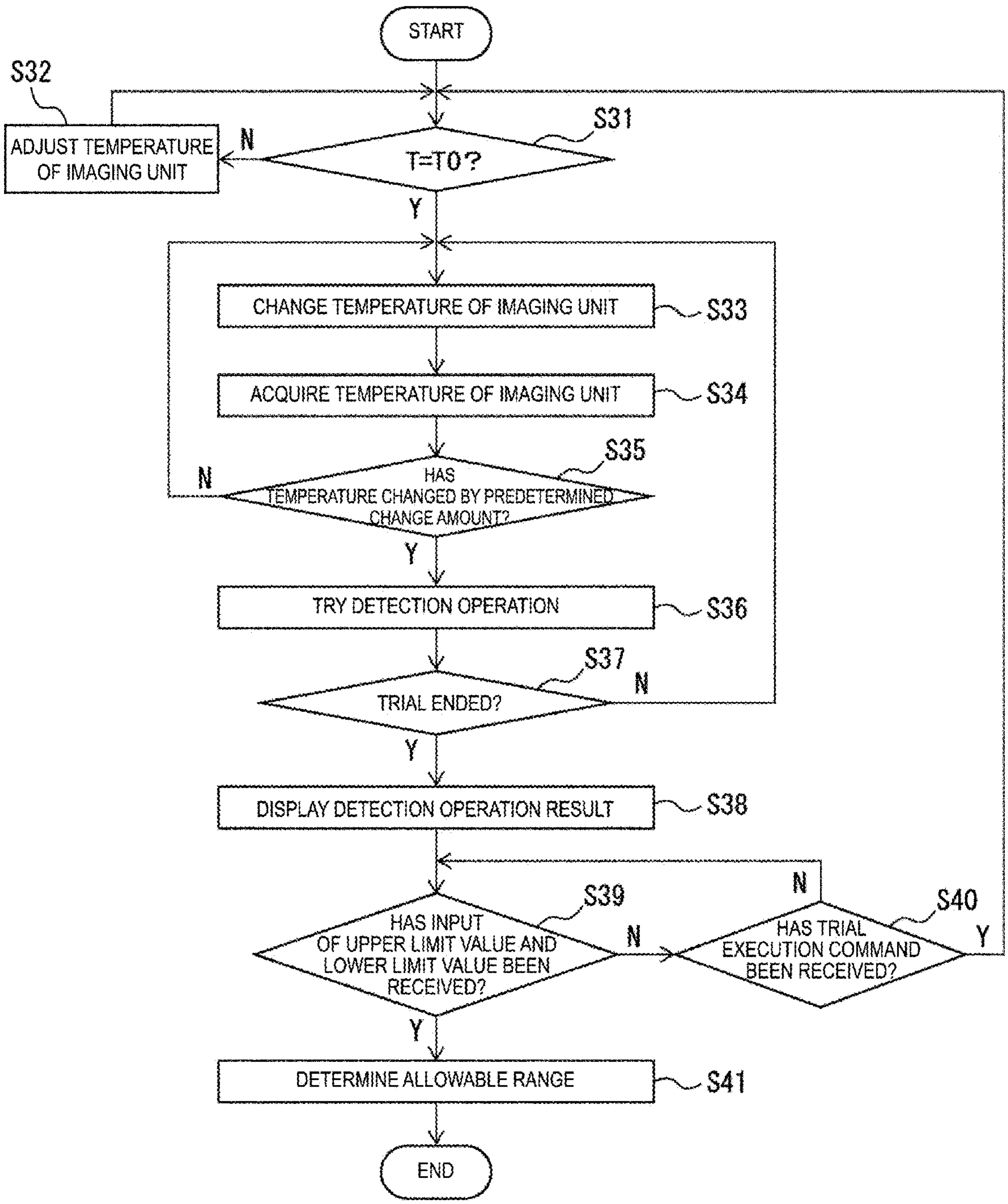

START
S32
ADJUST TEMPERATURE OF IMAGING UNIT
N
S31
T=T0?
Y
CHANGE TEMPERATURE OF IMAGING UNIT
S33
ACQUIRE TEMPERATURE OF IMAGING UNIT
S34
S35
N
HAS TEMPERATURE CHANGED BY PREDETERMINED CHANGE AMOUNT?
Y
TRY DETECTION OPERATION
S36
S37
N
TRIAL ENDED?
Y
DISPLAY DETECTION OPERATION RESULT
S38
N
S39
HAS INPUT OF UPPER LIMIT VALUE AND LOWER LIMIT VALUE BEEN RECEIVED?
N
S40
HAS TRIAL EXECUTION COMMAND BEEN RECEIVED?
Y
Y
DETERMINE ALLOWABLE RANGE
S41
END

Fig. 12

RI1

Temp. (70)	X (72)	Y (72)	Z (72)	SCOR (74)	CONT (76)	DIST (78)
10	x10	y10	z10	α10	β10	γ10
15	x15	y15	z15	α15	β15	γ15
20	x20	y20	z20	α20	β20	γ20
25	x25	y25	z25	α25	β25	γ25
30	x30	y30	z30	α30	β30	γ30
35	x35	y35	z35	α35	β35	γ35
40	x40	y40	z40	α40	β40	γ40
45	x45	y45	z45	α45	β45	γ45
50	x50	y50	z50	α50	β50	γ50
55	x55	y55	z55	α55	β55	γ55
60	x60	y60	z60	α60	β60	γ60

Fig. 13

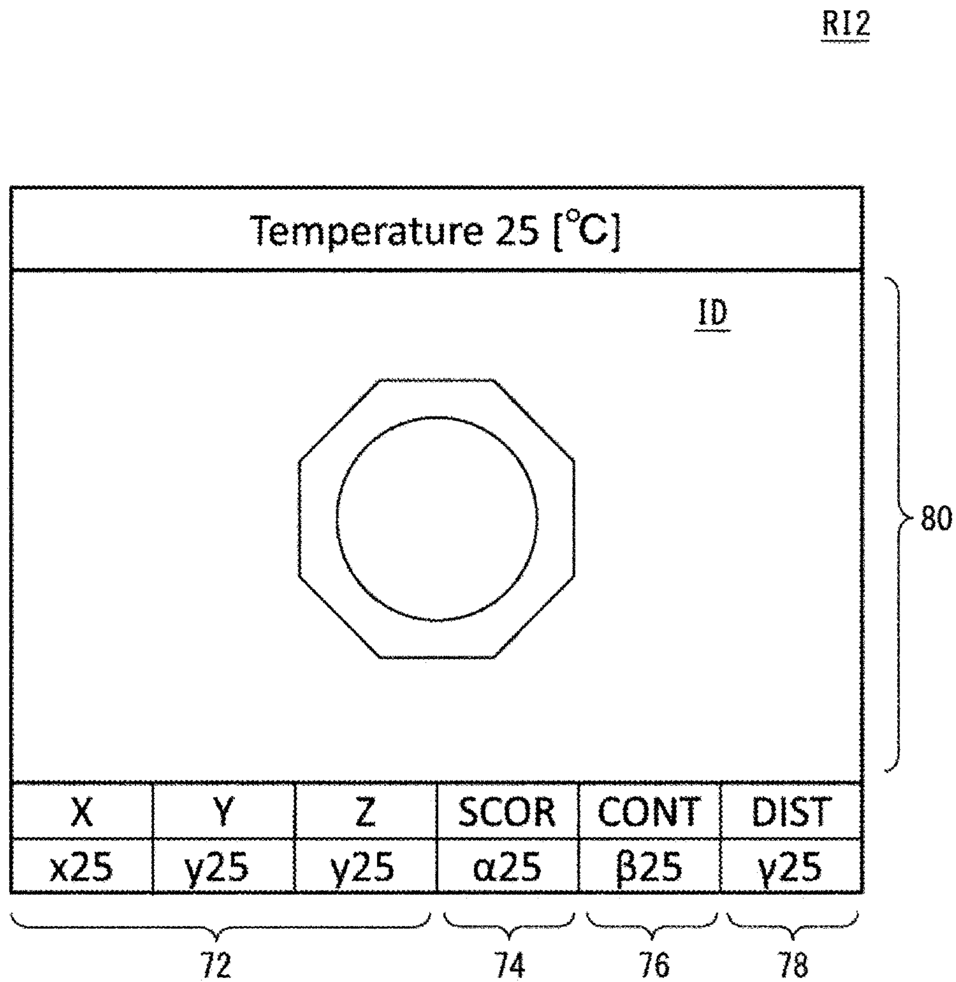

RI2
Temperature 25 [°C]
ID
80
X
Y
Z
SCOR
CONT
DIST
x25
y25
y25
α25
β25
γ25
72
74
76
78

Fig. 14

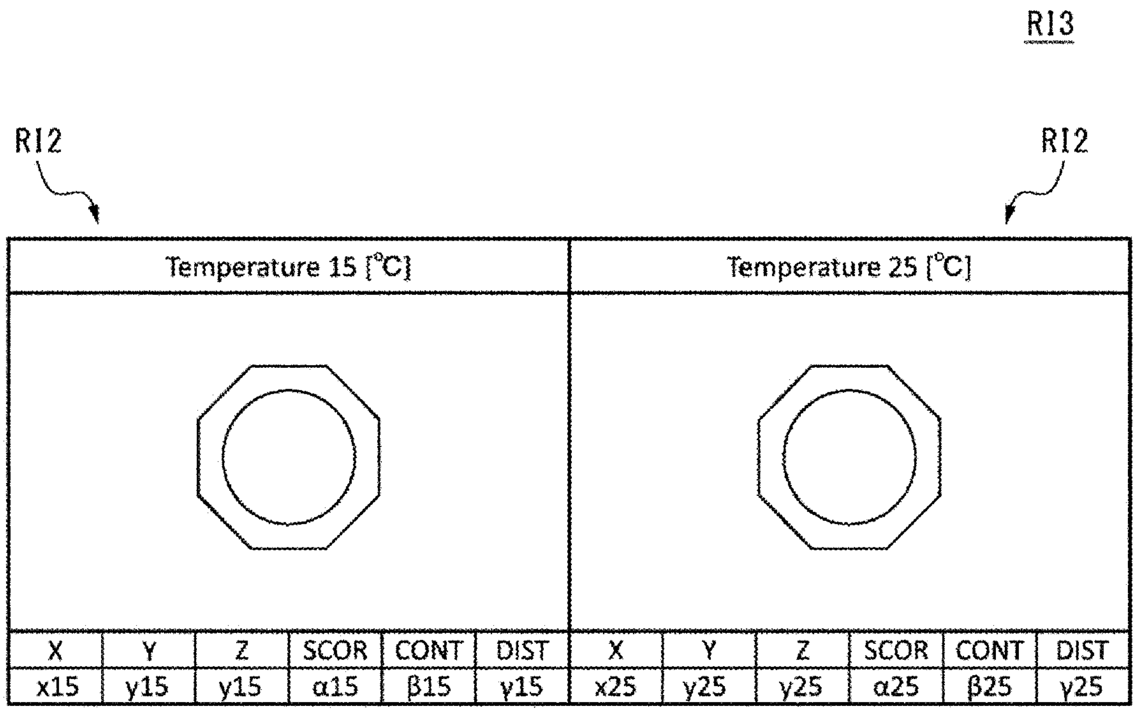

RI3
RI2
RI2
Temperature 15 [°C]
Temperature 25 [°C]
X Y Z SCOR CONT DIST X Y Z SCOR CONT DIST
x15 y15 y15 α15 β15 γ15 x25 y25 y25 α25 β25 γ25

Fig. 15

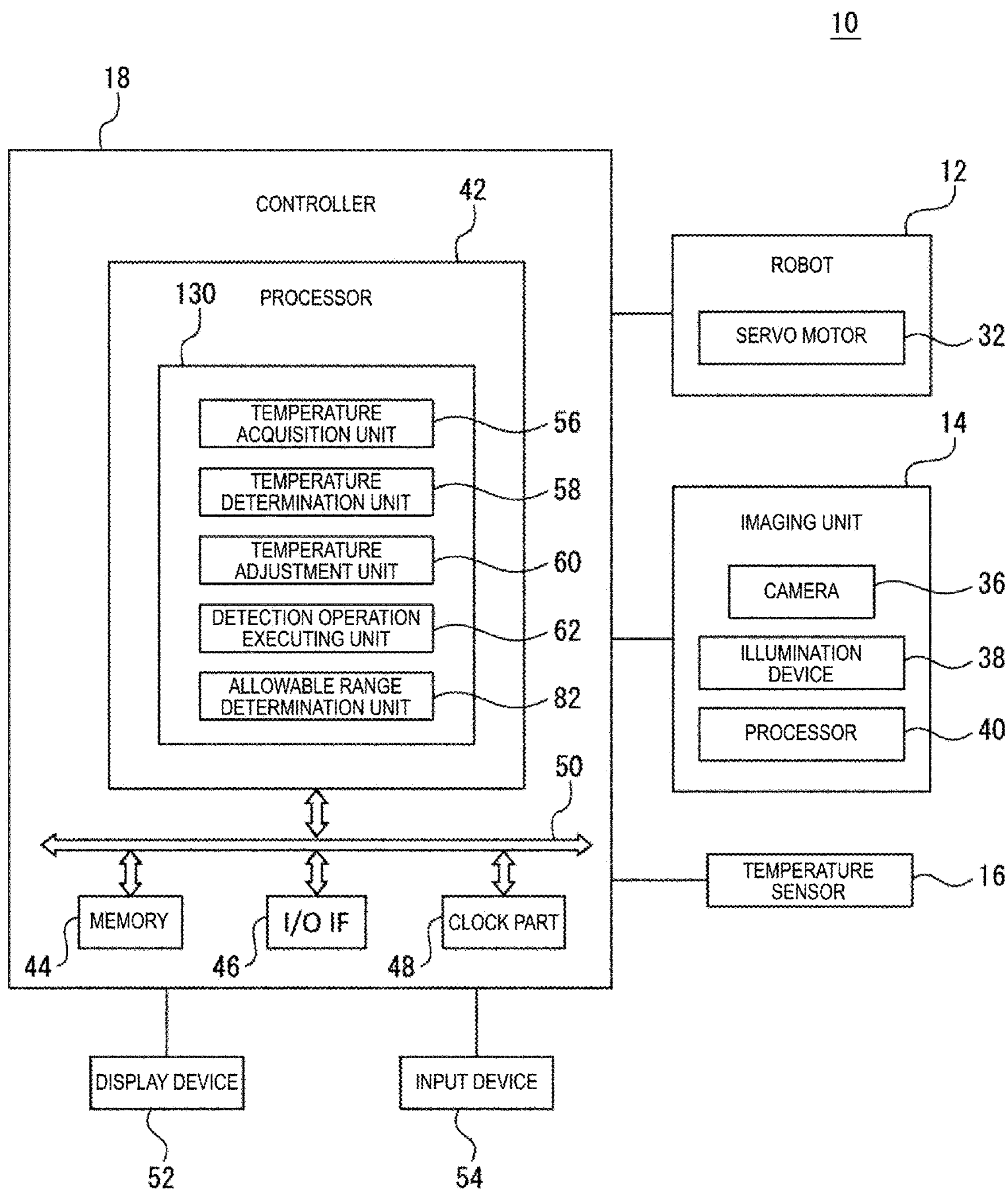

10
18
CONTROLLER
42
PROCESSOR
130
TEMPERATURE ACQUISITION UNIT
56
TEMPERATURE DETERMINATION UNIT
58
TEMPERATURE ADJUSTMENT UNIT
60
DETECTION OPERATION EXECUTING UNIT
62
ALLOWABLE RANGE DETERMINATION UNIT
82
50
MEMORY
44
I/O IF
46
CLOCK PART
48
12
ROBOT
SERVO MOTOR
32
14
IMAGING UNIT
CAMERA
36
ILLUMINATION DEVICE
38
PROCESSOR
40
TEMPERATURE SENSOR
16
DISPLAY DEVICE
52
INPUT DEVICE
54

