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Control device, system program, and method

Abstract

A control device includes a control operation performing unit that performs control operation on a control target in accordance with a user program, a data collector that collects one or more pieces of data designated in advance and has the data stored in a storage designated in advance, and a data manager that manages shared information that can be accessed by the control operation performing unit and the data collector. The data collector writes into the shared information, information indicating completion of storage of data in the storage. In the user program executed by the control operation performing unit, the shared information can be referred to.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

(1) This application is a National Stage of International Application No. PCT/JP2022/014425 filed Mar. 25, 2022, claiming priority based on Japanese Patent Application No. 2021-110651 filed Jul. 2, 2021, the contents of each of which being herein incorporated by reference in their entireties.

TECHNICAL FIELD

(2) The present technology relates to a control device that controls a control target, a system program that implements the control device, and a method performed by the control device.

BACKGROUND ART

(3) At various production sites, there are demands for improvement in availability of facilities by predictive maintenance. There are also demands for collection of a history (guaranteed traceability) of a process of manufacturing of all products.

(4) In order to meet such demands, for example, a scheme for collection of data collected and managed by a control device such as a programmable logic controller (PLC) has been put into practical use. For example, Japanese Patent Laying-Open No. 2007-249937 (PTL 1) discloses a method of monitoring collected data, the method allowing free generation of a desired variable even after the PLC makes transition to an operating state. In this monitoring method, the collected data is stored in a CSV file format.

(5) With rapid progress of the information communication technology in recent years, more data is collected in shorter cycles. In addition, a scheme for collection not only of data collected and managed by the PLC but also of image data (still images and moving images) together has been proposed.

CITATION LIST

Patent Literature

(6) PTL 1: Japanese Patent Laying-Open No. 2007-249937

SUMMARY OF INVENTION

Technical Problem

(7) As described above, importance of data collection at production sites has become greater. Therefore, any trouble in data collection may have influence such as failure in shipment of produced products themselves.

(8) The present technology provides solving means for more reliable collection of data by a control system including a control device.

Solution to Problem

(9) A control device according to an example of the present technology includes a control operation performing unit configured to perform control operation on a control target in accordance with a user program, a data collector configured to collect one or more pieces of data designated in advance and have the data stored in a storage designated in advance, and a data manager configured to manage shared information that can be accessed by the control operation performing unit and the data collector. The data collector is configured to write into the shared information, information indicating completion of storage of data in the storage. In the user program executed by the control operation performing unit, the shared information can be referred to. According to this configuration, the information indicating completion of storage of data in the storage can be referred to in the user program executed by the control operation performing unit. Therefore, such control as start of next processing on condition that storage of data in the storage has been completed can be implemented. The data can thus more reliably be collected.

(10) The information indicating completion of storage of the data in the storage may include information indicating time and day of completion of storage of the data in the storage. According to this configuration, whether or not storage of data in the storage has been completed can be determined by monitoring of time and day included in the shared information.
(11) The control operation performing unit may set a collection trigger to ON when a condition designated in advance is satisfied, and the data collector may start data collection when the collection trigger is set to ON. According to this configuration, timing of start of data collection by the data collector can be controlled by appropriate control of ON/OFF of the collection trigger by the control operation performing unit.
(12) The storage may be connected to the control device over a network. According to this configuration, even in the case of a storage connected over the network, data transmission to which cannot immediately be completed, completion of storage of data in the storage can be checked and monitored by utilization of the scheme described above.
(13) The data collector may write into the shared information, information indicating whether or not data can be stored in the storage. According to this configuration, before start of storage of data in the storage, determination as to readiness for start of processing for data storage can be made.
(14) The shared information may include information on a usage rate of the storage. According to this configuration, before start of storage of data in the storage, determination as to readiness for start of processing for data storage can be made.
(15) The data collector may cause information on a part of presently collected data to be stored in the storage, the part of the presently collected data being a part that has changed from data collected immediately before. According to this configuration, a capacity of data stored in the storage can be reduced.
(16) When collected data is identical in a plurality of times of data collection, the data collector may cause contents of identical data and the number of times of repeated collection of the identical data to be stored in the storage. According to this configuration, necessary information also on a control target, data of which does not change, can be collected without the capacity of the storage being strained.
(17) A system program according to another example of the present technology causes a computer to perform performing control operation on a control target in accordance with a user program, collecting one or more pieces of data designated in advance and storing the data in a storage designated in advance, and writing into shared information, information indicating completion of storage of data in the storage. In the user program, the shared information can be referred to.
(18) According to yet another example of the present technology, a method performed by a control device is provided. The method includes performing control operation on a control target in accordance with a user program, collecting one or more pieces of data designated in advance and storing the data in a storage designated in advance, and writing into shared information, information indicating completion of storage of data in the storage. In the user program, the shared information can be referred to.
Advantageous Effects of Invention
(19) According to the present technology, solving means for more reliable collection of data by a control system including a control device can be provided.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a schematic diagram showing a main configuration of a control device of a control system according to the present embodiment.
(2) FIG. **2** is a schematic diagram showing an exemplary overall configuration of the control

system according to the present embodiment.
(3) FIG. **3** is a block diagram showing an exemplary hardware configuration of the control device of the control system according to the present embodiment.
(4) FIG. **4** is a schematic diagram showing an exemplary functional configuration for implementing data collection provided by the control system according to the present embodiment.
(5) FIG. **5** is a time chart showing exemplary processing for data collection in the control system according to the present embodiment.
(6) FIG. **6** is a schematic diagram showing an exemplary data structure of status monitoring data managed by the control system according to the present embodiment.
(7) FIG. **7** is a flowchart showing a procedure of processing performed by a data collection module of the control device according to the present embodiment.
(8) FIG. **8** is a diagram showing an exemplary user program executed in the control device according to the present embodiment.
(9) FIG. **9** is a diagram showing another exemplary user program executed in the control device according to the present embodiment.
(10) FIGS. **10**A to **10**C are time charts each showing exemplary processing for data collection by the control system according to the present embodiment.
(11) FIGS. **11**A and **11**B are diagrams each showing an example of data compression by the control system according to the present embodiment.
(12) FIGS. **12**A and **12**B are diagrams each showing another example of data compression by the control system according to the present embodiment.

