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Inventor(s)	Sasaki; Tomonori

PRODUCTION SYSTEM, AND METHOD OF PRODUCING ARTICLE

Abstract

In a production system, a control unit controls a first apparatus configured to start to operate after a waiting time and a second apparatus configured to starting to operation after a waiting time. A first sensor outputs a value that changes in response to operation of the first apparatus. A second sensor outputs a value that changes in response to operation of the second apparatus. The control unit compares a first time period from a starting of the operation of the first apparatus to an occurrence of a change in the value of the first sensor with a predetermined first threshold value, and compares a second time period from a starting of the operation of the second apparatus to an occurrence of a change in the value of the second sensor with a predetermined second threshold value.

Inventors:	**Sasaki; Tomonori (Tokyo, JP)**
Applicant:	**CANON KABUSHIKI KAISHA** (Tokyo, JP)
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Background/Summary

BACKGROUND [0001] This application is a a Continuation of U.S. patent application Ser. No. 18/325,843, filed on May 30, 2023, which is a Continuation of U.S. patent application Ser. No. 16/522,546, filed on Jul. 25, 2019 and issued as U.S. Pat. No. 11,703,834 on Jul. 18, 2023, which claims the benefit of Japanese Patent Application No. 2019-123147, filed Jul. 1, 2019, and Japanese Patent Application No. 2018-144010, filed Jul. 31, 2018, all of which are hereby incorporated by reference herein in their entirety.

FIELD OF THE DISCLOSURE
[0002] The present disclosure relates to a production system configured to monitor whether a machine used in a production line is operating normally.
DESCRIPTION OF THE RELATED ART
[0003] In a production line including a plurality of machines controlled by a sequence control apparatus, if a failure due to degradation of a machine or the like occurs, the whole production line may stop until the failed machine is restored, which may cause a large production loss. To avoid such a situation, early prediction of a failure or early detection of degradation of a machine may be performed, and predictive maintenance may be performed before a failure occurs. To this end, it has been proposed to monitor an operation state of a machine (for example, timing of starting the operation of the machine) and automatically detect a difference from a normal operation and notify a user of the detected difference.
[0004] However, even a normal operation may have a certain variation in operating time. The variation may be different from one machine to another.
[0005] For example, Japanese Patent No. 5021547 discloses a technique in which operation timing is measured for each of devices of an automated machine in a normal operation, and reference timing data is produced. Actual operation timing is detected and compared with the reference timing data.
[0006] In production lines, to reduce cost, there is a trend to control many machines by using one control apparatus. However, in a production line, a part is not supplied from a present process to a next process until an operation in the present process is completed. Therefore, if a trouble occurs in a certain process, a machine in a following process is not allowed to operate. In many control systems, a machine starts to operate when a part is supplied to the machine. Therefore, all machines do not necessarily start to operate at the same timing.
[0007] To monitor whether operations are normal or not for each of machines which are different in operation start timing based on an ON/OFF time of each machine as in the technique disclosed in Japanese Patent No. 5021547, it is necessary to previously provide a measurement standard for each signal.
[0008] However, in the technique disclosed in Japanese Patent No. 5021547, as the number of machines and/or the number of signals controlled by a single control apparatus increase, the amount of operation necessary to provide the measurement standard for each signal increases, and thus a great increase occurs in the amount of work performed manually.

SUMMARY

[0009] In an aspect, the present disclosure provides a production system configured to produce an article via at least a first process and a second process, including a control unit configured to control the first process operated repeatedly while having a waiting time between repetitions and control the second process operated repeatedly while having a waiting time between repetitions, a first sensor configured such that a value changes in response to an operation of the first process, and a second sensor configured such that a value changes in response to an operation of the second process, wherein the control unit compares a first time period from a beginning of an operation of the first process to an occurrence of a change in the value of the first sensor with a predetermined first threshold value, and compares a second time period from a beginning of an operation of the second process to an occurrence of a change in the value of the second sensor with a predetermined second threshold value.

[0010] In an aspect, the present disclosure provides a method of producing an article using the production system described above.

[0011] Further features of the present disclosure will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIG. **1** is a block diagram illustrating a system configuration according to one or more aspects of the present disclosure.

[0013] FIG. **2** is a diagram illustrating a configuration of a production line according to one or more aspects of the present disclosure.

[0014] FIGS. **3**A to **3**C are operation timing charts according to one or more aspects of the present disclosure.

[0015] FIG. **4** is a diagram illustrating a signal in use list according to one or more aspects of the present disclosure.

[0016] FIG. **5** is an operation timing chart regarding signals extracted from the charts shown in FIGS. **3**A to **3**C, that is, only signals with signal codes used by a process code A are shown over a plurality of cycles according to one or more aspects of the present disclosure.