Fig. 16

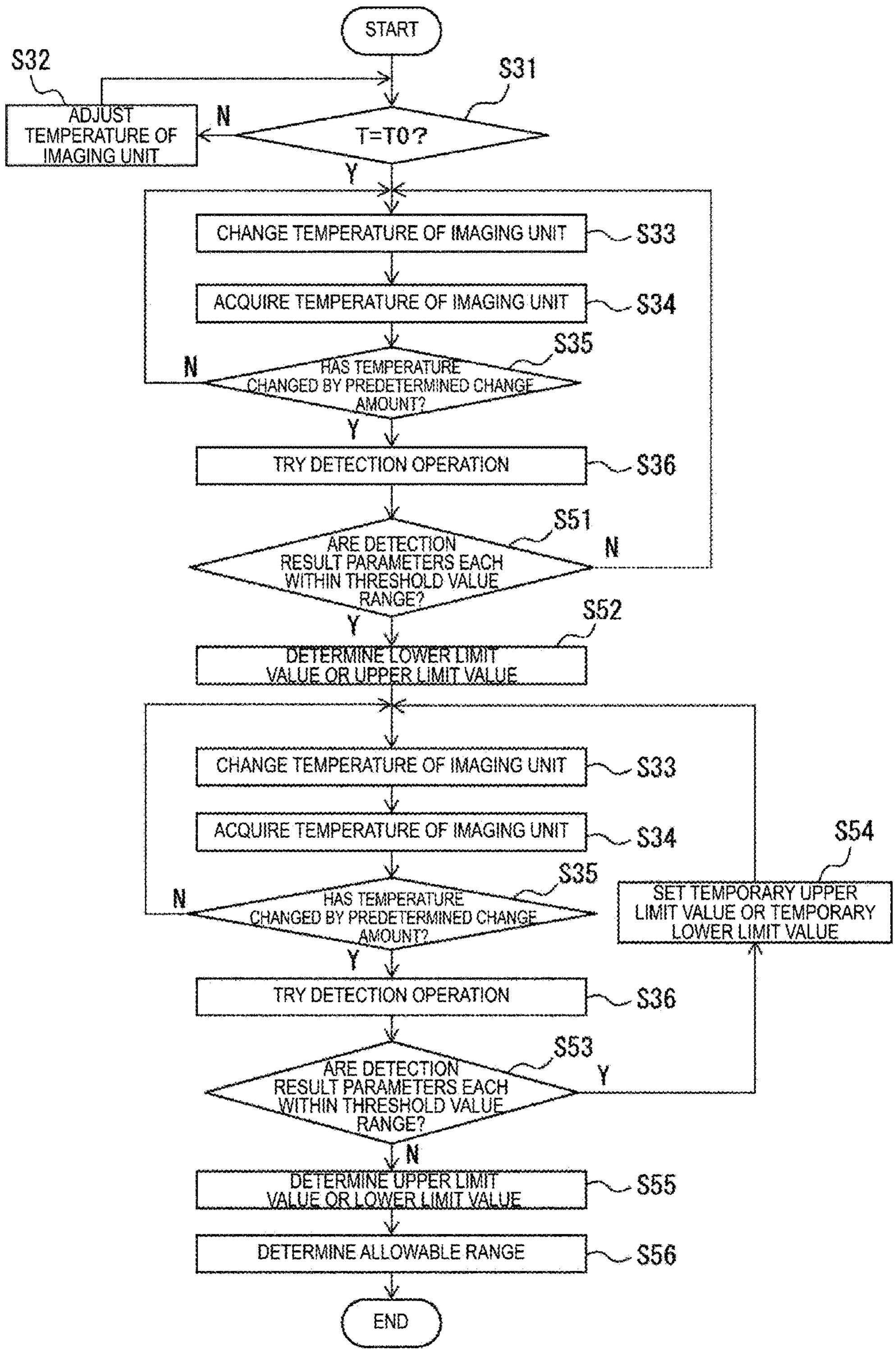
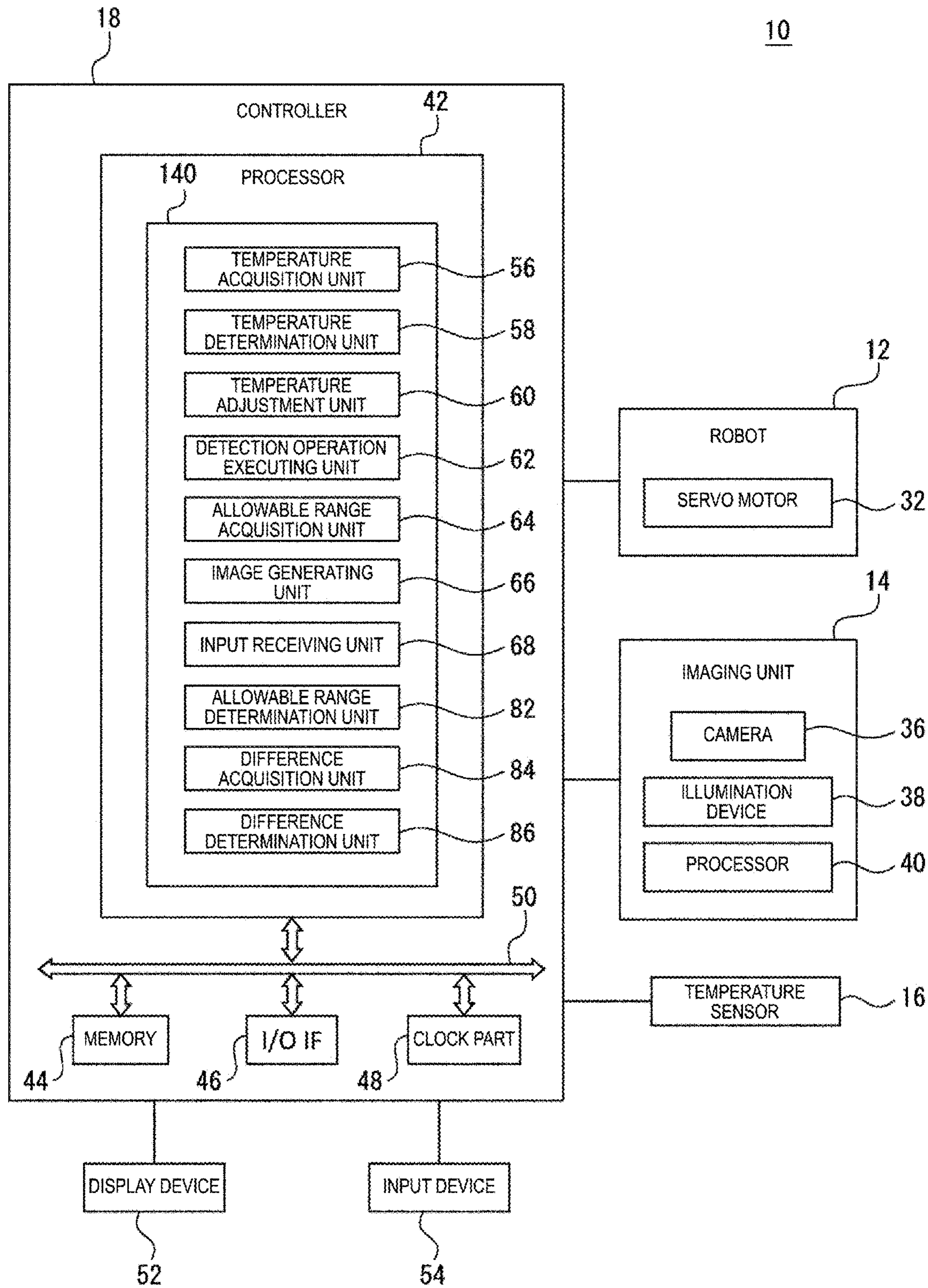

START
S31
T=T0?
N
S32
ADJUST TEMPERATURE OF IMAGING UNIT
Y
CHANGE TEMPERATURE OF IMAGING UNIT
S33
ACQUIRE TEMPERATURE OF IMAGING UNIT
S34
HAS TEMPERATURE CHANGED BY PREDETERMINED CHANGE AMOUNT?
S35
N
Y
TRY DETECTION OPERATION
S36
ARE DETECTION RESULT PARAMETERS EACH WITHIN THRESHOLD VALUE RANGE?
S51
N
Y
DETERMINE LOWER LIMIT VALUE OR UPPER LIMIT VALUE
S52
CHANGE TEMPERATURE OF IMAGING UNIT
S33
ACQUIRE TEMPERATURE OF IMAGING UNIT
S34
HAS TEMPERATURE CHANGED BY PREDETERMINED CHANGE AMOUNT?
S35
N
Y
TRY DETECTION OPERATION
S36
ARE DETECTION RESULT PARAMETERS EACH WITHIN THRESHOLD VALUE RANGE?
S53
Y
SET TEMPORARY UPPER LIMIT VALUE OR TEMPORARY LOWER LIMIT VALUE
S54
N
DETERMINE UPPER LIMIT VALUE OR LOWER LIMIT VALUE
S55
DETERMINE ALLOWABLE RANGE
S56
END

Fig. 17



18
10
CONTROLLER
42
PROCESSOR
140
TEMPERATURE ACQUISITION UNIT
56
TEMPERATURE DETERMINATION UNIT
58
TEMPERATURE ADJUSTMENT UNIT
60
DETECTION OPERATION EXECUTING UNIT
62
ALLOWABLE RANGE ACQUISITION UNIT
64
IMAGE GENERATING UNIT
66
INPUT RECEIVING UNIT
68
ALLOWABLE RANGE DETERMINATION UNIT
82
DIFFERENCE ACQUISITION UNIT
84
DIFFERENCE DETERMINATION UNIT
86
50
MEMORY
44
I/O IF
46
CLOCK PART
48
12
ROBOT
SERVO MOTOR
32
14
IMAGING UNIT
CAMERA
36
ILLUMINATION DEVICE
38
PROCESSOR
40
TEMPERATURE SENSOR
16
DISPLAY DEVICE
52
INPUT DEVICE
54

Fig. 18

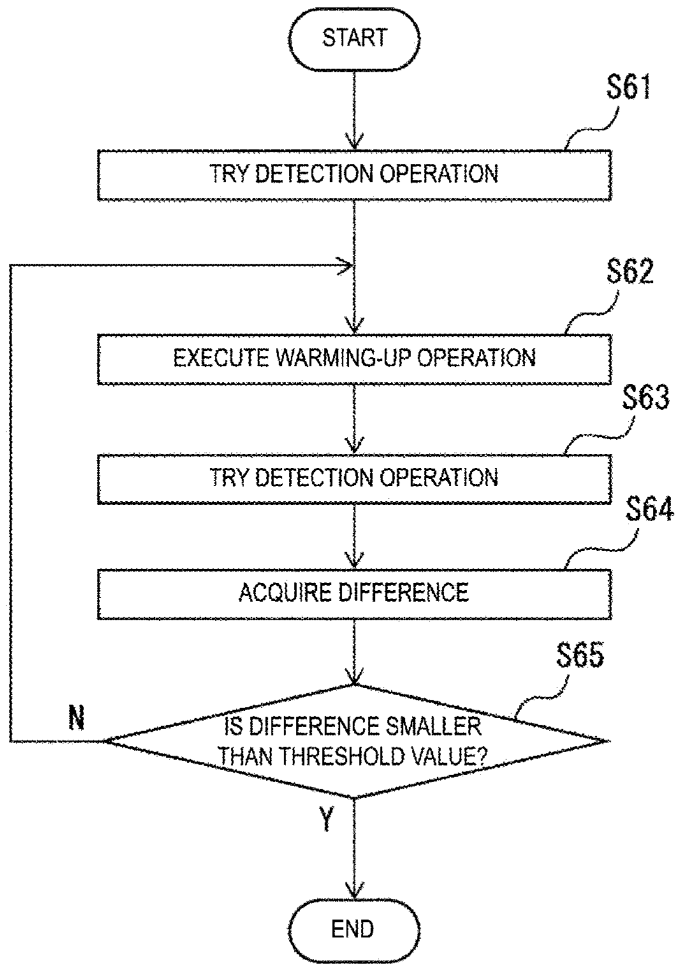
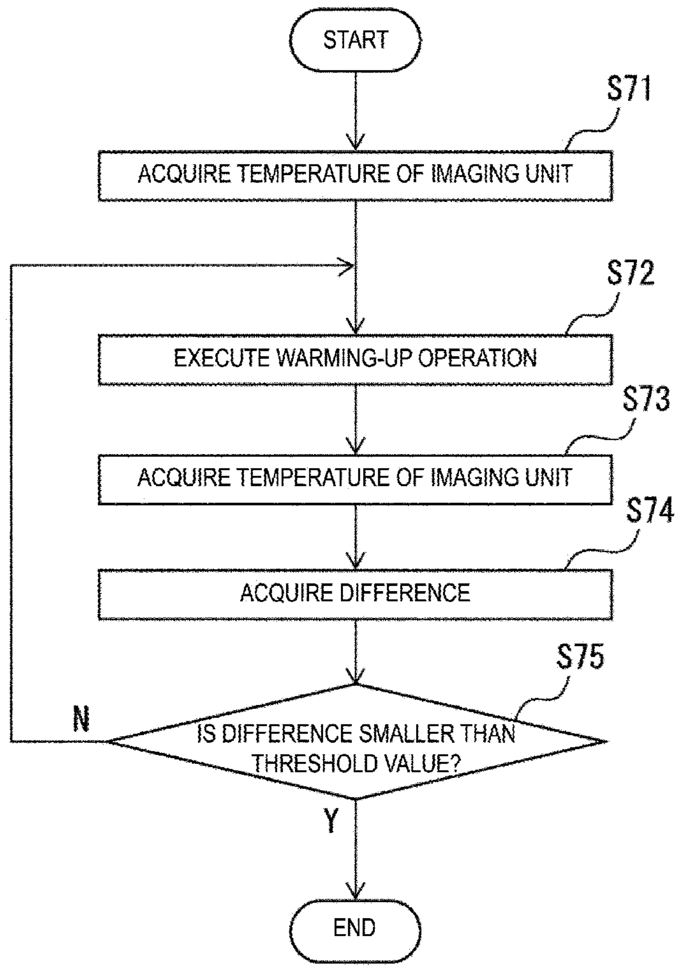

START
S61
TRY DETECTION OPERATION
S62
EXECUTE WARMING-UP OPERATION
S63
TRY DETECTION OPERATION
S64
ACQUIRE DIFFERENCE
S65
IS DIFFERENCE SMALLER THAN THRESHOLD VALUE?
N
Y
END

Fig. 19


START
S71
ACQUIRE TEMPERATURE OF IMAGING UNIT
S72
EXECUTE WARMING-UP OPERATION
S73
ACQUIRE TEMPERATURE OF IMAGING UNIT
S74
ACQUIRE DIFFERENCE
S75
N
IS DIFFERENCE SMALLER THAN THRESHOLD VALUE?
Y
END

APPARATUS, CONTROL DEVICE, METHOD, AND COMPUTER PROGRAM FOR MANAGING TEMPERATURE OF AN IMAGING UNIT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a bypass continuation application of International Application No. PCT/JP2022/041368 filed Nov. 7, 2022.

BACKGROUND

Field

[0002] The present disclosure relates to an apparatus, a controller, a method, and a computer program configured to manage a temperature of an imaging unit of an industrial machine.

Discussion of the Related Art

[0003] There is known a technique for adjusting an interval at which an imaging device executes an imaging operation in response to a temperature of the imaging device.

[0004] In an industrial machine configured to execute a detection operation for detecting a workpiece on the basis of image data obtained by imaging the workpiece by an imaging unit, there has been a problem that the accuracy of the detection operation is affected by the temperature of the imaging unit.

SUMMARY

[0005] According to an aspect of the present disclosure, in an industrial machine which executes a detection operation to detect a workpiece on the basis of image data of the workpiece imaged by an imaging unit and which carries out work on the detected workpiece, an apparatus configured to manage a temperature of the imaging unit includes: a temperature acquisition unit configured to acquire a temperature measured by a temperature sensor; a temperature determination unit configured to determine whether or not the temperature, which is acquired by the temperature acquisition unit when the detection operation for the work is executed, falls within an allowable range predetermined for securing accuracy of the detection operation; and a temperature adjustment unit configured to execute a warming-up operation to raise the temperature when the temperature determination unit determines that the temperature is lower than a lower limit value of the allowable range, while executing a cooling operation to lower the temperature when the temperature determination unit determines that the temperature is higher than an upper limit value of the allowable range.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** is a schematic diagram of an industrial machine according to an embodiment.

[0007] FIG. **2** is a block diagram of the industrial machine illustrated in FIG. **1**.

[0008] FIG. **3** is an enlarged diagram of an imaging unit illustrated in FIG. **1**.

[0009] FIG. **4** is a flowchart illustrating an example of an operation flow of the industrial machine illustrated in FIG. **1**.

[0010] FIG. **5** illustrates an example of image data of a workpiece imaged by an imaging unit.

[0011] FIG. **6** is a flowchart illustrating another example of the operation flow of the industrial machine illustrated in FIG. **1**.

[0012] FIG. **7** is a flowchart illustrating an example of a flow of step S**10** in FIG. **6**.

[0013] FIG. **8** is a block diagram illustrating another function of the industrial machine illustrated in FIG. **1**.

[0014] FIG. **9** is a flowchart illustrating an example of an operation flow of an industrial machine illustrated in FIG. **8**.

[0015] FIG. **10** is a block diagram illustrating another function of the industrial machine illustrated in FIG. **1**.

[0016] FIG. **11** is a flowchart illustrating an example of an operation flow of an industrial machine illustrated in FIG. **10**.

[0017] FIG. **12** illustrates an example of a result list image.

[0018] FIG. **13** illustrates an example of a result detail image.

[0019] FIG. **14** illustrates an example of a result comparison image.

[0020] FIG. **15** is a block diagram illustrating still another function of the industrial machine illustrated in FIG. **1**.