DESCRIPTION OF EMBODIMENTS

(13) An embodiment of the present invention will be described in detail with reference to the drawings. The same or corresponding elements in the drawings have the same reference characters allotted and description thereof will not be repeated.

<A. Exemplary Application>

(14) <A. Exemplary Application>
(15) An exemplary scene to which the present invention is applied will initially be described.
(16) FIG. **1** is a schematic diagram showing a main configuration of a control device **100** of a control system **1** according to the present embodiment. Control device **100** is a computer that controls a control target, and typically implemented by a programmable logic controller (PLC).
(17) Referring to FIG. **1**, control device **100** includes, as its functional configuration, a PLC engine **150**, a data collection module **160**, and a data manager **170**.
(18) PLC engine **150** corresponds to a control operation performing unit that performs control operation on a control target in accordance with a user program **132**.
(19) Any object that directly or indirectly relates to control operation performed by the control device is herein referred to as a “control target.” The term “control target” is not limited to a machine alone or an apparatus alone to which the control device gives a command and a machine alone or an apparatus alone from which the control device collects information but may encompass a facility or a unit of a larger scale including such a machine or an apparatus.
(20) Data collection module **160** corresponds to the data collector. Data collection module **160** collects one or more pieces of data designated in advance and has the data stored in a storage designated in advance.
(21) Data manager **170** manages shared information that can be accessed by PLC engine **150** and data collection module **160**. Status monitoring data **178** as exemplary shared information will be described below.
(22) Data collection module **160** writes into the shared information, information indicating completion of storage of data in the storage. In user program **132** executed by PLC engine **150**, the shared information can be referred to. In other words, by inclusion of an instruction contingent on the shared information in user program **132**, such control operation that prescribed processing is not started until completion of storage of data in the storage can be implemented.

(23) By thus sharing the shared information between PLC engine **150** and data collection module **160**, data can more reliably be collected.
(24) <B. Exemplary Overall Configuration>
(25) FIG. **2** is a schematic diagram showing an exemplary overall configuration of control system **1** according to the present embodiment. Referring to FIG. **2**, control system **1** according to the present embodiment includes, as its main components, control device **100** that controls a control target, a server apparatus **200**, and a network storage **250**. These components are connected over a local network **2** and a global network **4**. One or more network cameras **50-1**, **50-2**, and **50-3** (which are also collectively referred to as a "network camera **50**" below) are connected to local network **2**. A support apparatus **300** which is an exemplary information processing apparatus may be connected to control device **100**.
(26) Control device **100** may be embodied as a kind of a computer such as a programmable logic controller (PLC). Control device **100** is connected to a field apparatus group **10** over a field network **6**. Field network **6** preferably adopts an industrial communication protocol. EtherCAT®, EtherNet/IP®, DeviceNet®, CompoNet®, and the like have been known as such a communication protocol.
(27) Field apparatus group **10** includes an apparatus that collects input data from a manufacturing apparatus and a production line (which are also collectively referred to as a "field" below) relating to a control target or control. An input relay and various sensors are assumed as such an apparatus that collects input data. Field apparatus group **10** further includes an apparatus that exerts some action onto a field based on a command generated by control device **100** (which is also referred to as "output data" below). An output relay, a contactor, a servo driver and a servo motor, and any other actuator are assumed as such an apparatus that exerts some action onto the field. Field apparatus group **10** exchanges data including the input data and the output data with control device **100** over field network **6**.
(28) In the exemplary configuration shown in FIG. **2**, field apparatus group **10** includes a remote input/output (I/O) apparatus **12**, a relay group **14**, a servo driver **16**, and a servo motor **18**.
(29) Remote I/O apparatus **12** includes a communication unit that communicates through field network **6** and an input and output unit (which is also referred to as an "I/O unit" below) that collects input data and provides output data. The input data and the output data are exchanged between control device **100** and the field through such an I/O unit. FIG. **2** shows an example in which a digital signal is exchanged as the input data and the output data through relay group **14**. The I/O unit may directly be connected to field network **6**.
(30) Servo driver **16** drives servo motor **18** in accordance with the output data (for example, a position command or the like) from control device **100**.
(31) As described above, the input data and the output data are exchanged between control device **100** and field apparatus group **10** over field network **6**. Such exchanged data is normally updated in very short cycles from the order of several hundred microseconds to the order of several ten milliseconds.
(32) Control device **100** transmits to server apparatus **200** and/or network storage **250**, data (input data and/or output data) exchanged with field apparatus group **10** and data (internal data and/or working data) referred to or updated in computing processing in control device **100**.
(33) The storage at a transmission destination or a storage destination may thus be connected to control device **100** over the network.
(34) Network camera **50** transmits an image (still images or moving images) picked up at any timing to server apparatus **200** and/or network storage **250**.
(35) Server apparatus **200** includes a storage for storage of data and stores the data in response to a request from control device **100** and/or network camera **50**. Data is stored similarly also in network storage **250**, in response to a request from control device **100** and/or network camera **50**. Both of server apparatus **200** and network storage **250** do not have to be provided, and only one of them

may be provided. Alternatively, a plurality of server apparatuses **200** or network storages **250** may be provided.
(36) Support apparatus **300** is an information processing apparatus (an exemplary computer) that supports preparation necessary for control of a control target by control device **100**. Specifically, support apparatus **300** provides a development environment (a program creation and edition tool, a parser, a compiler, and the like) for a user program to be executed by control device **100**, a setting environment for setting of a parameter (configuration) of control device **100** and various devices connected to control device **100**, a function to transmit the generated user program to control device **100**, and a function to correct or modify on-line, the user program or the like to be executed on control device **100**.
(37) <C. Exemplary Hardware Configuration>
(38) An exemplary hardware configuration of a main apparatus of control system **1** according to the present embodiment will now be described.
(39) (c1: Exemplary Hardware Configuration of Control Device **100**)
(40) FIG. **3** is a block diagram showing an exemplary hardware configuration of control device **100** of control system **1** according to the present embodiment. Referring to FIG. **3**, control device **100** includes a processor **102** such as a central processing unit (CPU) or a micro-processing unit (MPU), a chip set **104**, a main storage **106**, a secondary storage **108**, a network controller **110**, a universal serial bus (USB) controller **112**, a memory card interface **114**, an internal bus controller **122**, a field network controller **118**, and I/O units **124-1**, **124-2**, ...
(41) Processor **102** reads various programs stored in secondary storage **108**, develops the programs on main storage **106**, and executes the programs, to thereby implement processing and functions as will be described later. Chip set **104** controls data transmission or the like between processor **102** and each component.
(42) In addition to a system program **131**, user program **132** that describes control operation, and data collection setting **133** that defines an object from which data is to be collected or a cycle of data collection are stored in secondary storage **108**.
(43) Network controller **110** controls exchange of data with another apparatus over local network **2**. USB controller **112** controls exchange of data with support apparatus **300** through USB connection.
(44) Memory card interface **114** is constructed such that a memory card **116** can be attached thereto and detached therefrom, and allows writing of data into memory card **116** and reading of various types of data (user program **132** or trace data) from memory card **116**.
(45) Internal bus controller **122** is an interface for exchange of data with I/O units **124-1**, **124-2**, . . . mounted on control device **100**.
(46) Field network controller **118** controls exchange of data with another apparatus over field network **6**.
(47) Though FIG. **3** shows an exemplary configuration in which a necessary function is provided by execution of a program by processor **102**, a part or the entirety of these provided functions may be performed by using dedicated hardware circuitry (for example, an application specific integrated circuit (ASIC) or a field-programmable gate array (FPGA)). Alternatively, a principal part of control device **100** may be implemented by hardware (for example, an industrial personal computer based on a general-purpose personal computer) in accordance with a general-purpose architecture. In this case, using virtualization technology, a plurality of operating systems (OSs) different in application are executed in parallel and a necessary application may be executed on each OS.
(48) (c2: Exemplary Hardware Configuration of Server Apparatus **200**)
(49) Server apparatus **200** according to the present embodiment is implemented by hardware (for example, a general-purpose personal computer) in accordance with a general-purpose architecture by way of example. Since the hardware in accordance with the general-purpose architecture has been known, detailed description will not be given.
(50) (c3: Exemplary Hardware Configuration of Network Storage **250**)

(51) Network storage **250** according to the present embodiment is implemented by hardware (for example, a general-purpose personal computer) in accordance with a general-purpose architecture by way of example. A configuration with hardware resources less than in server apparatus **200** may be adopted. Since the hardware in accordance with the general-purpose architecture has been known, detailed description will not be given.
(52) (c4: Exemplary Hardware Configuration of Support Apparatus **300**)
(53) Support apparatus **300** according to the present embodiment is implemented by execution of a program with the use of hardware (for example, a general-purpose personal computer) in accordance with a general-purpose architecture by way of example. Since the hardware in accordance with the general-purpose architecture has been known, detailed description will not be given.
(54) <D. Data Collection>
(55) A function and processing for data collection provided by control system **1** according to the present embodiment will now be described.
(56) FIG. **4** is a schematic diagram showing an exemplary functional configuration for implementing data collection provided by control system **1** according to the present embodiment.
(57) Referring to FIG. **4**, control device **100** includes, as its functional configuration, PLC engine **150**, data collection module **160**, and data manager **170**.
(58) Data manager **170** holds input data **172** collected from a field, output data **174** which is a command outputted to the field, and internal data **176** referred to and updated in control operation performed by PLC engine **150** in accordance with user program **132**. Data manager **170** updates input data **172**, output data **174**, and internal data **176** every predetermined cycle (I/O refreshing processing).
(59) PLC engine **150** is a programmable execution entity that performs control operation on a control target in accordance with user program **132**. More specifically, PLC engine **150** performs control operation described in user program **132** by referring to input data **172** and internal data **176** managed by data manager **170** and outputs to output data **174**, a result of operation calculated by performing the control operation. When the control operation is performed, internal data **176** is referred to and updated.
(60) Data collection module **160** performs processing involved with data collection. Specifically, data collection module **160** collects one or more pieces of data designated in advance and has the data stored in a storage designated in advance. More specifically, data collection module **160** collects in designated cycles, designated one or more pieces of data among input data **172**, output data **174**, and internal data **176** in accordance with data collection setting **133**. Data collection module **160** then transmits the collected data to a designated storage destination (for example, server apparatus **200** and/or network storage **250**).
(61) A condition to start and quit data collection may also be designated in data collection setting **133**. In this case, data collection module **160** determines whether or not one or more designated conditions are satisfied based on data collection setting **133**. Typically, when the condition to start data collection is satisfied, data collection module **160** starts data collection, and when the condition to quit data collection is satisfied, data collection module **160** quits data collection. These conditions can be set based on any data managed by data manager **170**.
(62) Data collection module **160** can also transmit an instruction for image pick-up (image pick-up trigger) to designated network camera **50** in accordance with data collection setting **133**. Though network camera **50** may successively pick up images, it may pick up images in response to the image pick-up trigger from control device **100** (data collection module **160**). When moving images are to be picked up, an image pick-up start trigger and an image pick-up end trigger may be transmitted to network camera **50**.
(63) Network camera **50** transmits image data generated as a result of image pick-up to a designated storage destination (for example, server apparatus **200** and/or network storage **250**).