[0021] FIG. **16** is a flowchart illustrating an example of an operation flow of an industrial machine illustrated in FIG. **15**.

[0022] FIG. **17** is a block diagram illustrating yet another function of the industrial machine illustrated in FIG. **1**.

[0023] FIG. **18** is a flowchart illustrating an example of a warming-up scheme executed by an industrial machine illustrated in FIG. **17**.

[0024] FIG. **19** is a flowchart illustrating another example of the warming-up scheme executed by the industrial machine illustrated in FIG. **17**.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0025] Embodiments of the present disclosure are described in detail below with reference to the drawings. Note that in various embodiments described below, the same elements are denoted with the same reference numerals, and overlapping description is omitted. Referring first to FIGS. **1** to **3**, an industrial machine **10** according to an embodiment will be described. The industrial machine **10** includes a robot **12**, an imaging unit **14**, a temperature sensor **16**, and a controller **18**.

[0026] In the present embodiment, the robot **12** is a vertical articulated robot, which includes a robot base **20**, a swivel body **22**, a lower arm **24**, an upper arm **26**, a wrist **28**, and an end effector **30**. The robot base **20** is fixed on the floor of a work cell or on an automatically guided vehicle (AGV). The swivel body **22** is mounted on the robot base **20** to be rotatable around a vertical axis. A proximal end part of the lower arm **24** is provided to the swivel body **22** to be rotatable about a horizontal axis, and a proximal end part of the upper arm **26** is rotatably provided to a distal end part of the lower arm **24**.

[0027] The wrist **28** includes a wrist base **28*a*** provided at a distal end part of the upper arm **26** to be rotatable about two axes orthogonal to each other, and a wrist flange **28*b*** provided to the wrist base **28*a*** to be rotatable about a wrist axis A**1**. The end effector **30** is detachably attached to the wrist flange **28***b*. The end effector **30** includes, for example, a robot hand, a cutting tool, a laser process head, or a welding torch, and carries out predetermined work (such as workpiece handling, cutting, laser processing, or welding) on a workpiece W.

[0028] The robot base **20**, the swivel body **22**, the lower arm **24**, the upper arm **26**, and the wrist **28** are respectively provided with a plurality of servo motors **32** (FIG. **2**). In response to a command from the controller **18**, the servo motors **32** rotate each of the swivel body **22**, the lower arm **24**, the upper arm **26**, the wrist base **28***a*, and the wrist flange **28***b* about drive shafts, thereby moving the end effector **30**.

[0029] The imaging unit **14** images the workpiece W in response to a command from the controller **18**. In the present embodiment, the imaging unit **14** is fixed to the end effector **30** (or the wrist flange **28***b*) and moved by the robot **12**. Specifically, as illustrated in FIG. **3**, the imaging unit **14** includes a housing **34**, a camera **36**, an illumination device **38**, and a processor **40**. The housing **34** is hollow and accommodates therein electronic components such as the processor **40**.

[0030] The camera **36** of the present embodiment is a two-dimensional camera capable of imaging two-dimensional image data, and is provided in the housing **34**. To be specific, the camera **36** includes an image sensor (CCD, CMOS, or the like), an optical lens (collimator lens, focus lens, or the like) that guides a subject image to the image sensor, a shutter that opens/closes an optical path of the subject image to be incident on the image sensor, and the like, and images the subject image (i.e., the workpiece W) along an optical axis A**2**.

[0031] The illumination device **38** includes an LED illumination, a halogen lamp, a fluorescent lamp, or the like, and is provided in the housing **34** to be adjacent to the camera **36**. When the camera **36** images the workpiece W, the illumination device **38** irradiates the workpiece W with light in response to a command from the controller **18**. As described above, in the present embodiment, the camera **36** and the illumination device **38** are integrally incorporated in the housing **34**. The processor **40** includes, for example, an image processing processor (DSP, ISP, or the like) configured to perform image processing on image data imaged by the camera **36**, and supplies the acquired image data to the controller **18**.

[0032] The temperature sensor **16** includes a platinum temperature measuring resistor, a thermocouple, or the like, and measures a temperature T of the imaging unit **14**. In the present embodiment, the temperature sensor **16** is provided in the housing **34**. However, the temperature sensor **16** may be disposed on any component of the imaging unit **14**, such as the camera **36** (specifically, the image sensor or the optical lens), the illumination device **38**, or the processor **40**. The temperature sensor **16** supplies data of the measured temperature T to the controller **18**.

[0033] Referring to FIG. **2**, the controller **18** controls the operations of the robot **12** and the imaging unit **14**. Specifically, the controller **18** is a computer including a processor **42**, a memory **44**, an I/O interface **46**, and a clock part **48**. The processor **42** includes a CPU, a GPU, or the like, is communicably connected to the memory **44**, the I/O interface **46**, and the clock part **48** via a bus **50**, and performs arithmetic processing to enable a temperature management function described later while communicating with these components.

[0034] The memory **44** includes a RAM, a ROM, or the like and temporarily or permanently stores various types of data. The memory **44** may be a non-transitory computer readable recording medium such as a semiconductor memory, a magnetic recording medium, or an optical recording medium. The I/O interface **46** includes, for example, an Ethernet (registered trademark) port, a USB port, an optical fiber connector, or an HDMI (registered trademark) terminal, and communicates data with the external device in a wired or wireless manner under a command from the processor **42**. In the present embodiment, the imaging unit **14**, the temperature sensor **16**, and each of the servo motors **32** are communicably connected to the I/O interface **46**. In response to a command from the processor **42**, the clock part **48** clocks an elapsed time t from a certain time point.

[0035] The controller **18** is provided with a display device **52** and an input device **54**. The display device **52** includes a liquid crystal display, an organic EL display, or the like, and visibly displays various types of data under a command from the processor **42**. The input device **54** includes a push button, a switch, a keyboard, a mouse, a touch panel, or the like, and receives an input of data from an operator. The display device **52** and the input device **54** may be integrally incorporated in a housing of the controller **18**, or may be constituted as one computer (such as a PC) with a body separate from the housing of the controller **18**, and may be connected to the I/O interface **46**.

[0036] As illustrated in FIG. **1**, a robot coordinate system (or a world coordinate system) C**1** and a tool coordinate system C**2** are set for the robot **12**. The robot coordinate system C**1** is a coordinate system for controlling the operations of movable components (i.e., the swivel body **22**, the lower arm **24**, the upper arm **26**, and the wrist **28**) of the robot **12**. In the present embodiment, the robot coordinate system C**1** is set for the robot base **20** such that the origin is arranged at the center of the robot base **20** and the z axis coincides with a swivel shaft of the swivel body **22**.

[0037] On the other hand, the tool coordinate system C**2** is set for the end effector **30** and determines the position of the end effector **30** in the robot coordinate system C**1**. In the present embodiment, the tool coordinate system C**2** is set for the end effector **30** such that the origin (i.e., the TCP) is arranged at a work position (e.g., a workpiece gripping position, a tool distal end point, a laser beam exit port, or a welding position) of the end effector **30** and the z axis is parallel to (specifically, coincides with) a wrist axis A**1**.

[0038] When moving the end effector **30**, the processor **42** of the controller **18** sets the tool coordinate system C**2** in the robot coordinate system C**1**, and generates a command for each of the servo motors **32** of the robot **12** so as to arrange the end effector **30** at a position represented by the set tool coordinate system C**2**. In this way, the end effector **30** is positioned at an optional position in the robot coordinate system C**1** by the operation of the robot **12**.

[0039] On the other hand, a camera coordinate system C**3** is set for the camera **36** of the imaging unit **14** as illustrated in FIG. **3**. The camera coordinate system C**3** determines the position of the camera **36** in the robot coordinate system C**1** (i.e., the coordinates of the optical axis A**2**) and also determines the coordinates of each pixel of the image data (or the image sensor) imaged by the camera **36**. In the present embodiment, the camera coordinate system C**3** is two-dimensional and is set for the camera **36** such that the origin is arranged at the center of the image sensor of the camera **36**.

[0040] In the industrial machine **10**, the processor **42** of the controller **18** operates the imaging unit **14** to image the workpiece W, and executes a detection operation DO to detect the workpiece W on the basis of image data ID of the imaged workpiece W. Then, the processor **42** operates the robot **12** to carry out work (workpiece handling, cutting, laser processing, welding, or the like) on the workpiece W detected by the detection operation DO.

[0041] As the imaging unit **14** is operated for the work, the temperature T of the imaging unit **14** fluctuates. Such a fluctuation in the temperature T affects image quality of the image data ID imaged by the imaging unit **14**. Specifically, for example, when the temperature T rises, distortion occurs in the image sensor or optical lens of the camera **36**, or the light amount of the illumination device **38** changes (e.g., increases). As a result, distortion of the imaged image data ID or brightness of the pixel may change.

[0042] When the image quality of the image data ID is affected as described above, the accuracy of the detection operation DO executed on the basis of the image data ID may be lowered. Accordingly, in the present embodiment, the processor **42** manages the temperature T of the imaging unit **14** in order to secure the accuracy of the detection operation DO when carrying out work on the workpiece W. Hereinafter, an operation flow of the industrial machine **10** will be described with reference to FIG. **4**.

[0043] The flow illustrated in FIG. **4** starts when the processor **42** receives a work start command from an operator, a host controller, or a computer program PG. In step S**1**, the processor **42** acquires the temperature T of the imaging unit **14**. Specifically, the processor **42** acquires data of the temperature T measured by the temperature sensor **16** at this time point, from the temperature sensor **16**. In this manner, in the present embodiment, the processor **42** functions as a temperature acquisition unit **56** (FIG. **2**) configured to acquire the temperature T measured by the temperature sensor **16**.

[0044] In step S**2**, the processor **42** determines whether or not the temperature T acquired in the most recent step S**1** falls within an allowable range $[T_{th1}, T_{th2}]$. The allowable range $[T_{th1}, T_{th2}]$ is predetermined in order to secure the accuracy of the detection operation DO executed in step S**6** described below. A method of determining the allowable range $[T_{th1}, T_{th2}]$ will be described later. Data of a lower limit value T_{th1} and an upper limit value T_{th2} defining the allowable range $[T_{th1}, T_{th2}]$ is stored in advance in the memory **44**.

[0045] When the temperature T falls within the allowable range $[T_{th1}, T_{th2}]$ (i.e., $T_{th1} \leq T \leq T_{th2}$), the processor **42** determines YES, and proceeds to step S**6**. On the other hand, when the temperature T is outside the allowable range $[T_{th1}, T_{th2}]$ (i.e., $T < T_{th1}$ or $T_{th2} < T$), the processor **42** determines NO, and proceeds to step S**3**. As discussed above, in the present embodiment, the processor **42** functions as a temperature determination unit **58** (FIG. **2**) configured to determine whether or not the temperature T falls within the allowable range $[T_{th1}, T_{th2}]$.

[0046] In step S**3**, the processor **42** functions as the temperature determination unit **58** and determines whether or not the temperature T acquired in the most recent step S**1** is higher than the upper limit value T_{th2} of the allowable range $[T_{th1}, T_{th2}]$ or lower than the lower limit value T_{th1} of the allowable range $[T_{th1}, T_{th2}]$. The processor **42** determines YES when the temperature T is higher than the upper limit value T_{th2} (i.e., $T_{th2} < T$), and proceeds to step S**4**. On the other hand, the processor **42** determines NO when the temperature T is lower than the lower limit value T_{th1} (i.e., $T < T_{th1}$), and proceeds to step S**5**.

[0047] In step S**4**, the processor **42** executes a cooling operation CO to lower the temperature T of the imaging unit **14**. Specifically, the processor **42** activates the clock part **48** to start the clocking of an elapsed time t**1** from the start time point of step S**4**. The processor **42** may activate the clock part **48** at the start time point or the end time point of step S**1** mentioned above to clock the elapsed time t**1** from the start time point or the end time point thereof.

[0048] Then, when the elapsed time t**1** clocked by the clock part **48** reaches a predetermined cooling time t_{th1}, the processor **42** ends step S**4**. As an example, the cooling time t_{th1} may be predetermined by an operator as a required value. As another example, the processor **42** may determine the cooling time t_{th1} in response to the temperature T of the imaging unit **14**. For example, a data table DT**1** (or a graph) is stored in advance in the memory **44**. In the data table DT**1**, the temperature T of the imaging unit **14** and the cooling time t_{th1} required to lower the temperature T to the upper limit value T_{th2} or less are stored in association with each other. The data table DT**1** is generated in advance by an experimental method or simulation carried out by the operator, for example.

[0049] When the processor **42** starts step S**4** (or determined YES in step S**3**), the processor **42** may determine the cooling time t_{th1} corresponding to the temperature T by applying the temperature T acquired in the most recent step S**1** to the data table DT**1**. Thus, the processor **42** can determine the cooling time t_{th1} to be referred to in step S**4** in response to the temperature T. The processor **42** can also determine the cooling time t_{th1} in response to the temperature T by executing a predetermined calculation using the temperature T and a heat dissipation parameter of the imaging unit **14** (e.g., thermal conductivity of the housing **34**).

[0050] Until the elapsed time t**1** clocked by the clock part **48** reaches the cooling time t_{th1}, the processor **42** stops the operations of the components of the imaging unit **14** (i.e., the camera **36**, the illumination device **38**, and the processor **40**). As an example, the processor **42** stops the operation of each component (e.g., the processor **40**) of the imaging unit **14** by stopping the command toward the component.

[0051] At this time, the processor **42** may continue to provide minimal power to at least one component of imaging unit **14**. This configuration makes it possible to suppress power consumption in the imaging unit **14**, whereby the temperature T of the imaging unit **14** can be lowered, and various setting information temporarily stored in a memory (not illustrated) of the imaging unit **14** can be maintained.

[0052] As another example, the processor **42** may stop the operation of each component of the imaging unit **14** by stopping the power supply to the component. Thus, the processor **42** can lower the temperature T of the imaging unit **14** by stopping the operation of the imaging unit **14** for the predetermined cooling time t_{th1}.

[0053] Referring to FIG. **4** again, in a case where the determination made in step S**3** is NO, the processor **42**

executes a warming-up operation WO to raise the temperature T of the imaging unit **14** in step S**5**. As an example of the warming-up operation WO, the processor **42** causes the camera **36** to simulatively execute an imaging operation IO. In the imaging operation IO, the camera **36** may image the workpiece W or may image any subject other than the workpiece W. Alternatively, the camera **36** may execute the imaging operation IO in a state where the shutter is closed. In this case, a subject image of the shutter (i.e., a black image) is captured by the image sensor.

[0054] In the imaging operation IO, the camera **36** may repeatedly execute imaging of the subject image a predetermined number of times, or may continuously image the subject image for a predetermined time (i.e., moving image capturing). Imaging conditions CDi (exposure time, shutter speed, resolution, sensitivity, and the like) when the imaging operation IO is executed may be completely identical to the imaging conditions CDi when the workpiece W is imaged in step S**6** described later, or may be at least partially different therefrom.

[0055] As another example of the warming-up operation WO, the processor **42** causes the processor **40** incorporated in the imaging unit **14** to execute predetermined arithmetic processing CL. For example, the processor **40** executes image processing CL**1**, as the arithmetic processing CL, on the image data ID of the workpiece W imaged in step S**6** (FIG. **4**) executed before step S**5**.

[0056] As the image processing CL**1**, the processor **40** executes, for example, processing of obtaining an edge or a contour of the workpiece W appearing in the image data ID, or processing of eliminating noise from the image data ID. As described above, by executing the image processing CL**1** on the image data ID accumulated in the past while making use of the warming-up operation WO, the cycle time of the flow in FIG. **4** can be reduced.

[0057] The processor **40** may execute any processing other than the image processing CL**1** (or in addition to the image processing CL**1**), as the arithmetic processing CL. As discussed above, the processor **42** of the controller **18** causes the processor **40** of the imaging unit **14** to execute the arithmetic processing CL so as to operate the processor **40**, thereby making it possible for the processor **40** to generate heat. As a result, the temperature T of the imaging unit **14** can be raised.

[0058] As still another example of the warming-up operation WO, the processor **42** executes a lighting operation LO to turn on the illumination device **38**. As a result, the illumination device **38** generates heat, whereby the temperature T of the imaging unit **14** can be raised. Lighting conditions CDI (power, illuminance, frequency, and the like) when the lighting operation LO is executed may be completely identical to the lighting conditions CDI when the lighting operation LO is executed in step S**6** described later, or may be at least partially different therefrom. For example, at least one of the lighting conditions CDI (e.g., power or illuminance) in the warming-up operation WO may be set to be larger than that in step S**6**.

[0059] The processor **40** may execute the warming-up operation WO in step S**5** (i.e., the simulative imaging operation IO, the arithmetic processing CL, or the lighting operation LO) for a predetermined warming-up time t_{th2}. Specifically, the processor **42** activates the clock part **48** to start the clocking of a third elapsed time t**3** from the start time point of step S**5**. The processor **42** may activate the clock part **48** at the start time point or the end time point of the above-mentioned step S**1** to clock the elapsed time t**3** from the start time point or the end time point thereof.

[0060] Then, when the elapsed time t**3** clocked by the clock part **48** reaches the predetermined warming-up time t_{th2}, the processor **42** ends step S**5**. As an example, the warming-up time t_{th2} may be predetermined by the operator as a required value. As another example, the processor **42** may determine the warming-up time t_{th2} in response to the temperature T of the imaging unit **14**. For example, a data table DT**2** (or a graph) is stored in advance in the memory **44**. In the data table DT**2**, the temperature T of the imaging unit **14** and the warming-up time t_{th2} required to raise the temperature T to the lower limit value T_{th1} or more are stored in association with each other.

[0061] The data table DT**2** is generated in advance by an experimental method or simulation carried out by the operator, for example. When the processor **42** starts step S**5** (or determined NO in step S**3**), the processor **42** may determine the warming-up time t_{th2} corresponding to the temperature T by applying the temperature T acquired in the most recent step S**1** to the data table DT**2**.

[0062] As described above, in the present embodiment, when it is determined as a result of steps S**2** and S**3** that the temperature T is higher than the upper limit value T_{th2} of the allowable range $[T_{th1}, T_{th2}]$, the processor **42** executes the cooling operation CO to lower the temperature T in step S**4**. On the other hand, when it is determined that the temperature T is lower than the lower limit value T_{th1} of the allowable range $[T_{th1}, T_{th2}]$, the processor **42** executes the warming-up operation WO to raise the temperature T in step S**5**. Thus, the processor **42** functions as a temperature adjustment unit **60** (FIG. **2**) configured to execute the cooling operation CO and the warming-up operation WO.

[0063] In step S**6**, the processor **42** executes the detection operation DO configured to detect the workpiece W. To be specific, the processor **42** operates the robot **12** to arrange the imaging unit **14** at an imaging position IP**1**, at which the workpiece W set on a jig J falls within the field of view of the camera **36**. Subsequently, the processor **42** causes the illumination device **38** to execute the lighting operation LO to irradiate the workpiece W with light.

[0064] While the illumination device **38** is executing the lighting operation LO, the camera **36** is activated to execute the imaging operation IO for imaging the workpiece W. The processor **42** acquires the image data ID imaged by the imaging operation IO from the camera **36**. An example of the image data ID acquired at this time is illustrated in FIG. **5**. Each pixel of the image data ID is represented as coordinates in the camera coordinate system C**3**.

[0065] Subsequently, the processor **42** detects the workpiece W appearing in the image data ID by matching a teaching shape TS taught in advance of the workpiece W with the image data ID. Then, the processor **42** acquires coordinates Qc in the camera coordinate system C**3** of a feature point (e.g., a center point) of the workpiece W in the detected image data ID.

[0066] Here, the positional relationship between the camera coordinate system C**3** and the robot coordinate system C**1** (i.e., the tool coordinate system C**2**) is known by a calibration process CB described later. Thus, the coordinates of the camera coordinate system C**3** and the coordinates of the robot coordinate system C**1** can be transformed to each other through a known transformation matrix M_{cr} (e.g., homogeneous transformation matrix or Jacobian matrix).

[0067] On the other hand, in the present embodiment, a distance d between the camera **36** arranged at the imaging position IP**1** (i.e., the origin of the camera coordinate system C**3**) and the workpiece W set on the jig J is also known. The processor **42** acquires a position P (x, y, z) of the workpiece W in the robot coordinate system C**1** on the basis of the acquired coordinates Qc in the camera coordinate system C**3**, the distance d, and the transformation matrix M_{cr}. Thus, the processor **42** executes the detection operation DO to detect the workpiece W on the basis of the image data ID, and acquires the position P of the workpiece W in the robot coordinate system C**1** as a detecting position P (x, y, z). Accordingly, the processor **42** functions as a detection operation executing unit **62** (FIG. **2**) configured to execute the detection operation DO.

[0068] In step S**7**, the processor **42** executes work on the workpiece W. To be specific, on the basis of the detecting position P acquired in the most recent step S**6** and a teaching position P**0** taught in advance, the processor **42** calculates a deviation amount δP from the teaching position P**0** to the detecting position P. The teaching position P**0** is taught in advance together with the above-described teaching shape TS in a teaching process TP to be described later, and is determined in the computer program PG for the flow of FIG. **4**.

[0069] Then, the processor **42** corrects a command (e.g., a position command) toward each servo motor **32** for positioning the end effector **30** (i.e., the TCP) to the teaching position P**0**, which is determined in the computer program PG on the basis of the calculated deviation amount OP, and drives each servo motor **32** in accordance with the corrected command. With this, the processor **42** moves the end effector **30** by the operation of the robot **12**, and carries out work (workpiece handling, cutting, laser processing, welding, or the like) on the workpiece W arranged at the detecting position P by the end effector **30**.

[0070] In step S**8**, the processor **42** determines whether or not the work has been carried out on all the workpieces W. The processor **42** ends the flow illustrated in FIG. **4** upon determining YES, or returns to step S**1** upon determining NO. In this manner, the processor **42** repeatedly executes a loop of step S**1** to step S**8** until determining YES in step S**8**.

[0071] As described above, in the present embodiment, the industrial machine **10** (to be specific, the processor **42** of the controller **18**) executes the detection operation DO for detecting the workpiece W on the basis of the image data ID obtained by imaging the workpiece W by the imaging unit **14** (step S**6**), and carries out work on the detected workpiece W (step S**7**). In this type of industrial machine **10**, the processor **42** functions as the temperature acquisition unit **56**, the temperature determination unit **58**, the temperature adjustment unit **60**, and the detection operation executing unit **62**, and manages the temperature T of the imaging unit **14**. Accordingly, the temperature acquisition unit **56**, the temperature determination unit **58**, the temperature adjustment unit **60**, and the detection operation executing unit **62** constitute an apparatus **100** (FIG. **2**) configured to manage the temperature T of the imaging unit **14**.

[0072] In the apparatus **100**, the temperature determination unit **58** determines whether or not the temperature T, which is acquired by the temperature acquisition unit **56** when the detection operation DO (step S**6**) for the work (step S**7**) is executed, falls within the allowable range $[T_{th1}, T_{th2}]$ predetermined to secure the accuracy of the detection operation DO (step S**2**). When the temperature determination unit **58** determines that the temperature T is lower than the lower limit value T_{th1} of the allowable range $[T_{th1}, T_{th2}]$ (i.e., NO in step S**3**), the temperature adjustment unit **60** executes the warming-up operation WO for raising the temperature T (step S**5**).

[0073] On the other hand, when the temperature determination unit **58** determines that the temperature T is higher than the upper limit value T_{th2} of the allowable range $[T_{th1}, T_{th2}]$ (i.e., YES in step S**3**), the temperature adjustment unit **60** executes the cooling operation CO for lowering the temperature T (step S**4**). This configuration makes it possible to manage the temperature T of the imaging unit **14** when the detection operation DO is executed so that the temperature T is brought close to the allowable range $[T_{th1}, T_{th2}]$, in which the accuracy of the detection operation DO can be secured. Accordingly, the accuracy of the detection operation DO can effectively be secured.

[0074] In addition, in the apparatus **100**, the temperature adjustment unit **60** causes the imaging unit **14** to simulatively execute the imaging operation IO as an example of the warming-up operation WO. According to this configuration, it is possible to easily raise the temperature T of the imaging unit **14** without separately providing a heating device (e.g., a heater). As another example of the warming-up operation WO, the temperature adjustment unit **60** causes the processor **40** incorporated in the imaging unit **14** to execute the predetermined arithmetic processing CL.

[0075] In a case where the processor **40** is caused to execute the above-described image processing CL**1** as the arithmetic processing CL, the temperature T can be raised without using a heating device, and the cycle time of the work can be reduced. As still another example of the warming-up operation WO, the temperature adjustment unit **60** turns on the illumination device **38** provided in the imaging unit **14**. This configuration makes it possible to easily and reliably raise the temperature T of the imaging unit **14** without using a heating device.

[0076] Further, in the apparatus **100**, the temperature adjustment unit **60** lowers the temperature T by stopping the operation of the imaging unit **14** for the predetermined cooling time t_{th1} as the cooling operation CO. This configuration makes it possible to easily and reliably lower the temperature T of the imaging unit **14** without separately providing a cooling device (e.g., a cooling fan).

[0077] In step S**5** described above, the processor **42** may execute at least two (e.g., all) of the simulative imaging operation IO, the arithmetic processing CL, and the lighting operation LO of the illumination device **38** in parallel as the warming-up operation WO. A heating device (a heater or the like) may be further provided in the imaging unit **14**, and the processor **42** may operate the heating device as the warming-up operation WO in step S**5** to raise the temperature T of the imaging unit **14** by the heating device. The imaging unit **14** may be further provided with a cooling device (a cooling fan or the like), and the processor **42** may operate the cooling device as the cooling operation CO in step S**4** described above to lower the temperature T of the imaging unit **14** by the cooling device.

[0078] Next, another example of the operation flow of the industrial machine **10** will be described with reference to FIGS. **6** and **7**. In the flow illustrated in FIGS. **6** and **7**, the same processing as that in the flow of FIG. **4** is denoted by the same step number, and redundant description thereof will be omitted. In the present embodiment, when the processor **42** determines NO in step S**2**, a temperature management scheme is executed in step S**10**.

[0079] As illustrated in FIG. **7**, after step S**10** is started, the processor **42** executes the above-described steps S**3** to S**5** in sequence. After step S**4** or S**5**, the processor **42** functions as the temperature acquisition unit **56** to acquire the temperature T of the imaging unit **14** in step S**11**, as in step S**1** described above. In step S**12**, as in step S**2** described above, the processor **42** functions as the temperature determination unit **58** to determine whether or not the temperature T acquired in the most recent step S**11** falls within the allowable range $[T_{th1}, T_{th2}]$. The processor **42** proceeds to step S**6** in FIG. **6** upon determining YES, or proceeds to step S**13** upon determining NO.

[0080] In step S**13**, the processor **42** determines whether or not the third elapsed time t**3** clocked by the clock part **48** has reached a predetermined time limit t_{th3} (i.e., $t3 \geq t_{th3}$). In the present embodiment, the processor **42** activates the clock part **48** at the start time point of step S**10** (i.e., the time point at which determining NO in step S**2**), and the clock part **48** clocks the third elapsed time t**3** from this time point. The processor **42** may activate the clock part **48** at the start time point or the end time point of step S**1** described above to clock the elapsed time t**3** from this time point.

[0081] When the processor **42** determines that the elapsed time t**3** clocked by the clock part **48** has reached the time limit t_{th3} (i.e., YES), the processor **42** proceeds to step S**6** in FIG. **6**. On the other hand, when determining NO, the processor **42** returns to step S**3**. In this manner, the processor **42** repeatedly executes a loop of steps S**3** to S**4** and S**11** to S**13** in FIG. **7** until determining YES in step S**12** or S**13**, so as to function as the temperature adjustment unit **60** to execute the cooling operation CO in step S**4** or the warming-up operation WO in step S**5**.

[0082] As described above, in the present embodiment, the temperature determination unit **58** determines whether or not the temperature T falls within the allowable range $[T_{th1}, T_{th2}]$ (step S**12**) each time the temperature adjustment unit **60** executes the cooling operation CO (step S**4**) or the warming-up operation WO (step S**5**). When the temperature determination unit **58** determines that the temperature T falls within the allowable range $[T_{th1}, T_{th2}]$ (YES in step S**12**), the detection operation executing unit **62** executes the detection operation DO (step S**6** in FIG. **6**) for the work (step S**7** in FIG. **6**).

[0083] On the other hand, the detection operation executing unit **62** does not execute the detection operation DO for the work while it is determined that the temperature T is outside the allowable range $[T_{th1}, T_{th2}]$ (NO in step S**12**). This configuration makes it possible to execute the detection operation DO in a state where the temperature T of the imaging unit **14** falls within the allowable range $[T_{th1}, T_{th2}]$, thereby making it possible to more reliably secure the accuracy of the detection operation DO.

[0084] In the present embodiment, the detection operation executing unit **62** executes the detection operation DO for the work (step S**6** in FIG. **6**) when the elapsed time t**3**, which is clocked by the clock part **48** while the temperature determination unit **58** determines that the temperature T is outside the allowable range $[T_{th1}, T_{th2}]$ (NO in step S**12**), reaches the predetermined time limit t_{th3} (determined YES in step S**13**). Here, it is requested to prevent an excessive increase in a cycle time tc of the flow in FIG. **6**. Thus, by setting the above-described time limit t_{th3} in the flow of FIG. **7**, an excessive increase in the cycle time tc can be prevented.

[0085] The processor **42** may determine the time limit t_{th3} on the basis of the target cycle time tc. In this case, for example, the operator operates the input device **54** to input the target cycle time tc. The processor **42** automatically determines the time limit t_{th3} on the basis of the input cycle time tc. With this configuration, the time limit t_{th3} may be optimized.

[0086] Next, a method of determining the allowable range $[T_{th1}, T_{th2}]$ will be described with reference to FIGS. **1** and **8**. Before executing the flow in FIG. **4** or **6**, the operator executes the teaching process TP for teaching the shape TS and the teaching position P**0** of the workpiece W in order to detect the workpiece W by the detection operation DO in step S**6** described above. The teaching process TP will be described below. The operator may execute the teaching process TP described below using a teaching device (a teach pendant or the like). The teaching device is communicably connected to the I/O interface **46** of the controller **18**.

[0087] First, the operator sets the workpiece W at the predetermined teaching position P**0** using the jig J. Next, the operator gives a teaching command to the controller **18** by operating the teaching device, for example. In response to the teaching command, the processor **42** of the controller **18** operates the robot **12** to position the imaging unit **14** to the imaging position IP**1**.

[0088] Then, the processor **42** causes the illumination device **38** to execute the lighting operation LO to irradiate the workpiece W with light, and causes the imaging unit **14** to execute the imaging operation IO to image the workpiece W set at the teaching position P**0**. As a result, the image data ID is imaged as illustrated in FIG. **5**. The processor **42** displays the imaged image data ID on the display device **52** (or a display device of the teaching device).

[0089] Next, while visually recognizing the image data ID displayed on the display device **52**, the operator operates the input device **54** (or the input device of the teaching device) to designate a contour useful for the detection operation DO among contours of the workpiece W (an edge or a surface of the workpiece W, a boundary between the workpiece W and the background, or the like) appearing in the image data ID, and give input for masking the contours unnecessary for the detection operation DO to the controller **18**. Thus, the processor **42** of the controller **18** can recognize the teaching shape TS of the workpiece W.

[0090] Subsequently, the processor **42** detects the workpiece W appearing in the image data ID by matching the taught teaching shape TS with the imaged image data ID. Then, the processor **42** acquires the position P**0** of the detected workpiece W in the robot coordinate system C**1** as the teaching position P**0** (x0, y0, z0). By executing this type of teaching process TP, the teaching shape TS of the workpiece W and the teaching position P**0** of the workpiece W are taught.

[0091] In the present embodiment, the temperature sensor **16** measures a temperature T**1** (first temperature) of the imaging unit **14** when the imaging unit **14** executes the imaging operation IO for the teaching process TP. For example, the temperature sensor **16** measures the temperature T**1** immediately before, immediately after, or during the execution of the imaging operation IO by the imaging unit **14** in the teaching process TP. The processor **42** functions as the temperature acquisition unit **56** and acquires the temperature T**1** measured by the temperature sensors **16** in the teaching process TP.

[0092] Then, on the basis of the acquired temperature T**1**, the operator determines the lower limit value T_{th1} and the upper limit value T_{th2} of the allowable range [T_{th1}, T_{th2}]. For example, the operator sets the lower limit value T_{th1} and the upper limit value T_{th2} so as to satisfy the relation of T_{th1}<T**1**<T_{th2}. For example, the operator operates the input device **54** (or the input device of the teaching device) to input the lower limit value T_{th1} and the upper limit value T_{th2}, and the processor **42** acquires the lower limit value T_{th1} and the upper limit value T_{th2} via the input device **54** and stores the acquired values in the memory **44**.

[0093] Thus, the processor **42** acquires the allowable range [T_{th1}, T_{th2}] determined on the basis of the temperature T**1**. Accordingly, the processor **42** functions as an allowable range acquisition unit **64** (FIG. **8**) configured to acquire the allowable range [T_{th1}, T_{th2}]. After acquiring the allowable range [T_{th1}, T_{th2}], the processor **42** executes the flow in FIG. **4** or **6**, refers to the allowable range [T_{th1}, T_{th2}] stored in the memory **44**, and executes step S**2**, S**3**, or S**12**.