(64) In control system **1** according to the present embodiment, a status about data collection is shared between PLC engine **150** and data collection module **160**. More specifically, PLC engine **150** and data collection module **160** share status monitoring data **178**. In other words, data manager **170** manages status monitoring data **178** (shared information) that can be accessed by PLC engine **150** and data collection module **160**. In the exemplary functional configuration shown in FIG. **4**, data manager **170** manages status monitoring data **178**, however, status monitoring data **178** may be managed by any entity independent of data manager **170**.
(65) Control system **1** according to the present embodiment can perform processing while it monitors that processing involved with data collection is appropriately performed, with the use of status monitoring data **178**.
(66) <E. Status Monitoring Data>
(67) A data structure of status monitoring data **178** and processing with the use of status monitoring data **178** will now be described.
(68) FIG. **5** is a time chart showing exemplary processing for data collection in control system **1** according to the present embodiment. Referring to FIG. **5**, for example, processing involved with production is performed for each workpiece (production process).
(69) When control device **100** starts the processing involved with production in the production process (time t**1**), it starts collection of a production history (time t**2**). In succession, control device **100** (and network camera **50**) starts storage of the collected production history (collected data) in the storage (time t**3**).
(70) It is assumed that the processing involved with production ends at time t**4**. Collection of the production history also ends with the processing involved with production. Finally, it is assumed that storage of the collected production history (collected data) in the storage is completed at time t**5**.
(71) Control device **100** (control operation in accordance with user program **132**) confirms completion of storage of the collected production history (collected data) in the storage (time t**7**), and then starts the processing involved with production in a next production process (time t**7**).
(72) Thus, in control system **1** according to the present embodiment, control device **100** can confirm completion of storage of the collected data in the storage, and control start or the like of the processing in the production process on condition that storage in the storage is completed as such. For example, when the collected data cannot be stored in the storage for some reason, production or the like of a next workpiece can also be withheld. By adopting such control, such a situation as failure in storage of the production history of produced workpieces, that is, failure in guaranteeing traceability, can be avoided.
(73) By thus starting a next cycle after completion of the cycle of the production process and after completion of storage of the production history, highly reliable data collection can be achieved.
(74) As shown in FIG. **5**, influence on a tact time can be minimized by collecting data on the production history in parallel to the production process. Influence on the tact time can be minimized also by increase in speed and capacity in collection of data on the production history.
(75) Completion of storage in the storage shown in FIG. **5** can be detected, for example, by update of a last output time stamp (see FIG. **6**) as will be described next. Specifically, timing of start of the production process or the like can appropriately be controlled in control operation in accordance with user program **132** executed by control device **100** with the use of status monitoring data **178**.
(76) FIG. **6** is a schematic diagram showing an exemplary data structure of status monitoring data **178** managed by control system **1** according to the present embodiment. Referring to FIG. **6**, status monitoring data **178** includes a heart beat **1781**, error information **1782**, warning information **1783**, storage usage rate information **1784**, and a last output time stamp **1785**.
(77) In heart beat **1781**, a time stamp is stored which indicates time and day of determination that collected data can normally be stored, which is made in response to an inquiry as to whether or not collected data can normally be stored. In other words, data collection module **160** writes into status

monitoring data **178** (shared information), heart beat **1781** which is information indicating whether or not data can be stored in the storage.
(78) When data can normally be collected, a value of the time stamp is updated every prescribed cycle. When data cannot normally be collected, on the other hand, the time stamp of heart beat **1781** is not updated and a value indicating old time and day is maintained as it is. The cycle of update of the time stamp in heart beat **1781** may be defined in data collection setting **133**.
(79) Information on an error in connection with the storage that has occurred latest is stored in error information **1782**. In an example shown in FIG. **6**, an error code indicating a type of the error that has occurred, an error message indicating contents of the error that has occurred, and time and day of occurrence of the error are stored in error information **1782**.
(80) Information on a warning (an abnormal state before it leads to the error) in connection with the storage that has been issued latest is stored in warning information **1783**. In the example shown in FIG. **6**, a warning code indicating a type of the warning that has been issued, a warning message indicating contents of the warning that has been issued, and time and day of issuance of the warning are stored in warning information **1783**.
(81) Information on a usage rate of the storage which is the storage destination is stored in storage usage rate information **1784**. In the example shown in FIG. **6**, a usage rate (numerical value) of the storage which is the storage destination, whether or not the usage rate of the storage has exceeded a prescribed warning threshold value (warning flag), and whether or not the usage rate of the storage has exceeded a prescribed abnormality threshold value (abnormality flag) are stored in storage usage rate information **1784**.
(82) A time stamp of latest processing in processing for output of collected data (processing for storage in the storage) is stored in last output time stamp **1785**. Therefore, while the collected data is being stored in the storage, the time stamp stored in last output time stamp **1785** is sequentially updated. When storage of the collected data in the storage is completed, on the other hand, the time stamp stored in last output time stamp **1785** does not change.
(83) For example, when completion of storage of collected data over a certain period is to be checked, a difference between the time stamp at the timing of buffering of collected data before transmission thereof and the time stamp stored in last output time stamp **1785** (completion of storage in the storage) should only be evaluated.
(84) Status monitoring data **178** shown in FIG. **6** is updated (written) by data collection module **160** (FIG. **4**) of control device **100** and referred to by PLC engine **150** (FIG. **4**) of control device **100**.
(85) Data collection module **160** thus writes into status monitoring data **178** (shared information), information indicating completion of storage of data in the storage. In user program **132** executed in PLC engine **150**, status monitoring data **178** (shared information) can be referred to.
(86) In the exemplary data structure shown in FIG. **6**, information (last output time stamp **1785**) indicating time and day of completion of storage of data in the storage is used as the information indicating completion of storage of data in the storage. The information indicating time and day of completion of storage of data in the storage, however, is not limited to the time stamp, and a counter incremented/decremented each time of completion of storage or a state value may be applicable.
(87) When a condition for data collection designated in advance is satisfied, PLC engine **150** sets a collection trigger to ON. When the collection trigger is set to ON, data collection module **160** starts collection of data and storage of the collected data.
(88) FIG. **7** is a flowchart showing a procedure of processing performed by data collection module **160** of control device **100** according to the present embodiment. Each step shown in FIG. **7** is typically performed by execution of system program **131** (FIG. **3**) by processor **102** of control device **100**.
(89) Referring to FIG. **7**, control device **100** determines whether or not the collection trigger has been set to ON (step S**2**). When the collection trigger has not been set to ON (NO in step S**2**),