[0094] As discussed above, in the industrial machine **10** illustrated in FIG. **8**, the processor **42** functions as the temperature acquisition unit **56**, the temperature determination unit **58**, the temperature adjustment unit **60**, the detection operation executing unit **62**, and the allowable range acquisition unit **64**, so as to manage the temperature T of the imaging unit **14**. Accordingly, the temperature acquisition unit **56**, the temperature determination unit **58**, the temperature adjustment unit **60**, the detection operation executing unit **62**, and the allowable range acquisition unit **64** constitute an apparatus **110** configured to manage the temperature T of the imaging unit **14**.

[0095] In the present embodiment, the temperature acquisition unit **56** acquires the first temperature T**1** measured by the temperature sensor **16** when the imaging unit **14** executes the imaging operation IO for the teaching process TP for teaching the shape of the workpiece W. Then, the allowable range acquisition unit **64** acquires the allowable range [T_{th1}, T_{th2}] determined on the basis of the first temperature T**1** and stores the acquired allowable range in the memory **44**.

[0096] According to this configuration, it is possible to effectively determine the allowable range [T_{th1}, T_{th2}] so that the accuracy of the detection operation DO can be secured. To be more specific, the teaching shape TS and the teaching position P**0** are taught on the basis of the image data ID imaged by the imaging operation IO executed in the teaching process TP. In a case where the temperature T of the imaging unit **14** can be brought close to the first temperature T**1** measured in the imaging operation IO of the teaching process TP when step S**6** is executed, the accuracy of the detection operation DO executed in step S**6** mentioned above may be improved. Thus, according to the present embodiment, since the allowable range acquisition unit **64** acquires the allowable range [T_{th1}, T_{th2}] determined on the basis of the first temperature T**1**, the accuracy of the detection operation DO can be more effectively secured.

[0097] Next, another method of determining the allowable range [T_{th1}, T_{th2}] will be described with reference to FIGS. **1** and **8**. Before executing the flow in FIG. **4** or **6**, the operator executes the calibration process CB of calibrating imaging parameters PRi of the imaging unit **14**. The operator may execute the calibration process CB described below using the above-described teaching device.

[0098] First, the operator sets an index DX (not illustrated) for calibration at a known position in the robot coordinate system C**1**. The index DX includes, for example, a dot pattern. Next, the operator gives a calibration command to the controller **18** by operating the teaching device, for example. In response to the calibration command, the processor **42** of the controller **18** operates the robot **12** to position the imaging unit **14** to an imaging position IP**2**, at which the index DX falls within the field of view of the camera **36**.

[0099] Next, the processor **42** causes the imaging unit **14** to execute the imaging operation IO to image the index DX. As a result, image data ID' is acquired, in which the index DX appears. Next, the processor **42** acquires respective parameters of the transformation matrix M_{cr} representing the positional relationship between the robot coordinate system C**1** and the camera coordinate system C**3** as the imaging parameters PRi, on the basis of the acquired image data ID'.

[0100] Further, on the basis of the image data ID', the processor **42** acquires, as the imaging parameters PRi, correction parameters for correcting distortion of the image data ID' caused by distortion of an optical lens of the camera **36** or the like. By executing this type of calibration process CB, the imaging parameters PRi (the parameters of the transformation matrix M_{cr}, the correction parameters, and the like) are calibrated.

[0101] In the present embodiment, the temperature sensor **16** measures a temperature T**2** (first temperature) of the imaging unit **14** when the imaging unit **14** executes the imaging operation IO for the calibration process CB. For example, the temperature sensor **16** measures the temperature T**2** immediately before, immediately after, or during the execution of the imaging operation IO by the imaging unit **14** in the calibration process CB. The processor **42** functions as the temperature acquisition unit **56** and acquires the temperature T**2** measured by the temperature sensors **16** in the calibration process CB.

[0102] As in the teaching process TP described above, the operator determines the lower limit value T_{th1} and the upper limit value T_{th2} of the allowable range [T_{th1}, T_{th2}] on the basis of the acquired temperature T**2**. The processor **42** functions as the allowable range acquisition unit **64** to acquire the allowable range [T_{th1}, T_{th2}] determined on the basis of the temperature T**2** and store the acquired allowable range in the memory **44**. According to this configuration, the accuracy of the detection operation DO may be secured more effectively.

[0103] Next, an operation flow executed by the industrial machine **10** illustrated in FIG. **8** will be described with reference to FIG. **9**. Note that in the flow illustrated in FIG. **9**, the same processing as that in the flow of FIG. **4** is denoted by the same step number, and redundant description thereof will be omitted. The processor **42** sets a number of error times "n" to "0" in step S**21**. The number of error times "n" indicates the number of times of determining NO in step S**2** in FIG. **9**. After step S**21**, the processor **42** sequentially executes the above-described steps S**1** and S**2**.

[0104] When the determination made in step S**2** is NO, the processor **42** increments the number of error times "n" by "1" (n=n+1) in step S**22**. In step S**23**, the processor **42**

determines whether or not the number of error times "n" at this time point has reached a predetermined threshold value n_{th} ($n=n_{th}$). The threshold value n_{th} is predetermined by the operator (e.g., $n_{th}=100$). The processor **42** proceeds to step S**24** upon determining YES, or proceeds to step S**3** upon determining NO and sequentially executes step S**3** to step S**8** described above.

[0105] In step S**24**, the processor **42** obtains a recommended temperature Tr. Here, when the determination made in step S**23** is YES, it means that it is repeatedly determined n_{th} (=100) times that the temperature T is outside the allowable range $[T_{th1}, T_{th2}]$ (i.e., NO) in step S**2**. In this case, the cycle time tc of the work may increase.

[0106] For example, in a case where the allowable range $[T_{th1}, T_{th2}]$ is determined in the teaching process TP or the calibration process CB as described above, the temperature error determination mentioned above may occur due to the temperature T**1** or T**2** acquired in the teaching process TP or the calibration process CB being inappropriately low or high. In this case, by executing the teaching process TP or the calibration process CB again at a more appropriate temperature T, it is possible to reduce the cycle time tc of the work while securing the accuracy of the detection operation DO.

[0107] Therefore, in the present embodiment, in step S**24**, the processor **42** obtains the recommended temperature Tr when the teaching process TP or the calibration process CB is executed again on the basis of a plurality of the temperatures T acquired each time step S**1** of FIG. **9** is executed. As an example, the processor **42** obtains the temperature T acquired in the m-th (e.g., m=100) execution of step S**1** as the recommended temperature Tr.

[0108] As another example, the processor **42** obtains, as the recommended temperature Tr, a mean value of the temperatures T collected while executing step S**1** a predetermined number of times m. As still another example, the processor **42** may multiply the temperatures T collected while executing step S**1** *m* times by weighting coefficients, and obtain a weighted mean value as the recommended temperature Tr. The processor **42** may obtain the recommended temperature Tr by any calculation using the collected temperatures T other than the mean value and the weighted mean value. In this way, the processor **42** obtains the recommended temperature Tr on the basis of the temperatures T collected in step S**1** and stores the obtained recommended temperature Tr in the memory **44**.

[0109] In step S**25**, the processor **42** outputs an alarm AL**1** and the recommended temperature Tr obtained in step S**24**. As an example, the processor **42** generates the alarm AL**1** saying "Temperature error determination frequently occurs. It is recommended to carry out the teaching process or the calibration process again." as image data or sound data.

[0110] Then, the processor **42** outputs the generated alarm AL**1** to the display device **52** or to a speaker (not illustrated) provided in the controller **18**. This makes it possible to report the alarm AL**1** to the operator by the image or sound. The processor **42** displays the recommended temperature Tr obtained in step S**24** on the display device **52** (or outputs from the speaker) together with the alarm AL**1**. After step S**25**, the processor **42** ends the flow in FIG. **9** (or proceeds to step S**6**).

[0111] According to the present embodiment, for example, in a case where the allowable range $[T_{th1}, T_{th2}]$ is determined on the basis of the temperature T**1** or T**2** acquired in the teaching process TP or the calibration process CB, the operator can easily recognize that there is a possibility that the temperature T**1** or T**2** is inappropriate. In addition, the operator can recognize that the teaching process TP or the calibration process CB needs to be performed again, and can automatically acquire the recommended temperature Tr when the teaching process TP or the calibration process CB is performed again. Note that step S**24** may be omitted from the flow in FIG. **9**. In this case, the processor **42** may output only the alarm AL**1** in step S**25**.

[0112] Steps S**21** to S**25** in FIG. **9** can also be applied to the flow in FIG. **6**. For example, after the flow in FIG. **6** is started, the processor **42** may execute step S**21** and execute steps S**22** to S**25** when the determination made in step S**2** of FIG. **6** is NO. Alternatively, the processor **42** may execute steps S**22** to S**25** when the determination made in step S**12** of FIG. **7** is NO. In step S**24** executed in this case, the processor **42** may obtain the recommended temperature Tr on the basis of the temperature T acquired each time step S**11** of FIG. **7** is executed.

[0113] In the above-described step S**25**, the processor **42** may propose a modification of the computer program PG instead of outputting the alarm AL**1** (or in addition to outputting the alarm AL**1**). For example, the computer program PG may include a robot program PG**1** for executing the flow of FIG. **9** and a detection program PG**2** for causing the imaging unit **14** to execute the detection operation DO of step S**6**.

[0114] In this case, the processor **42** may propose to modify the robot program PG**1** so as to add an instruction code for additionally executing the cooling operation CO or warming-up operation WO in the flow of FIG. **9** (e.g., when the determination made in step S**8** is NO). For example, the processor **42** may generate an alarm AL**2** saying "Temperature error determination occurs frequently. It is recommended to add an instruction code of the cooling operation or the warming-up operation to the robot program." and output the generated alarm to the display device **52** or the speaker. This makes it possible for the operator to automatically recognize that it is necessary to modify the robot program PG**1** in order to prevent frequent temperature error determinations.

[0115] Next, still another method of determining the allowable range $[T_{th1}, T_{th2}]$ will be described with reference to FIGS. **10** and **11**. In the industrial machine **10** illustrated in FIG. **10**, the processor **42** of the controller **18** executes the flow of FIG. **11** before the flow of FIG. **4**, **6**, or **9** in order to determine the allowable range $[T_{th1}, T_{th2}]$. The flow in FIG. **11** is started when the processor **42** receives an allowable range setting command from the operator, the host controller, or the computer program PG. Before the start of the flow in FIG. **11**, the operator sets the workpiece W at the teaching position P**0** by using the jig J.

[0116] In step S**31**, the processor **42** determines whether or not the temperature T of the imaging unit **14** has reached a predetermined initial temperature T**0**. Specifically, the processor **42** functions as the temperature acquisition unit **56** and acquires the temperature T of the imaging unit **14** measured by the temperature sensor **16** at this time point. Then, the processor **42** determines whether or not the acquired temperature T is equal to the initial temperature T**0** (or whether or not the acquired temperature T falls within a range determined on the basis of the initial temperature T**0**). The initial temperature T**0** is predetermined by the operator (e.g., T**0**=10° C. or 60° C.). The processor **42** proceeds to step S**33** upon determining YES, or proceeds to step S**32** upon determining NO.

[0117] In step S**32**, the processor **42** functions as the temperature adjustment unit **60** and adjusts the temperature T of the imaging unit **14**. For example, when the determination made in the most recent step S**31** is NO because the temperature T is lower than the initial temperature T**0**, the processor **42** executes the above-described warming-up operation WO. On the other hand, when the processor **42** determines NO because the temperature T is higher than the initial temperature T**0** in the most recent step S**31**, the processor **42** executes the above-described cooling operation CO. After step S**32**, the processor **42** returns to step S**31**.

[0118] In contrast, when the determination made in step S**31** is YES, the processor **42** functions as the temperature adjustment unit **60** and changes the temperature T of the imaging unit **14** in step S**33**. As an example, when the initial temperature T**0** is set to 10° C., the processor **42** raises the temperature T of the imaging unit **14** by executing the warming-up operation WO described above. As another example, when the initial temperature T**0** is set to 60° C., the processor **42** lowers the temperature T of the imaging unit **14** by executing the cooling operation CO described above.

[0119] In step S**34**, the processor **42** functions as the temperature acquisition unit **56** to acquire the temperature T of the imaging unit **14** as in step S**1** described above. In step S**35**, on the basis of the temperature T acquired in step S**34**, the processor **42** determines whether or not the temperature T of the imaging unit **14** has been changed (i.e., raised or lowered) by a predetermined change amount δT by executing the most recent step S**33**.

[0120] The change amount δT is predetermined by the operator (e.g., δT=5° C.). The processor **42** proceeds to step S**36** upon determining YES, or returns to step S**33** upon determining NO. In this way, the processor **42** changes the temperature T of the imaging unit **14** by the predetermined change amount δT by executing a loop of step S**33** to step S**35**.

[0121] In step S**36**, the processor **42** functions as the detection operation executing unit **62**, and performs a trial of the detection operation DO. Specifically, the processor **42** arranges the imaging unit **14** at the imaging position IP**1** by the robot **12**. Then, the processor **42** causes the illumination device **38** to execute the lighting operation LO to irradiate the workpiece W with light, and causes the imaging unit **14** to execute the imaging operation IO to image the workpiece W. The imaging conditions CDi when the imaging operation IO is executed or the lighting conditions CDI when the lighting operation LO is executed in step S**36** may be completely identical to those in step S**6** described above, or may be at least partially different therefrom. As a result of the detection operation DO, the processor **42** acquires detection result data RD.

[0122] The detection result data RD includes, for example, the imaged image data ID and detection result parameters PRr. The detection result parameters PRr are parameters related to the accuracy of the result of the detection operation DO, and may include, for example, a detecting position P (x, y, z) of the workpiece W acquired as the result of the detection operation DO, and a score α, contrast β and distortion γ of the image data ID. The score α indicates, for example, the degree of coincidence between the shape of the workpiece W detected from the image data ID and the teaching shape TS taught in advance.

[0123] The processor **42** stores the acquired detection result data RD (the image data ID and the detection result parameters PRr) in the memory **44**. The detection result parameters PRr may include any parameter related to the accuracy of the result of the detection operation DO other than the detecting position P, the score a, the contrast B, and the distortion γ. For example, the detection result parameters PRr may further include a deviation amount OP between the detecting position P and the teaching position P**0** taught in advance.

[0124] The detection result data RD may include any data indicating a result of the detection operation DO other than the image data ID and the detection result parameters PRr. In the case where the determination made in step S**31** described above is YES, the trial of the detection operation DO may be performed in the same manner as in step S**36**, and the detection result data RD at the initial temperature T**0** may be further acquired.

[0125] In step S**37**, the processor **42** determines whether or not to end the trial of the detection operation DO. For example, the operator optionally sets the initial temperature T**0**, the change amount δT, and a maximum temperature Tmax or a minimum temperature Tmin in order to change (raise or lower) the temperature T of the imaging unit **14** from the initial temperature T**0** (=10° C. or 60° C.) to the maximum temperature Tmax (=60° C.) or to the minimum temperature Tmin (=10° C.) by the change amount δT (=5° C.) each through a loop of step S**33** to step S**37**.

[0126] In this case, prior to the flow in FIG. **11**, the operator may operate the input device **54** to input the initial temperature T**0**, the change amount δT, and the maximum temperature Tmax or the minimum temperature Tmin. The processor **42** may determine YES in step S**37** when the temperature T at the time the processor **42** determined YES in step S**35** has reached the maximum temperature Tmax or the minimum temperature Tmin.

[0127] The processor **42** proceeds to step S**38** upon determining YES, or returns to step S**33** upon determining NO. In this way, the processor **42** repeatedly executes the loop of steps S**33** to S**37** until the processor **42** determines YES in step S**37**, and every time the temperature T is changed by the change amount δT, the processor **42** performs the trial of the detection operation DO in step S**36** to acquire the detection result data RD.

[0128] In step S**38**, the processor **42** displays the result of the detection operation DO executed in step S**36** described above (i.e., the detection result data RD). Specifically, the processor **42** generates a detection result image RI for display of the detection result data RD, and displays the generated image on the display device **52**. FIG. **12** illustrates a result list image RI**1** as an example of the detection result image RI.

[0129] The result list image RI**1** indicates, of the detection result data RD, the detection result parameters PRr (the detecting position P, the score a, the contrast B, and the distortion γ) in list form for each temperature T, at which the trial of the detection operation DO is performed. To be specific, the result list image RI**1** includes an image region **70** indicating the temperature T, an image region **72** indicating the detecting position P (x, y, z), an image region **74** indicating the score a, an image region **76** indicating the contrast B, and an image region **78** indicating the distortion

y. The operator can easily confirm the relationship between the temperature T, at which the trial of the detection operation DO is performed in step S**36**, and the detection result parameters PRr by referring to the result list image RI**1**.

[0130] FIG. **13** illustrates a result detail image RI**2** as another example of the detection result image RI. The result detail image RI**2** depicts details of the detection result data RD (the image data ID, the detecting position P, the score a, the contrast β, and the distortion γ) at a specific temperature T (in the example of FIG. **13**, T=25° C.). To be specific, the result detail image RI**2** includes an image region **80** indicating the image data ID, the image region **72** indicating the detecting position P (x, y, z), the image region **74** indicating the score a, the image region **76** indicating the contrast B, and the image region **78** indicating the distortion y. The operator can easily confirm the details of the result of the detection operation DO at the specific temperature T by referring to the result detail image RI**2**.