processing in steps S**4** to S**10** is skipped and processing in step S**12** or later is repeated.
(90) When the collection trigger has been set to ON (YES in step S**2**), control device **100** has one or more pieces of designated data once buffered (step S**4**). When buffering of one or more pieces of designated data has been completed, control device **100** starts transmission of the buffered data to a designated storage destination (step S**6**).
(91) Control device **100** determines whether or not transmission of the data to the storage destination has been completed (step S**8**). When transmission of the data to the storage destination has not been completed (NO in step S**8**), processing in step S**8** is repeated.
(92) Control device **100** thus performs processing for collecting one or more pieces of data designated in advance and storing the data in the storage designated in advance (steps S**4** to S**8**).
(93) When transmission of the data to the storage destination has been completed (YES in step S**8**), control device **100** updates last output time stamp **1785** with the time stamp indicating the current time and day (step S**10**).
(94) Control device **100** thus performs processing (steps S**8** and S**10**) for writing into status monitoring data **178** (shared information), the information indicating completion of storage of data in the storage.
(95) Control device **100** then determines whether or not an event of an error or a warning has occurred (step S**12**). When the event of the error or the warning has occurred (YES in step S**12**), control device **100** writes into error information **1782** or warning information **1783**, information on the error or the warning that has occurred (step S**14**). Processing in step S**2** or later is then repeated.
(96) When the event of the error or the warning has not occurred (NO in step S**12**), control device **100** determines whether or not a cycle of update of storage usage rate information **1784** has come (step S**16**). When the cycle of update of storage usage rate information **1784** has come (YES in step S**16**), control device **100** obtains the usage rate of the storage which is the storage destination and updates storage usage rate information **1784** with the obtained information (step S**18**).
(97) When the cycle of update of storage usage rate information **1784** has not yet come (NO in step S**16**), processing in step S**18** is skipped.
(98) Control device **100** then determines whether or not the obtained usage rate of the storage has exceeded a predetermined threshold value (step S**20**).
(99) When the obtained usage rate of the storage has not exceeded the predetermined threshold value (NO in step S**20**), control device **100** determines whether or not the cycle of update of heart beat **1781** has come (step S**22**). When the cycle of update of heart beat **1781** has come (YES in step S**22**), control device **100** determines whether or not access to the storage which is the storage destination can be made (step S**24**). When access to the storage which is the storage destination can be made (YES in step S**24**), control device **100** updates heart beat **1781** with the time stamp indicating the current time and day (step S**26**). The processing in step S**2** or later is then repeated.
(100) When the obtained usage rate of the storage has exceeded the predetermined threshold value (YES in step S**20**), processing in steps S**22** to S**26** is skipped. When the cycle of update of heart beat **1781** has not yet come (NO in step S**22**), processing in steps S**24** and S**26** is skipped. When access to the storage which is the storage destination cannot be made (NO in step S**24**), processing in step S**26** is skipped.
(101) Data is collected and status monitoring data **178** is updated through the processing procedure as set forth above.
(102) FIG. **8** is a diagram showing exemplary user program **132** executed in control device **100** according to the present embodiment. FIG. **8** shows an exemplary code for checking completion of storage of collected data in the storage destination in PLC engine **150** (user program **132**).
(103) Referring to FIG. **8**, a code in the first line of user program **132** indicates processing for storage of time and day (time stamp) of start of data collection by data collection module **160** in a variable **1322**. More specifically, in a control cycle in which a collection trigger **1320** has changed from OFF to ON, a data write instruction **1321** is executed. Data write instruction **1321** has a value

of last output time stamp **1785** written in variable **1322**. In other words, the time stamp at the time of start of data collection is set in variable **1322**.
(104) A code in the second line of user program **132** indicates processing for determining whether or not a value of last output time stamp **1785** has changed. More specifically, a comparison instruction **1324** outputs ON (TRUE) when the value of last output time stamp **1785** is larger than the value of variable **1322** (the time stamp at the time when collection trigger **1320** has changed to ON).
(105) A comparison instruction **1323** outputs ON (TRUE) when the value of a time stamp **1327** indicating reference time and day is different from the value of last output time stamp **1785**. In other words, comparison instruction **1323** is a start-up condition for avoiding erroneous determination as a result of execution of comparison instruction **1324** in the second line in the control cycle the same as the control cycle in which data write instruction **1321** included in the code in the first line is executed.
(106) When comparison instruction **1324** outputs ON (TRUE), a completion flag **1325** is set to ON (TRUE) and a data write instruction **1326** is executed. Data write instruction **1326** has a value of time stamp **1327** indicating the reference time and day written into variable **1322**. In other words, the time stamp at the time of completion of storage of data is set in variable **1322**.
(107) The code of user program **132** as set forth above can be used to monitor update (change) of last output time stamp **1785** to thereby detect completion of storage of collected data in the storage.
(108) FIG. **9** is a diagram showing another exemplary user program **132** executed in control device **100** according to the present embodiment. FIG. **9** shows an exemplary code for setting a condition for start of a cycle of the production process in PLC engine **150** (user program **132**).
(109) Referring to FIG. **9**, user program **132** defines three conditions for starting the cycle of the production process. More specifically, a ready flag **1330** indicating completion of preparation for start of the production process, a completion flag **1325** indicating completion of storage of collected data performed previously, and a heart beat normality flag **1335** indicating normal update of heart beat **1781** are defined as the conditions. All of ready flag **1330**, completion flag **1325**, and heart beat normality flag **1335** being ON (TRUE) is set as the condition. When all conditions are satisfied, a production process preparation completion flag **1336** is set to ON (TRUE).
(110) A temporal subtraction instruction **1331** calculates a difference between a value of a time stamp **1332** indicating the current time and day and a value of heart beat **1781**. Comparison instruction **1333** sets heart beat normality flag **1335** to ON (TRUE) when the difference between the value of time stamp **1332** indicating the current time and day and the value of heart beat **1781** is equal to or less than a heart beat update cycle length **1334**. In other words, when the time stamp in heart beat **1781** is updated within update cycle length **1334** from the current time point, determination as being ready for normal storage of collected data is made and determination as being ready for start of a next cycle is made.
(111) By thus including heart beat **1781** in the condition for start of the cycle of the production process, such restriction that the next cycle of the production process does not start until collected data can normally be stored can be set. By adopting such a condition, such a situation as inappropriate start of the cycle of the production process in the case of (1) a network failure between control device **100** (or network camera **50**) and the storage (server apparatus **200** and/or network storage **250**), (2) a hardware failure of control device **100** (or network camera **50**), (3) decrease in available space in the storage, or (4) erroneous setting of a collection condition can be avoided.
(112) <F. Exemplary Processing>
(113) Exemplary processing in data collection by control system **1** according to the present embodiment will now be described.
(114) FIGS. **10**A to **10**C are time charts each showing an example of processing for data collection by control system **1** according to the present embodiment.

(115) FIG. **10**A shows exemplary processing in which the collection trigger is set to ON only for one control cycle. In this example, data is collected in coordination with the collection trigger. In response to rise (change from OFF to ON) of the collection trigger, storage in the storage is started with delay of a prescribed time period. When storage in the storage is completed, last output time stamp **1785** is updated. On condition that last output time stamp **1785** is updated, a next cycle is started.
(116) FIG. **10**B shows exemplary processing in which the collection trigger is set to ON a plurality of times. The data is collected in coordination with the collection trigger also in this example. Storage in the storage is done continuously in accordance with data that may successively be generated by data collection. In storage in the storage, each time storage of data in prescribed units (for example, in units of file) is successively completed, last output time stamp **1785** is also successively updated. Update per se of the value of last output time stamp **1785** may be done in constant cycles. In an example where the value of last output time stamp **1785** is updated in constant cycles, when storage in the storage has not been completed in a previous cycle or when storage in the storage has not been done in the previous cycle, last output time stamp **1785** is not updated.
(117) FIG. **10**C shows exemplary processing in which the collection trigger is maintained at ON over a plurality of control cycles. The data is collected in coordination with the collection trigger also in this example. Storage in the storage is done continuously in accordance with data that may successively be generated by data collection. In storage in the storage, each time storage of data in prescribed units (for example, in units of file) is successively completed, last output time stamp **1785** is also successively updated. Update per se of the value of last output time stamp **1785** may be done in constant cycles. In an example where the value of last output time stamp **1785** is updated in constant cycles, when storage in the storage has not been completed in a previous cycle or when storage in the storage has not been done in the previous cycle, last output time stamp **1785** is not updated.
(118) As shown in FIGS. **10**A to **10**C, any data collection and control of the production process in accordance with an application or a purpose can be realized with the use of change in value of the collection trigger and last output time stamp **1785**.
(119) <G. Format in Storage of Data>
(120) Data to be stored in the storage in storage of data described above may be stored in a format reduced in data amount as below. More specifically, data collection module **160** of control device **100** may compress buffered data in processing as below and then transmit the compressed data to the storage. A processing method for data compression which will be described below is suitable for information from a production site collected by control device **100**.
(121) FIGS. **11**A and **10**B are diagrams each showing an example of data compression by control system **1** according to the present embodiment. FIG. **11**A shows exemplary collected data **180** yet to be compressed. Collected data **180** includes a plurality of records composed of a time stamp **181** indicating collection timing and collected data **182**. Data **182** collected by control device **100** changes sporadically as compared with the collection cycle. Therefore, only a part of pieces of data aligned in a time-series manner, the value of which has changed, may be extracted, and outputted as collected data **180**.
(122) FIG. **11**B shows exemplary collected data **190** obtained by compression of collected data **180**. Collected data **190** includes time stamp **191** indicating collection timing, elapsed time **192**, a change flag **193**, a state of variable **194**, and a storage area **195**.
(123) A time stamp indicating reference time and day is stored in time stamp **191** in a specific (normally top) record. Time elapsed since the reference time and day stored in time stamp **191** is stored in elapsed time **192**.
(124) A flag indicating whether or not data stored in storage area **195** in a corresponding record has changed from data stored in storage area **195** in an immediately preceding record is stored in