[0131] FIG. **14** illustrates a result comparison image RI**3** as still another example of the detection result image RI. In the result comparison image RI**3**, the result detail images RI**2** at the plurality of temperatures T (15° C. and 25° C. in the example of FIG. **14**) are displayed side by side. By referring to the result comparison image RI**3**, the operator can compare and examine the details of the results of the detection operations DO at the plurality of temperatures T. The result comparison image RI**3** in FIG. **14** displays two result detail images RI**2** at the temperatures T being 15° C. and 25° C. side by side, but the result comparison image RI**3** may display the result detail images RI**2** at three or more temperatures T side by side.

[0132] The processor **42** may selectively display the result list image RI**1** of FIG. **12**, the result detail image RI**2** of FIG. **13**, or the result comparison image RI**3** of FIG. **14** in response to an input operation performed on the input device **54** by the operator. For example, at the time when the result list image RI**1** of FIG. **12** is displayed on the display device **52**, the operator operates the input device **54** to select one of the temperatures T (or the detection result parameters PRr) in the result list image RI**1** by clicking on the image. In response to this input operation, the processor **42** may display the result detail image RI**2** (FIG. **13**) corresponding to the selected temperature T on the display device **52**.

[0133] Further, the operator operates the input device **54** to select at least two of the temperatures T (or the detection result parameters PRr) in the result list image RI**1** displayed on the display device **52** by clicking on the image. In response to this input operation, the processor **42** may display the result comparison image RI**3** (FIG. **14**) corresponding to the selected plurality of temperatures T, on the display device **52**.

[0134] As described above, in the present embodiment, the processor **42** generates the detection result image RI (specifically, the result list image RI**1**, the result detail image RI**2**, and the result comparison image RI**3**) displaying the results (the detection result data RD) of the plurality of detection operations DO repeatedly tried in step S**36**. Accordingly, the processor **42** functions as an image generating unit **66** (FIG. **10**) configured to generate the detection result image RI.

[0135] Referring to FIG. **11** again, in step S**39**, the processor **42** determines whether or not input of the lower limit value T_{th1} and the upper limit value T_{th2} of the allowable range [T_{th1}, T_{th2}] has been received. Here, the operator can determine the lower limit value T_{th1} and the upper limit value T_{th2} of the temperature T capable of securing the accuracy of the detection operation DO, by examining the detection result data RD depicted in the detection result image RI (the result list image RI**1**, the result detail image RI**2**, and the result comparison image RI**3**) displayed in step S**38** described above.

[0136] For example, by comparing the detecting position P (x, y, z) depicted in the detection result image RI with the teaching position P**0** (x0, y0, z0) taught in advance, the operator can be aware of a deviation of the detecting position P from the teaching position P**0**, and as a result, the operator can recognize the relationship between the deviation and the temperature T. In addition, the operator can recognize the relationship between the temperature T and the score α, the contrast β and the distortion γ, which may affect the accuracy of the detection operation DO.

[0137] The operator operates the input device **54** to input the lower limit value T_{th1} and the upper limit value T_{th2} determined as a result of examining the detection result image RI. At this time, the processor **42** may generate an input image for receiving the input of the lower limit value T_{th1} and the upper limit value T_{th2}, and display the generated input image on the display device **52**, together with the detection result image RI (or by switching from the detection result image RI).

[0138] The processor **42** determines YES in step S**39** and proceeds to step S**41** in the case where the input of the lower limit value T_{th1} and the upper limit value T_{th2} is received, whereas the processor **42** proceeds to step S**40** upon determining NO. Thus, in the present embodiment, the processor **42** functions as an input receiving unit **68** (FIG. **10**) configured to receive the input of the lower limit value T_{th1} and the upper limit value T_{th2}.

[0139] In step S**40**, the processor **42** determines whether or not a trial execution command for executing the trial of the detection operation DO again has been received from the operator. For example, the operator performs the trial of the detection operation DO while raising the temperature T stepwise from the initial temperature T**0** being 10° C. to the maximum temperature Tmax being 60° C. through the first-time loop of step S**31** to step S**40**.

[0140] Subsequently, the operator performs the trial of the detection operation DO while lowering the temperature T stepwise from the initial temperature T**0** being 60° C. to the minimum temperature Tmin being 10° C. through the second-time loop of step S**31** to step S**40**. In this way, in order to execute the loop of step S**31** to step S**40** a plurality of times, the operator may give the trial execution command to the processor **42** in step S**40**. The processor **42** returns to step S**31** upon determining YES, or returns to step S**39** upon determining NO.

[0141] In step S**41**, the processor **42** determines the allowable range [T_{th1}, T_{th2}] by the lower limit value T_{th1} and the upper limit value T_{th2} received in the immediately preceding step S**39**, and stores the determined allowable range in the memory **44**. The processor **42** executes the flow in FIG. **4**, **6**, or **9** by referring to the allowable range [T_{th1}, T_{th2}] determined as described above.

[0142] As discussed above, in the industrial machine **10** illustrated in FIG. **10**, the processor **42** functions as the temperature acquisition unit **56**, the temperature determination unit **58**, the temperature adjustment unit **60**, the detection operation executing unit **62**, the image generating unit

66, and the input receiving unit 68, so as to manage the temperature T of the imaging unit 14. Accordingly, the temperature acquisition unit 56, the temperature determination unit 58, the temperature adjustment unit 60, the detection operation executing unit 62, the image generating unit 66, and the input receiving unit 68 constitute an apparatus 120 configured to manage the temperature T of the imaging unit 14.

[0143] In the apparatus 120, in order to determine the allowable range $[T_{th1}, T_{th2}]$, the temperature adjustment unit 60 changes the temperature T (step S33) by executing the warming-up operation WO or the cooling operation CO before the work (step S6). Then, the detection operation executing unit 62 performs the trial of the detection operation DO when the temperature adjustment unit 60 changes the temperature T (step S36). This configuration makes it possible to clarify the relationship between the temperature T and the result of the detection operation DO. Thus, it is possible to determine the allowable range $[T_{th1}, T_{th2}]$ so that the accuracy of the detection operation DO can be secured.

[0144] In the apparatus 120, the image generating unit 66 generates the detection result image RI displaying the result of the plurality of detection operations DO repeatedly tried by the detection operation executing unit 62 (step S38). Then, the input receiving unit 68 receives the input of the lower limit value T_{th1} and the upper limit value T_{th2} determined by the operator on the basis of the result of the detection operations DO (step S39). According to this configuration, the operator can easily examine the relationship between the temperature T and the detection result by referring to the detection result image RI. As a result, the operator can appropriately determine the lower limit value T_{th1} and the upper limit value T_{th2} of the allowable range $[T_{th1}, T_{th2}]$.

[0145] Next, still another method of determining the allowable range $[T_{th1}, T_{th2}]$ will be described with reference to FIGS. 15 and 16. In the industrial machine 10 illustrated in FIG. 15, the processor 42 of the controller 18 executes a flow of FIG. 16 before the flow of FIG. 4, 6, or 9 in order to determine the allowable range $[T_{th1}, T_{th2}]$. Note that, in the flow illustrated in FIG. 16, processing similar to that in the flow of FIG. 11 is denoted by the same step number, and redundant description thereof will be omitted.

[0146] The flow in FIG. 16 is started when the processor 42 receives an allowable range setting command from the operator, the host controller, or the computer program PG. After the flow illustrated in FIG. 16 is started, the processor 42 sequentially executes step S31 to step S36 discussed above. In the following description, a case will be explained where the processor 42 raises the temperature T from the initial temperature T0 (=10° C.) by the change amount δT in steps S33 to S35 in FIG. 16.

[0147] In step S51, the processor 42 determines whether or not the detection result parameters PRr included in the detection result data RD acquired by executing the immediately preceding step S36 fall within threshold value ranges capable of securing the accuracy of the detection operation DO. As an example, +5% threshold value ranges of [x0×0.95, x0×1.05], [y0×0.95, y0×1.05], and [z0×0.95, z0×1.05] are respectively set for the coordinates x0, y0, and z0 of the teaching position P0 taught in advance.

[0148] In this case, the processor 42 determines whether or not the coordinates x, y, and z of the detecting position P (x, y, z) acquired as the detection result parameters PRr in the immediately preceding step S36 respectively fall within the threshold value ranges of [x0×0.95, x0×1.05], [y0×0.95, y0×1.05], and [z0×0.95, z0×1.05] (i.e., x0× 0.95≤ x≤ x0×1.05, y0×0.95<y≤ y0×1.05, and z0×0.95≤ z≤ z0×1.05).

[0149] When each of the coordinates x, y, and z of the detecting position P falls within the threshold value range, it can be considered that the accuracy of the detection operation DO is secured. Therefore, when at least one of the coordinates x, y, and z is outside the threshold value range, the processor 42 determines NO in step S51. The threshold value ranges are not limited to +5% of the coordinates of the detecting position P, and may each be a range of any percentage such as +1% or +10%.

[0150] As another example, in the immediately preceding step S36, the processor 42 acquires, as the detection result parameter PRr, a deviation amount OP between the detecting position P (x, y, z) and the teaching position P0 (x0, y0, z0) taught in advance. The deviation amount OP is obtained by the calculation of $((x-x0)^2+(y-y0)^2+(z-z0)^2)^{1/2}$. When the deviation amount OP exceeds a predetermined threshold value δP_{th} (i.e., $\delta P>\delta P_{th}$), the processor 42 determines that the deviation amount OP is outside the threshold value range capable of securing the accuracy of the detection operation DO (i.e., NO).

[0151] As still another example, when the score α, the contrast β, or the distortion γ acquired as the detection result parameter PRr in the immediately preceding step S36 is smaller or larger than a predetermined threshold value α_{th}, β_{th}, or γ_{th} (e.g., $\alpha<\alpha_{th}$, $\beta<\beta_{th}$, or $\gamma>\gamma_{th}$), the processor 42 determines that the score α, contrast β, or distortion y is outside the threshold value range capable of securing the accuracy of the detection operation DO (i.e., NO).

[0152] The processor 42 may determine whether or not all the detection result parameters PRr including the coordinates x, y, and z of the detecting position P, the deviation amount OP, the score α, the contrast B, and the distortion y fall within the respective threshold value ranges, and may determine NO in step S51 when at least one of the detection result parameters PRr is outside the threshold value range.

[0153] The processor 42 returns to step S33 upon determining NO, or proceeds to step S52 upon determining YES. When the determination made in step S51 is YES, it can be considered that the temperature T raised stepwise in step S33 exceeds the lower limit value T_{th1} of the allowable range $[T_{th1}, T_{th2}]$ capable of securing the accuracy of the detection operation DO and falls within the allowable range $[T_{th1}, T_{th2}]$.

[0154] In this way, the processor 42 repeatedly executes a loop of steps S33 to S36 and step S51 until the processor 42 determines YES in step S51, and every time the temperature T of the imaging unit 14 is raised by the change amount δT, the processor 42 repeatedly performs the trial of the detection operation DO. Each time the trial of the detection operation DO is performed, it is determined whether or not the detection result parameters PRr each fall within the threshold value range capable of securing the accuracy of the detection operation DO, thereby searching for the lower limit value T_{th1} Of the temperature T capable of securing the accuracy mentioned above. That is, in the present embodiment, the processor 42 functions as an allowable range determination unit 82 (FIG. 15) configured to automatically determine the lower limit value T_{th1} of the allowable range

$[T_{th1}, T_{th2}]$ on the basis of the results of the plurality of detection operations repeatedly tried (specifically, the detection result parameters PRr).

[0155] In step S**52**, the processor **42** functions as the allowable range determination unit **82** to determine the lower limit value T_{th1} of the allowable range $[T_{th1}, T_{th2}]$ on the basis of the determination result in step S**51**. To be specific, the processor **42** determines the temperature T at the time when the processor **42** determines YES in the immediately preceding step S**51** as the lower limit value T_{th1}, and stores the determined value in the memory **44**. After step S**52**, the processor **42** executes steps S**33** to S**36**.

[0156] In step S**53**, the processor **42** functions as the allowable range determination unit **82** to determine whether or not the detection result parameters PRr (the coordinates of the detecting position P, the deviation amount OP, the score α, the contrast B, and the distortion y) acquired by executing the immediately preceding step S**36** respectively fall within the threshold value ranges capable of securing the accuracy of the detection operation DO, similarly to step S**51** described above. The processor **42** proceeds to step S**54** upon determining YES, or proceeds to step S**55** upon determining NO.

[0157] In step S**54**, the processor **42** functions as the allowable range determination unit **82** to set a temporary upper limit value T_{th2}' as a temporary setting value of the upper limit value T_{th2} of the allowable range $[T_{th1}, T_{th2}]$. To be specific, the processor **42** determines the temperature T at the time when the processor **42** determines YES in the immediately preceding step S**53** as the temporary upper limit value T_{th2}', and stores the temporary value in the memory **44**. Thus, after step S**52** discussed above, the processor **42** repeatedly executes a loop of steps S**33** to S**36**, S**53**, and S**54** until determining NO in step S**53**. Then, the processor **42** updates the temporary upper limit value T_{th2}' stored in the memory **44** every time the processor **42** executes step S**54**.

[0158] On the other hand, when the determination made in step S**53** is NO, it can be considered that the temperature T raised stepwise in step S**33** exceeds the upper limit value T_{th2} of the allowable range $[T_{th1}, T_{th2}]$ capable of securing the accuracy of the detection operation DO and comes to be outside the allowable range $[T_{th1}, T_{th2}]$. In this manner, the processor **42** repeatedly executes the loop of steps S**33** to S**36**, S**53**, and S**54**, thereby searching for the upper limit value T_{th2} of the temperature T capable of securing the accuracy of the detection operation DO.

[0159] In step S**55**, the processor **42** functions as the allowable range determination unit **82** to determine the upper limit value T_{th2} on the basis of the determination result in step S**53**. To be specific, the processor **42** determines the temporary upper limit value T_{th2}' stored in the memory **44** at the time point when the determination made in the immediately preceding step S**53** is NO as the official upper limit value T_{th2} of the allowable range $[T_{th1}, T_{th2}]$, and stores the official value in the memory **44**. The temporary upper limit value T_{th2}' stored at this time point is the temperature T when the determination made most recently in step S**53** is YES (in other words, the temperature T acquired in the two-time earlier step S**34**).

[0160] In step S**56**, the processor **42** determines the allowable range $[T_{th1}, T_{th2}]$ by the lower limit value T_{th1} and the upper limit value T_{th2} determined in step S**52** and step S**55**, and stores the determined allowable range in the memory **44**. The processor **42** executes the flow in FIG. **4**, **6**, or **9** by referring to the allowable range $[T_{th1}, T_{th2}]$ determined as described above.

[0161] As discussed above, in the industrial machine **10** illustrated in FIG. **15**, the processor **42** functions as the temperature acquisition unit **56**, the temperature determination unit **58**, the temperature adjustment unit **60**, the detection operation executing unit **62**, and the allowable range determination unit **82**, so as to manage the temperature T of the imaging unit **14**. Accordingly, the temperature acquisition unit **56**, the temperature determination unit **58**, the temperature adjustment unit **60**, the detection operation executing unit **62**, and the allowable range determination unit **82** constitute an apparatus **130** configured to manage the temperature T of the imaging unit **14**.

[0162] In the apparatus **130**, the allowable range determination unit **82** automatically determines the lower limit value T_{th1} and the upper limit value T_{th2} of the allowable range $[T_{th1}, T_{th2}]$ on the basis of the results (specifically, the detection result parameters PRr) of the plurality of detection operations DO (step S**36**) repeatedly tried by the detection operation executing unit **62**. According to this configuration, since the allowable range $[T_{th1}, T_{th2}]$ can be automatically set, the burden on the operator can be reduced.

[0163] In the apparatus **130**, each time the detection operation executing unit **62** performs the trial of the detection operation DO (step S**36**), the allowable range determination unit **82** determines whether or not the detection result parameters PRr (the coordinates of the detecting position P, the deviation amount OP, the score α, the contrast B, the distortion y, and the like) included in the result of the detection operation DO fall within the threshold value ranges capable of securing the accuracy of the detection operation DO (steps S**51** and S**53**).

[0164] Then, the allowable range determination unit **82** determines the lower limit value T_{th1} and the upper limit value T_{th2} on the basis of the determination results of the detection result parameters PRr. According to this configuration, for example, as illustrated in FIG. **16**, the flow of setting the allowable range $[T_{th1}, T_{th2}]$ can be automated by a relatively simple algorithm.

[0165] In the present embodiment, the case has been described where the processor **42** raises the temperature T from the initial temperature T**0** (=10° C.) by the change amount δT in steps S**33** to S**35** in FIG. **16**. However, in steps S**33** to S**35** in FIG. **16**, the processor **42** may lower the temperature T from the initial temperature T**0** (=60° C.) by the change amount δT.

[0166] In this case, in step S**52**, the processor **42** determines the temperature T at the time when the processor **42** determines YES in the immediately preceding step S**51** as the upper limit value T_{th2}. In step S**54**, the processor **42** stores the temperature T at the time when the processor **42** determines YES in the immediately preceding step S**53** in the memory **44** as a temporary lower limit value T_{th1}'. Then, in step S**55**, the processor **42** determines the temporary lower limit value T_{th1}' stored in the memory **44** at the time point when the determination made in the immediately preceding step S**53** is NO, as the official lower limit value T_{th1} of the allowable range $[T_{th1}, T_{th2}]$.

[0167] Various changes can be added to the flow in FIG. **16**. For example, steps S**33** to S**36** and S**53** to S**55** after step S**52** may be omitted from the flow in FIG. **16**. In this case, the processor **42** may change (i.e., raise or lower) the temperature T from the initial temperature T**0** (=10° C. or 60° C.) by the change amount δT in steps S**33** to S**35**, and may determine the lower limit value T_{th1} or the upper limit value T_{th2} in step S**52**. That is, in this case, the processor **42** automatically determines one of the lower limit value T_{th1} and the upper limit value T_{th2}. Furthermore, steps S**31** and S**32** may be omitted from the flow in FIG. **11** or **16**. In this case, the initial temperature T**0** may be set to the ambient temperature at that time.

[0168] Next, another function of the industrial machine **10** will be described with reference to FIGS. **17** and **18**. In the industrial machine **10** illustrated in FIG. **17**, the processor **42** of the controller **18** functions as an apparatus **140** including the temperature acquisition unit **56**, the temperature determination unit **58**, the temperature adjustment unit **60**, the detection operation executing unit **62**, the allowable range acquisition unit **64**, the image generating unit **66**, the input receiving unit **68**, the allowable range determination unit **82**, a difference acquisition unit **84**, and a difference determination unit **86**. Accordingly, the processor **42** can execute the functions of the industrial machines **10** illustrated in FIGS. **2**, **8**, **10**, and **15** (i.e., the flows of FIGS. **4**, **6**, **9**, **11**, and **16**).

[0169] In the present embodiment, the processor **42** executes a warming-up scheme illustrated in FIG. **18** as a preparation process for the work immediately before (or immediately after) the start of the flow in FIG. **4**, **6**, or **9**. A flow illustrated in FIG. **18** is started when the imaging unit **14** is activated (i.e., powered on) for the flow in FIG. **4**, **6**, or **9**.

[0170] In step S**61**, the processor **42** functions as the detection operation executing unit **62** as in step S**36** described above, and performs the trial of the detection operation DO. As a result, the processor **42** acquires the detection result parameters PRr (the detecting position P, the score α, the contrast B, the distortion y, and the like). In step S**62**, the processor **42** functions as the temperature adjustment unit **60**, and executes the warming-up operation WO as in step S**5** described above. In step S**63**, the processor **42** functions as the detection operation executing unit **62** as in step S**61** described above, and performs the trial of the detection operation DO. As a result, the processor **42** acquires the detection result parameters PRr (the detecting position P, the score α, the contrast B, the distortion y, and the like) again.

[0171] In step S**64**, the processor **42** acquires a difference δr_i between a detection result parameter PRr_i included in the result of a detection operation DO_i (first detection operation) most recently tried and a detection result parameter PRr_{i-1} included in the result of a detection operation DO_{i-1} (second detection operation) tried before the detection operation DO_i. As an example, the processor **42** acquires a deviation amount between a detecting position P_i (x_i, y_i, z_i) acquired as the detection result parameter PRr_i and a detecting position P_{i-1} (x_{i-1}, y_{i-1}, z_{i-1}) acquired as the detection result parameter PRr_{i-1}, as a difference $\delta r1_i$. The deviation amount is obtained by the calculation of $((x_i-x_{i-1})\ 2+ (y_i-y_{i-1})^2+(z_i-z_{i-1})^2)^{1/2}$.

[0172] As another example, the processor **42** acquires a difference $\delta r2_i$ equal to $|\alpha_i-\alpha_{i-1}|$, a difference $\delta r3_i$ equal to $|\beta_i-\beta_{i-1}|$, or a difference $\delta r4_i$ equal to $|\gamma_i-\gamma_{i-1}|$ between a score α_i, a contrast β_i or a distortion γ_i acquired as the detection result parameter PRr_i and a score α_{i-1}, a contrast β_{i-1} or a distortion γ_{i-1} acquired as the detection result parameter PRr_{i-1}.

[0173] As described above, in the present embodiment, the processor **42** functions as the difference acquisition unit **84** (FIG. **17**) configured to acquire the difference δr_i ($\delta r1_i$, $\delta r2_i$, $\delta r3_i$, or $\delta r4_i$) between the detection result parameter PRr_i and the detection result parameter PRr_{i-1}. For example, when the processor **42** executes step S**64** after continuously executing steps S**61**, S**62**, and S**63**, the processor **42** acquires a difference δr_1 between a detection result parameter PRr_2 acquired in the immediately preceding step S**63** and a detection result parameter PRr_1 acquired in step S**61** executed before step S**63** mentioned above.

[0174] In step S**65**, the processor **42** determines whether or not the difference δr_i (e.g., $\delta r1_i$, $\delta r2_i$, $\delta r3_i$, or $\delta r4_i$) acquired in the immediately preceding step S**64** is smaller than a predetermined threshold value Orth. In a case of $\delta r_i<\delta r_{th}$, the processor **42** determines YES and ends the flow in FIG. **18**, and then executes the flow in FIG. **4**, **6**, or **9** so as to sequentially execute step S6 and step S7 discussed above.

[0175] On the other hand, in a case of $\delta n_i>\delta r_{th}$, the processor **42** determines NO, and returns to step S**62**. In this manner, in the present embodiment, the processor **42** functions as the difference determination unit **86** (FIG. **17**) configured to determine whether or not the difference δr_i (e.g., $\delta r1_i$, $\delta r2_i$, $\delta r3_i$, or $\delta r4_i$) is smaller than the predetermined threshold value Orth.

[0176] As described above, the processor **42** functions as the apparatus **140** configured to execute the warming-up scheme illustrated in FIG. **18** as the preparation process for the work. In the apparatus **140**, the temperature adjustment unit **60** executes the warming-up operation WO (step S**62**) when the imaging unit **14** is activated (after the power is turned on), and the detection operation executing unit **62** repeatedly performs the trial of the detection operation DO (step S**63**) each time the temperature adjustment unit **60** executes the warming-up operation WO.

[0177] The difference acquisition unit **84** acquires the difference δr_i between the detection result parameter PRr_i included in the result of the first detection operation DO_i tried by the detection operation executing unit **62** and the detection result parameter PRr_{i-1} included in the result of the second detection operation DO_{i-1} tried by the detection operation executing unit **62** before the first detection operation DO_i (step S**64**). Then, the difference determination unit **86** determines whether or not the difference δr_i acquired by the difference acquisition unit **84** is smaller than the predetermined threshold value Orth (step S**65**). When the difference determination unit **86** determines that the difference δr_i is smaller than the threshold value δr_{th} (YES in step S**65**), the detection operation executing unit **62** executes the detection operation DO for the work (step S6).

[0178] After the imaging unit **14** (i.e., the camera **36**, the illumination device **38**, and the processor **40**) is activated (e.g., powered on), since the temperature T of the imaging unit **14** rapidly rises, there is a possibility that the accuracy of the detection operation DO is unstable. Then, in the present embodiment, the warming-up operation WO is executed until a variation (i.e., difference δr) in the detection result parameters PRr acquired when the trial of the detection operation DO is repeatedly performed becomes small by executing the warming-up scheme illustrated in FIG. **18**. This configuration makes it possible to stabilize the accuracy of the detection operation DO to be executed thereafter.

[0179] Next, another example of the warming-up scheme will be described with reference to FIG. **19**. The processor **42** executes the warming-up scheme illustrated in FIG. **19** as a preparation process for the work immediately before (or immediately after) the start of the flow in FIG. **4**, **6**, or **9**. In step S**71**, the processor **42** functions as the temperature acquisition unit **56** to acquire the temperature T of the imaging unit **14** as in step S**1** described above. In step S**72**, the processor **42** functions as the temperature adjustment unit **60** as in step S**62** described above, and executes the warming-up operation WO.

[0180] In step S**73**, the processor **42** functions as the temperature acquisition unit **56** to acquire the temperature T of the imaging unit **14** as in step S**71** described above. In step S**74**, the processor **42** functions as the difference acquisition unit **84** to acquire a difference δM_i ($=T_i-T_{i-1}$) between a temperature T_i (first temperature) acquired in the immediately preceding step S**73** and a temperature T_{i-1} (second temperature) acquired before the temperature T_i.

[0181] In step S**75**, the processor **42** functions as the difference determination unit **86**, and determines whether or not the difference δM_i acquired in the immediately preceding step S**74** is smaller than a predetermined threshold value δM_{th}. In a case of $\delta M_i<\delta M_{th}$, the processor **42** determines YES and ends the flow in FIG. **19**, and then executes the flow in FIG. **4**, **6**, or **9** so as to sequentially execute step S**6** and step S**7** discussed above. On the other hand, in a case of $\delta M_i>\delta M_{th}$, the processor **42** determines NO, and returns to step S**72**.

[0182] As described above, the processor **42** functions as the apparatus **140** configured to execute the warming-up scheme illustrated in FIG. **19** as the preparation process for the work. In the apparatus **140**, the temperature acquisition unit **56** acquires the temperature T repeatedly measured by the temperature sensors **16** each time the temperature adjustment unit **60** executes the warming-up operation WO (step S**73**). The difference acquisition unit **84** acquires the difference δM_i between the temperature T_i acquired by the temperature acquisition unit **56** and the temperature T_{i-1} acquired by the temperature acquisition unit **56** before the temperature T_i (step S**74**). Then, the difference determination unit **86** determines whether or not the difference δM_i acquired by the difference acquisition unit **84** is smaller than the predetermined threshold value δM_{th} (step S**75**).

[0183] When the difference determination unit **86** determines that the difference δM_i is smaller than the threshold value δM_{th} (YES in step S**75**), the detection operation executing unit **62** executes the detection operation DO for the work (step S**6**). This configuration makes it possible to stabilize the accuracy of the detection operation DO to be executed after the flow in FIG. **19**, as in the flow in FIG. **18**.

[0184] The processor **42** may execute the functions of the industrial machine **10** illustrated in FIGS. **2**, **8**, **10**, **15**, and **17** (i.e., the flows in FIGS. **4**, **6**, **9**, **11**, **16**, **18**, and **19**) in accordance with the computer program PG stored in advance in the memory **44**. The functions of the temperature acquisition unit **56**, the temperature determination unit **58**, the temperature adjustment unit **60**, the detection operation executing unit **62**, the allowable range acquisition unit **64**, the image generating unit **66**, the input receiving unit **68**, the allowable range determination unit **82**, the difference acquisition unit **84**, and the difference determination unit **86** executed by the processor **42** may be function modules implemented by the computer program PG.

[0185] In the above-described embodiment, the case where the camera **36** and the illumination device **38** are integrally incorporated in the housing **34** has been described. However, the present invention is not limited thereto, and the camera **36** and the illumination device **38** may be provided as separate devices in the imaging unit **14**. In this case, the temperature sensor **16** may be provided in one of the camera **36** and the illumination device **38**, and measure the temperature T of the one thereof.

[0186] Alternatively, the temperature sensor **16** may include a first temperature sensor **16**A provided to the camera **36** to measure a temperature Tc of the camera **36** and a second temperature sensor **16**B provided to the illumination device **38** to measure a temperature TI of the illumination device **38**. In this case, the processor **42** functions as the apparatus **100**, **110**, **120**, **130**, or **140** configured to execute a flow FL**1** for managing the temperature Tc of the camera **36**.

[0187] In the flow FL**1**, the processor **42** may execute S**1** to S**5** in FIG. **4**, steps S**1**, S**2** and S**10** in FIG. **6**, or S**21**, S**1**, S**2**, S**22** to S**25** and S**3** to S**5** in FIG. **9** on the basis of the temperature Tc of the camera **36** acquired by the processor **42** serving as the temperature acquisition unit **56**. In the warming-up operation WO of step S**5** executed in the flow FL**1**, the processor **42** executes, for example, the above-described simulative imaging operation IO or arithmetic processing CL.

[0188] On the other hand, the processor **42** functions as the apparatus **100**, **110**, **120**, **130**, or **140** configured to execute a flow FL**2** for managing the temperature TI of the illumination device **38** in parallel to the flow FL**1** for the camera **36**. In the flow FL**2**, the processor **42** may execute S**1** to S**5** in FIG. **4**, steps S**1**, S**2** and S**10** in FIG. **6**, or S**21**, S**1**, S**2**, S**22** to S**25** and S**3** to S**5** in FIG. **9** on the basis of the temperature TI of the illumination device **38** acquired by the processor **42** serving as the temperature acquisition unit **56**.

[0189] In the warming-up operation WO of step S**5** executed in the flow FL**2**, the processor **42** executes, for example, the above-described lighting operation LO. The allowable range [T_{th1}, T_{th2}] referred to in the flows FL**1** and FL**2** may be separately determined for the camera **36** and the illumination device **38** by the method described above.

[0190] The flow FL**1** for the temperature management of the camera **36** and the flow FL**2** for the temperature management of the illumination device **38** are applicable to the flow illustrated in FIG. **4**, FIG. **6**, or FIG. **9**. In this case, after starting the flow of FIG. **4**, **6**, or **9**, the processor **42** executes the flow FL**1** for the camera **36** and the flow FL**2** for the illumination device **38** in parallel, and thereafter executes steps S**6** to S**7**. Note that the processor **42** may include a first processor **42**A configured to execute the flow FL**1** and a second processor **42**B configured to execute the flow FL**2**.

[0191] In the case where the camera **36** and the illumination device **38** are integrally incorporated in the housing **34**, the temperature sensor **16** may include a first temperature sensor **16**A configured to measure the temperature Tc of the camera **36** and a second temperature sensor **16**B configured to measure the temperature TI of the illumination device **38**. In this case as well, the processor **42** may execute the flow FL**1** for managing the temperature Tc of the camera **36** and the flow FL**2** for managing the temperature TI of the illumination device **38** in parallel.

[0192] In this form, the processor **42** may determine YES in step S**2** executed in one of the flow FL**1** and the flow FL**2**, and may determine NO in step S2 executed in the other one of the flow FL1 and the flow FL2. In this case, the processor 42 may automatically determine which of the temperature management of the flow FL1 and the temperature management of the flow FL2 is prioritized.

[0193] For example, assume that the processor 42 determines YES in step S2 of the flow FL1 and determines NO in step S2 of the flow FL2 when the processor 42 are executing the flows FL1 and FL2 in parallel. In this case, the processor 42 may give priority to the flow FL1 for managing the temperature Tc of the camera 36, and may cancel step S4 (cooling operation CO) and step S5 (warming-up operation WO) to be executed in the flow FL2.

[0194] Alternatively, when the processor 42 executes the flows FL1 and FL2 in parallel and then executes steps S6 to S7, the processor 42 may automatically determine which of the temperature management in the flow FL1 and the temperature management in the flow FL2 is prioritized on the basis of the result of the detection operation DO (detection result data RD) in step S6. For example, on the basis of the detection result parameters PRr (the detecting position P, the score α, the contrast β, and the distortion Y) included in the detection result data RD, the processor 42 can determine which of the temperature Tc of the camera 36 and the temperature TI of the illumination device 38 causes the degradation in accuracy of the detection operation DO.

[0195] Therefore, the processor 42 may determine which temperature management of the flows FL1 and FL2 is prioritized on the basis of the detection result parameters PRr and execute step S4 (cooling operation CO) and step S5 (warming-up operation WO) of the prioritized flow FL1 or FL2, and may cancel steps S4 and S5 of the non-prioritized flow FL1 or FL2.

[0196] In the above-described embodiment, the case where the processor 42 of the controller 18 functions as the apparatuses 100, 110, 120, 130, and 140 has been described. However, the function of the apparatus 100, 110, 120, 130 or 140 may also be implemented in a device different from the controller 18. For example, the function of the apparatus 100 illustrated in FIG. 2 may be implemented in a host controller of the controller 18 or in the imaging unit 14. In this case, a processor of the host controller or the processor 40 of the imaging unit 14 functions as the apparatus 100. In this case, the detection operation executing unit 62 may be omitted from the apparatus 100.

[0197] Further, in the embodiment described above, the case where the camera 36 is a two-dimensional camera has been described. However, the camera 36 is not limited thereto and may be a three-dimensional vision sensor. In this case, the image data ID imaged by the camera 36 is, for example, three-dimensional point group image data, and each point appearing in the three-dimensional point group image data includes information on a distance d from the camera 36 to the subject (workpiece W). In this case, a three-dimensional camera coordinate system C3 is set for the camera 36, and each pixel of the image data ID to be imaged is represented by three-dimensional coordinates Qc (xc, yc, zc) in the camera coordinate system C3.