presence-of-change flag **193**. When there is change from the immediately preceding record, “1” (TRUE) is set, and when a record is the same as the immediately preceding record, “0” (FALSE) is set.
(125) A bit string having a length corresponding to the number of bits which corresponds to the number of pieces of data stored in storage area **195** is stored in state of variable **194**. A position of each bit is brought in correspondence with a position (a string number) of data stored in storage area **195**. In the bit string stored in state of variable **194**, “1” (TRUE) is set only for data that has changed from data in the immediately preceding record, and otherwise “0” (FALSE) is set.
(126) For example, “100000” means that data in the first place (string) (corresponding to data1 in FIG. **11**A) has changed and one corresponding value is stored in storage area **195**. In addition, “010100” means that only data in the second place (string) and data in the fourth place (string) (corresponding to data2 and data4 in FIG. **11**A) have changed and two corresponding values are stored in storage area **195**.
(127) Data set to “1” (TRUE) in the bit string in state of variable **194** is stored in storage area **195**.
(128) Collected data **190** thus includes only data that has changed from the data in the immediately preceding record based on comparison of records aligned in the time-series manner. In other words, data collection module **160** of control device **100** may cause information on a part of presently collected data to be stored in the storage, the part of the presently collected data being a part that has changed from the data collected immediately before.
(129) By adopting such a data compression technique, time-series data, the value of which changes sporadically as compared with the collection cycle, can efficiently be collected.
(130) FIGS. **12**A and **12**B are diagrams each showing another example of data compression by control system **1** according to the present embodiment. FIG. **12**A shows exemplary collected data **180** that has not been compressed. In collected data **180** shown in FIG. **12**A, a value of data **182** has not changed even after lapse of time. Such collected data **180** has not changed from data in the immediately preceding record (that is, a value the same as that of data **182** in the immediately preceding record is stored as data **182**). Therefore, the fact that the value of data **182** is the same should only be included as information in collected data **180**.
(131) FIG. **12**B shows exemplary collected data **190**A obtained by compression of collected data **180**. Collected data **190**A further includes the number of times of repetition **196** as compared with collected data **190** shown in FIG. **11**B.
(132) The number of times of repetition **196** indicates in how many records data the same as data stored in a corresponding record is repeated. In collected data **190**A shown in FIG. **12**B, “8” is stored in the number of times of repetition **196**, which indicates that eight records including data the same as that in the first record further follow. In other words, when collected data is identical in a plurality of times of data collection, data collection module **160** of control device **100** may cause contents of identical data and the number of times of repeated collection of the identical data to be stored in the storage.
(133) Thus, when the same records aligned in the time-series manner are successive, collected data **190**A includes only the number of successive records (the number of times of repetition) so that time-series data can efficiently be collected.
(134) <H. Additional Aspects>
(135) The present embodiment as described above encompasses technical concepts as below.
(136) [Configuration 1]
(137) A control device includes a control operation performing unit (**150**) configured to perform control operation on a control target in accordance with a user program (**132**), a data collector (**160**) configured to collect one or more pieces of data designated in advance and have the data stored in a storage (**200**, **250**) designated in advance, and a data manager (**170**) configured to manage shared information (**178**) that can be accessed by the control operation performing unit and the data collector. The data collector is configured to write into the shared information, information (**1785**)

indicating completion of storage of data in the storage. In the user program executed by the control operation performing unit, the shared information can be referred to.
(138) [Configuration 2]
(139) In the control device described in Configuration 1, the information indicating completion of storage of the data in the storage includes information indicating time and day of completion of storage of the data in the storage.
(140) [Configuration 3]
(141) In the control device described in Configuration 1 or 2, the control operation performing unit sets a collection trigger (**1320**) to ON when a condition designated in advance is satisfied, and the data collector starts data collection when the collection trigger is set to ON.
(142) [Configuration 4]
(143) In the control device described in any one of Configurations 1 to 3, the storage is connected to the control device over a network.
(144) [Configuration 5]
(145) In the control device described in any one of Configurations 1 to 4, the data collector is configured to write into the shared information (**1781**), information indicating whether or not data can be stored in the storage.
(146) [Configuration 6]
(147) In the control device described in any one of Configurations 1 to 4, the shared information includes information (**1784**) on a usage rate of the storage.
(148) [Configuration 7]
(149) In the control device described in any one of Configurations 1 to 6, the data collector is configured to cause information (**190**) on a part of presently collected data to be stored in the storage, the part of the presently collected data being a part that has changed from data collected immediately before.
(150) [Configuration 8]
(151) In the control device described in any one of Configurations 1 to 7, when collected data is identical in a plurality of times of data collection, the data collector causes contents of identical data and the number of times (**190**A) of repeated collection of the identical data to be stored in the storage.
(152) [Configuration 9]
(153) A system program (**131**) causes a computer (**100**) to perform performing control operation on a control target in accordance with a user program (**132**) (S**150**), collecting one or more pieces of data designated in advance and storing the data in a storage (**200**, **250**) designated in advance (S**4** to S**8**), and writing into shared information (**178**), information (**1785**) indicating completion of storage of data in the storage (S**10**). In the user program, the shared information can be referred to.
(154) [Configuration 10]
(155) A method performed by a control device includes performing control operation on a control target in accordance with a user program, collecting one or more pieces of data designated in advance and storing the data in a storage (**200**, **250**) designated in advance (S**4** to S**8**), and writing into shared information (**178**), information (**1785**) indicating completion of storage of data in the storage (S**10**). In the user program, the shared information can be referred to.
(156) <I. Advantage>
(157) The control system including the control device according to the present embodiment can provide solving means for more reliable collection of data.
(158) It should be understood that the embodiment disclosed herein is illustrative and non-restrictive in every respect. The scope of the present invention is defined by the terms of the claims rather than the description above and is intended to include any modifications within the scope and meaning equivalent to the terms of the claims.
REFERENCE SIGNS LIST