[0198] In the embodiment described above, the case where the imaging unit 14 is moved by the robot 12 has been described. However, the present invention is not limited thereto, and the imaging unit 14 may be fixed at the predetermined imaging position IP1. Further, the illumination device 38 may be omitted from the imaging unit 14. The allowable range $[T_{th1}, T_{th2}]$ is not limited to being determined by the various methods mentioned above, and may be determined by any method. Further, the robot 12 is not limited to the vertical articulated robot, and may be, for example, any type of robot such as a horizontal articulated robot or a parallel link robot.

[0199] The present disclosure has been described in detail thus far, but the present disclosure is not limited to the individual embodiments. Various additions, replacements, changes, partial deletions, and the like can be made to these embodiments without departing from the gist of the present disclosure or without departing from the gist of the present disclosure derived from the contents described in the claims and equivalents thereof. Further, these embodiments can also be combined with each other and implemented. For example, in the embodiment described above, the order of the operations and the order of the processing are given as an example, and are not limited thereto. The same applies to the case where numerical values or mathematical expressions are used in the description of the above-described embodiment.

[0200] With regard to the above-described embodiment, the following supplementary notes are disclosed.

[0201] (Supplementary Note 1) The apparatus 100, 110, 120, 130, or 140 configured to manage the temperature T of the imaging unit 14 in the industrial machine 10 which executes the detection operation DO to detect a workpiece W on the basis of the image data ID of the workpiece W imaged by the imaging unit 14 and which carries out work on the detected workpiece W, the apparatus 100, 110, 120, 130 or 140 including: the temperature acquisition unit 56 configured to acquire the temperature T measured by the temperature sensor 16; the temperature determination unit 58 configured to determine whether or not the temperature T, which is acquired by the temperature acquisition unit 56 when the detection operation DO for the work is executed, falls within the allowable range $[T_{th1}, T_{th2}]$ predetermined for securing accuracy of the detection operation DO; and the temperature adjustment unit 60 configured to execute the warming-up operation WO to raise the temperature T when the temperature determination unit 58 determines that the temperature T is lower than the lower limit value T_{th1} of the allowable range $[T_{th1}, T_{th2}]$, while executing the cooling operation CO to lower the temperature T when the temperature determination unit 58 determines that the temperature T is higher than the upper limit value T_{th2} of the allowable range $[T_{th1}, T_{th2}]$.

[0202] (Supplementary Note 2) The apparatus 110 or 140 of Supplementary Note 1, wherein the temperature acquisition unit 56 is configured to acquire the first temperature T1 or T2 measured by the temperature sensor 16 when the imaging unit 14 executes the imaging operation IO for the teaching process TP for teaching the shape TS of the workpiece W or the calibration process CB for calibrating the imaging parameter PRi of the imaging unit 14, and wherein the apparatus 110 or 140 further includes the allowable range acquisition unit 64 configured to acquire the allowable range $[T_{th1}, T_{th2}]$ determined on the basis of the first temperature T1 or T2, and store the acquired allowable range in the memory 44.

[0203] (Supplementary Note 3) The apparatus 120, 130, or 140 of Supplementary Note 1, wherein the temperature adjustment unit 60 is configured to change the temperature T by executing the warming-up operation WO or the cooling operation CO before the work, in order to determine the allowable range [T_{th1}, T_{th2}], and wherein the apparatus **120**, **130**, or **140** further includes the detection operation executing unit **62** configured to try the detection operation DO when the temperature adjustment unit **60** changes the temperature T.

[0204] (Supplementary Note 4) The apparatus **120** or **140** of Supplementary Note 3, further including: the image generating unit **66** configured to generate the detection result image RI displaying results of a plurality of the detection operations DO repeatedly tried by the detection operation executing unit **62**; and the input receiving unit **68** configured to receive an input of the lower limit value T_{th1} and the upper limit value T_{th2} determined on the basis of the results of the detection operations DO.

[0205] (Supplementary Note 5) The apparatus **130** or **140** of Supplementary Note 3, further including the allowable range determination unit **82** configured to automatically determine the lower limit value T_{th1} or the upper limit value T_{th2} of the allowable range [T_{th1}, T_{th2}], on the basis of results of a plurality of the detection operations DO repeatedly tried by the detection operation executing unit **62**

[0206] (Supplementary Note 6) The apparatus **130** or **140** of Supplementary Note 5, wherein the detection operation executing unit **62** is configured to repeatedly try the detection operation DO every time the temperature adjustment unit **60** changes the temperature T by the predetermined change amount δT, and

[0207] wherein the allowable range determination unit **82** is configured to:

[0208] determine whether or not a detection result parameter PRr included in the result of the detection operation DO falls within a threshold value range capable of securing the accuracy, every time the detection operation executing unit **62** tries the detection operation DO; and

[0209] determine the lower limit value T_{th1} or the upper limit value T_{th2} on the basis of the determination result of the detection result parameter PRr.

[0210] (Supplementary Note 7) The apparatus **100**, **110**, **120**, **130**, or **140** of any one of Supplementary Notes 1 to 6, wherein the temperature adjustment unit **60** is configured to raise the temperature T by causing the imaging unit **14** to simulatively execute the imaging operation IO, causing the processor **40** incorporated in the imaging unit **14** to execute the predetermined arithmetic processing CL, or turning on the illumination device **38** provided in the imaging unit **14**, as the warming-up operation WO.

[0211] (Supplementary Note 8) The apparatus **100**, **110**, **120**, **130**, or **140** of any one of Supplementary Notes 1 to 7, wherein the temperature adjustment unit **60** is configured to lower the temperature T by stopping an operation of the imaging unit **14** for the predetermined cooling time t_{th1}, as the cooling operation CO.

[0212] (Supplementary Note 9) The apparatus **100**, **110**, **120**, **130**, or **140** of any one of Supplementary Notes 1 to 8, wherein the temperature determination unit **58** is configured to determine whether or not the temperature T falls within the allowable range [T_{th1}, T_{th2}] every time the temperature adjustment unit **60** executes the warming-up operation WO or the cooling operation CO, and wherein the apparatus **100**, **110**, **120**, **130**, or **140** further includes the detection operation executing unit **62** configured to execute the detection operation DO for the work when the temperature determination unit **58** determines that the temperature T falls within the allowable range [T_{th1}, T_{th2}], while not executing the detection operation DO while the temperature determination unit **58** determines that the temperature T is outside the allowable range [T_{th1}, T_{th2}].

[0213] (Supplementary Note 10) The apparatus **100**, **110**, **120**, **130**, or **140** of Supplementary Note 9, wherein the detection operation executing unit **62** is configured to execute the detection operation DO for the work when the elapsed time t**3**, which is clocked while the temperature determination unit **58** determines that the temperature T is outside the allowable range [T_{th1}, T_{th2}], reaches the predetermined time limit t_{th3}.

[0214] (Supplementary Note 11) The apparatus **140** of any one of Supplementary Notes 1 to 10,

[0215] wherein the temperature adjustment unit **60** is configured to execute the warming-up operation WO when the imaging unit **14** is activated,

[0216] wherein the apparatus **140** further includes:

[0217] the detection operation executing unit **62** configured to repeatedly try the detection operation DO every time the temperature adjustment unit **60** executes the warming-up operation WO;

[0218] the difference acquisition unit **84** configured to acquire a difference δr_i between a detection result parameter PRr_i included in a result of a first detection operation DO_i tried by the detection operation executing unit **62** and a detection result parameter PRr_{i-1} included in a result of a second detection operation DO_{i-1} tried by the detection operation executing unit **62** before the first detection operation DO_i; and

[0219] the difference determination unit **86** configured to determine whether or not the difference δr_i acquired by the difference acquisition unit **84** is smaller than the predetermined threshold value Orth, and

[0220] wherein the detection operation executing unit **62** executes the detection operation DO for the work when the difference determination unit **86** determines that the difference δr_i is smaller than the threshold value Orth.

[0221] (Supplementary Note 12) The apparatus **140** of any one of Supplementary Notes 1 to 10,

[0222] wherein the temperature adjustment unit **60** is configured to execute the warming-up operation WO when the imaging unit **14** is activated,

[0223] wherein the temperature acquisition unit **56** is configured to acquire the temperature T repeatedly measured by the temperature sensor **16** every time the temperature adjustment unit **60** executes the warming-up operation WO, and

[0224] wherein the apparatus **140** further includes:

[0225] the difference acquisition unit **84** configured to acquire a difference δM_i between a first temperature T_i acquired by the temperature acquisition unit **56** and a second temperature T_{i-1} acquired by the temperature acquisition unit **56** before the first temperature T_i;

[0226] the difference determination unit **86** configured to determine whether or not the difference δM_i acquired by the difference acquisition unit **84** is smaller than the predetermined threshold value δM_{th}; and

[0227] the detection operation executing unit **62** configured to execute the detection operation DO for the work when the difference determination unit **86** determines that the difference δM_i is smaller than the threshold value δM_{th}.

[0228] (Supplementary Note 13) The controller **18** of the industrial machine **10**, including the apparatus **100**, **110**, **120**, **130**, or **140** of any one of Supplementary Notes 1 to 12.

[0229] (Supplementary Note 14) A method of managing the temperature T of the imaging unit **14** in the industrial machine **10** which executes the detection operation DO to detect a workpiece W on the basis of the image data ID of the workpiece W imaged by the imaging unit **14** and which carries out work on the detected workpiece W, the method including:

[0230] acquiring, by a processor, the temperature T measured by the temperature sensor **16**;

[0231] determining, by the processor, whether or not the temperature T, which is acquired when the detection operation DO for the work is executed, falls within the allowable range $[T_{th1}, T_{th2}]$ predetermined for securing accuracy of the detection operation DO; and

[0232] executing, by the processor, the warming-up operation WO to raise the temperature T when it is determined that the temperature T is lower than the lower limit value T_{th1} of the allowable range $[T_{th1}, T_{th2}]$, while executing the cooling operation CO to lower the temperature T when it is determined that the temperature T is higher than the upper limit value T_{th2} of the allowable range $[T_{th1}, T_{th2}]$.

[0233] (Supplementary Note 15) The computer program PG configured to cause the processor **42** to execute the method of Supplementary Note 14.

REFERENCE SIGNS LIST

[0234] **10** Industrial machine
[0235] **12** Robot
[0236] **14** Imaging unit
[0237] **16** Temperature sensor
[0238] **18** Controller
[0239] **36** Camera
[0240] **38** Illumination device
[0241] **40**, **42** Processor
[0242] **56** Temperature acquisition unit
[0243] **58** Temperature determination unit
[0244] **60** Temperature adjustment unit
[0245] **62** Detection operation executing unit
[0246] **64** Allowable range acquisition unit
[0247] **66** Image generating unit
[0248] **68** Input receiving unit
[0249] **82** Allowable range determination unit
[0250] **84** Difference acquisition unit
[0251] **86** Difference determination unit
[0252] **100**, **110**, **120**, **130**, **140** Apparatus

1. An apparatus configured to manage a temperature of an imaging unit in an industrial machine which executes a detection operation to detect a workpiece on the basis of image data of the workpiece imaged by the imaging unit and which carries out work on the detected workpiece, the apparatus comprising:

a temperature acquisition unit configured to acquire the temperature measured by a temperature sensor;

a temperature determination unit configured to determine whether or not the temperature, which is acquired by the temperature acquisition unit when the detection operation for the work is executed, falls within an allowable range predetermined for securing accuracy of the detection operation; and

a temperature adjustment unit configured to execute a warming-up operation to raise the temperature when the temperature determination unit determines that the temperature is lower than a lower limit value of the allowable range, while executing a cooling operation to lower the temperature when the temperature determination unit determines that the temperature is higher than an upper limit value of the allowable range.

2. The apparatus of claim **1**, wherein the temperature acquisition unit is configured to acquire a first temperature measured by the temperature sensor when the imaging unit executes an imaging operation for a teaching process for teaching a shape of the workpiece or a calibration process for calibrating an imaging parameter of the imaging unit, and

wherein the apparatus further includes an allowable range acquisition unit configured to acquire the allowable range determined on the basis of the first temperature, and store the acquired allowable range in a memory.

3. The apparatus of claim **1**, wherein the temperature adjustment unit is configured to change the temperature by executing the warming-up operation or the cooling operation before the work, in order to determine the allowable range, and

wherein the apparatus further includes a detection operation executing unit configured to try the detection operation when the temperature adjustment unit changes the temperature.

4. The apparatus of claim **3**, further comprising:

an image generating unit configured to generate a detection result image displaying results of a plurality of the detection operations repeatedly tried by the detection operation executing unit; and

an input receiving unit configured to receive an input of the lower limit value and the upper limit value determined on the basis of the results of the detection operations.

5. The apparatus of claim **3**, further comprising an allowable range determination unit configured to automatically determine the lower limit value or the upper limit value of the allowable range, on the basis of results of a plurality of the detection operations repeatedly tried by the detection operation executing unit.

6. The apparatus of claim **5**, wherein the detection operation executing unit is configured to repeatedly try the detection operation every time the temperature adjustment unit changes the temperature by a predetermined change amount, and

wherein the allowable range determination unit is configured to:

determine whether or not a detection result parameter included in the result of the detection operation falls within a threshold value range capable of securing the accuracy, every time the detection operation executing unit tries the detection operation; and

determine the lower limit value or the upper limit value on the basis of the determination result of the detection result parameter.

7. The apparatus of claim **1**, wherein the temperature adjustment unit is configured to raise the temperature by causing the imaging unit to simulatively execute an imaging operation, causing a processor incorporated in the imaging unit to execute predetermined arithmetic processing, or turning on an illumination device provided in the imaging unit, as the warming-up operation.

8. The apparatus of claim **1**, wherein the temperature adjustment unit is configured to lower the temperature by stopping an operation of the imaging unit for a predetermined cooling time, as the cooling operation.

9. The apparatus of claim **1**, wherein the temperature determination unit is configured to determine whether or not the temperature falls within the allowable range, every time the temperature adjustment unit executes the warming-up operation or the cooling operation, and

wherein the apparatus further comprises a detection operation executing unit configured to execute the detection operation for the work when the temperature determination unit determines that the temperature falls within the allowable range, while not executing the detection operation while the temperature determination unit determines that the temperature is outside the allowable range.

10. The apparatus of claim **9**, wherein the detection operation executing unit is configured to execute the detection operation for the work when an elapsed time, which is clocked while the temperature determination unit determines that the temperature is outside the allowable range, reaches a predetermined time limit.

11. The apparatus of claim **1**, wherein the temperature adjustment unit is configured to execute the warming-up operation when the imaging unit is activated,

wherein the apparatus further comprises:

a detection operation executing unit configured to repeatedly try the detection operation every time the temperature adjustment unit executes the warming-up operation;

a difference acquisition unit configured to acquire a difference between a detection result parameter included in a result of a first detection operation tried by the detection operation executing unit and a detection result parameter included in a result of a second detection operation tried by the detection operation executing unit before the first detection operation; and

a difference determination unit configured to determine whether or not the difference acquired by the difference acquisition unit is smaller than a predetermined threshold value, and

wherein the detection operation executing unit is configured to execute the detection operation for the work when the difference determination unit determines that the difference is smaller than the threshold value.

12. The apparatus of claim **1**, wherein the temperature adjustment unit is configured to execute the warming-up operation when the imaging unit is activated,

wherein the temperature acquisition unit is configured to acquire the temperature repeatedly measured by the temperature sensor every time the temperature adjustment unit executes the warming-up operation, and

wherein the apparatus further includes:

a difference acquisition unit configured to acquire a difference between a first temperature acquired by the temperature acquisition unit and a second temperature acquired by the temperature acquisition unit before the first temperature;

a difference determination unit configured to determine whether or not the difference acquired by the difference acquisition unit is smaller than a predetermined threshold value; and

a detection operation executing unit configured to execute the detection operation for the work when the difference determination unit determines that the difference is smaller than the threshold value.

13. A controller of the industrial machine, comprising the apparatus of claim **1**.

14. A method of managing a temperature of an imaging unit in an industrial machine which executes a detection operation to detect a workpiece on the basis of image data of the workpiece imaged by the imaging unit and which carries out work on the detected workpiece,

the method comprising:

acquiring, by a processor, the temperature measured by a temperature sensor;

determining, by the processor, whether or not the temperature, which is acquired when the detection operation for the work is executed, falls within an allowable range predetermined for securing accuracy of the detection operation; and

executing, by the processor, a warming-up operation to raise the temperature when it is determined that the temperature is lower than a lower limit value of the allowable range, while executing a cooling operation to lower the temperature when it is determined that the temperature is higher than an upper limit value of the allowable range.

15. A non-transitory computer-readable recording medium which stores a computer program configured to cause the processor to execute the method of claim **14**.

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