(159) **1** control system; **2** local network; **4** global network; **6** field network; **10** field apparatus group; **12** remote I/O apparatus; **14** relay group; **16** servo driver; **18** servo motor; **50** network camera; **100** control device; **102** processor; **104** chip set; **106** main storage; **108** secondary storage; **110** network controller; **112** USB controller; **114** memory card interface; **116** memory card; **118** field network controller; **122** internal bus controller; **124** I/O unit; **131** system program; **132** user program; **133** data collection setting; **150** PLC engine; **160** data collection module; **170** data manager; **172** input data; **174** output data; **176** internal data; **178** status monitoring data; **180**, **190**, **190**A collected data; **181**, **1327**, **1332** time stamp; **182** data; **192** elapsed time; **193** change flag; **194** state of variable; **195** storage area; **196** the number of times of repetition; **200** server apparatus; **250** network storage; **300** support apparatus; **1320** collection trigger; **1321**, **1326** data write instruction; **1322** variable; **1323**, **1324**, **1333** comparison instruction; **1325** completion flag; **1330** ready flag; **1331** temporal subtraction instruction; **1334** update cycle length; **1335** heart beat normality flag; **1336** preparation completion flag; **1781** heart beat; **1782** error information; **1783** warning information; **1784** storage usage rate information; **1785** last output time stamp

Claims

1. A control device comprising one or more memories storing a user program and at least one processor configured to access the one or more memories and execute the user program to implement: a programmable logic controller (PLC) engine configured to perform control operation on a control target; a data collector configured to receive one or more pieces of data designated in advance from a field apparatus group in a manufacturing apparatus and/or a production line over a field network and have the data stored in a storage designated in advance; and a data manager configured to manage shared information that can be accessed by the PLC engine and the data collector, wherein: the data collector is configured to write into the shared information, information indicating whether data can be stored in the storage and information indicating completion of storage of data in the storage, and the user program executed by the PLC engine refers to the shared information to perform the control operation on the control target in the manufacturing apparatus and/or the production line.
2. The control device according to claim 1, wherein the information indicating completion of storage of the data in the storage includes information indicating time and day of completion of storage of the data in the storage.
3. The control device according to claim 1, wherein the PLC engine sets a collection trigger to ON when a condition designated in advance is satisfied, and the data collector starts data collection when the collection trigger is set to ON.
4. The control device according to claim 1, wherein the storage is connected to the control device over a local network.
5. The control device according to claim 1, wherein the shared information includes information on a usage rate of the storage.
6. The control device according to claim 1, wherein the data collector is configured to cause information on a part of presently collected data to be stored in the storage, the part of the presently collected data being a part that has changed from data collected immediately before.
7. The control device according to claim 1, wherein when collected data is identical in a plurality of times of data collection, the data collector causes contents of identical data and the number of times of repeated collection of the identical data to be stored in the storage.
8. The control device according to claim 1, wherein the user program executed by the PLC engine controls a start of a next processing in the manufacturing apparatus and/or the production line based on the shared information indicating the completion of the storage of the data in the storage.
9. A non-transitory computer-readable medium storing a system program thereon, the system program, when executed by one or more processors, causing the one or more processors to

perform: performing control operation on a control target in accordance with a user program executed by a programmable logic controller (PLC) engine; receiving one or more pieces of data designated in advance from a field apparatus group in a manufacturing apparatus and/or a production line over a field network and storing the data in a storage designated in advance; and writing into shared information, information indicating whether data can be stored in the storage and information indicating completion of storage of data in the storage, wherein the user program executed by the PLC engine refers to the shared information to perform the control operation on the control target in the manufacturing apparatus and/or the production line.

10. The non-transitory computer-readable medium according to claim 9, wherein the information indicating completion of storage of the data in the storage includes information indicating time and day of completion of storage of the data in the storage.

11. The non-transitory computer-readable medium according to claim 9, wherein the system program further causes the one or more processors to perform: setting a collection trigger to ON when a condition designated in advance is satisfied, and starting data collection when the collection trigger is set to ON.

12. The non-transitory computer-readable medium according to claim 9, wherein the storage is connected to the control device over a local network.

13. The non-transitory computer-readable medium according to claim 9, wherein the shared information includes information on a usage rate of the storage.

14. The non-transitory computer-readable medium according to claim 9, wherein the user program executed by the PLC engine controls a start of a next processing in the manufacturing apparatus and/or the production line based on the shared information indicating the completion of the storage of the data in the storage.

15. A method performed by a control device, the method comprising: performing a control operation on a control target in accordance with a user program executed by a programmable logic controller (PLC) engine; receiving one or more pieces of data designated in advance from a field apparatus group in a manufacturing apparatus and/or a production line over a field network and storing the data in a storage designated in advance; and writing into shared information, information indicating whether data can be stored in the storage and information indicating completion of storage of data in the storage, wherein the user program executed by the PLC engine refers to the shared information to perform the control operation on the control target in the manufacturing apparatus and/or the production line.

16. The method according to claim 15, wherein the information indicating completion of storage of the data in the storage includes information indicating time and day of completion of storage of the data in the storage.

17. The method according to claim 15, further comprising: setting a collection trigger to ON when a condition designated in advance is satisfied, and starting data collection when the collection trigger is set to ON.

18. The method according to claim 15, wherein the storage is connected to the control device over a local network.

19. The method according to claim 15, wherein the shared information includes information on a usage rate of the storage.

20. The method according to claim 15, wherein the user program executed by the PLC engine controls a start of a next processing in the manufacturing apparatus and/or the production line based on the shared information indicating the completion of the storage of the data in the storage.