[0017] FIGS. **6**A and **6**B are diagrams illustrating a measurement result according to one or more aspects of the present disclosure.

[0018] FIGS. **7**A and **7**B are diagrams illustrating a judgment condition according to one or more aspects of the present disclosure.

[0019] FIG. **8** is a diagram illustrating an example of a screen of a display unit according to one or more aspects of the present disclosure.

DESCRIPTION OF THE EMBODIMENTS

[0020] Referring to FIG. **1**, an embodiment of the present disclosure is described below.

[0021] In a production line **100**, an article is produced via production processes **101** to **103** performed by a plurality of machines operable independently of each other. Each apparatus, which performs corresponding one of the processes **101** to **103**, includes a plurality of sensors, a pneumatic device, a robot, and/or the like. Each of the processes **101** to **103** is controlled by controlling each corresponding apparatus using a control unit. More specifically, for example, each process is controlled by sequence control using a single programmable logic controller (PLC) **110**. The programmable logic controller (PLC) **110** may be a control apparatus or a controller. In the present disclosure, the control unit, the PLC, the control apparatus, or the controller configured to control machines used in each of the processes **101** to **103** is referred to as the control unit.

[0022] A monitoring apparatus **120** is realized, for example, by installing a program on a generalpurpose computer. The monitoring apparatus **120** may include a processor (CPU), a memory, and a large-capacity non-volatile storage apparatus such as a magnetic disk apparatus. The monitoring apparatus **120** may further include a display unit **160** such as a display, and an input device **150** such as a mouse and/or a keyboard. In FIG. **1**, by way of example, but not limitation, the monitoring apparatus **120** is provided separately from the controller **110**. The monitoring apparatus **120** may be part of a computer by which the controller **110** is realized, or the monitoring apparatus **120** and the controller **110** may be realized in the same one control unit. In the present disclosure, because the monitoring apparatus **120** may be part of the computer by which the controller **110** is realized, the monitoring apparatus **120** in FIG. **1** may also be referred to as a monitoring unit or a control unit. In the present disclosure, the production line **100**, the controller **110**, and the monitoring apparatus **120** are, as a whole, referred to as a production system.

[0023] In FIG. **1**, a record processing unit **111** in the controller **110** reads out a current value of a signal indicating an operation state and/or a current value of a signal or the like associated with each apparatus in each process from a storage unit (also referred to as a memory) in synchronization with an operation clock of a PLC **110**, and transmits the read values to the monitoring apparatus. The monitoring apparatus receives the transmitted operation state and/or signal associated with each apparatus in each process and stores, in the storage unit, as an operation state **131** or a signal **132**. In a case where the monitoring apparatus is realized as a monitoring unit disposed in the same computer in which the controller is realized as described above, it is not necessary to transmit/receive the values, but signals indicating operation status of respective processes and/or signals or the like stored in the storage unit provided in the controller may be directly used. The operation state of each apparatus in each process is stored as the operation state **131** at predetermined time intervals or timings, for example, such that 1 is employed as a value when an apparatus in a process of interest (**101** to **103**) is in operation while 0 is employed as a value when an apparatus in a process of interest is in a waiting state. As for the signal **132**, a control signal used by the controller **110** to control each machine used in each of processes **101** to **103** is stored at predetermined time intervals or timings. A control signal is used by a sensor provided on each machine operating in each of processes **101** to **103** to notify the controller **110** that a work is detected, or is used by the controller **110** to instruct each machine used in each of the processes **101** to **103** to start to operate. For example, when a sensor detects a work, a value of 1 is stored in the storage unit (also referred to as the memory) of the controller, but when no work is detected, a value of 0 is stored. The values are read out by the record processing unit **111** of the controller **110** and transmitted to the monitoring apparatus. The monitoring apparatus stores each received signal as the signal **132** in the storage unit.

[0024] The operation state **131** and the signal **132** stored in the storage unit of the monitoring unit for each apparatus in each process is further described below with reference FIG. **2** and FIGS. **3**A to **3**C.

[0025] FIG. **2** is a simplified illustration of a production line. Each apparatus in each process has an input unit **203**, an adhesive applying unit **207**, and an output unit **209**, and works subjected to the respective production processes are conveyed by a conveyor **204**. In the example shown in FIG. **2**, units are controlled by a single controller. The input unit **203**, the adhesive applying unit **207**, and the output unit **209** shown in FIG. **2** respectively correspond to the process A (first process) **101**, the process B (second process) **102**, and the process C (third process) **103** shown in FIG. **1**.

[0026] FIGS. **3**A to **3**C are operation timing charts illustrating an operation state of each unit in the production line shown in FIG. **1**. On the left-hand side of the figures, process codes 1 to 3, names of machines (units) used in these processes, and states (operation states or waiting states) thereof are shown. Below those shown are signals X1 to X15 and Y1 to Y15 indicating the operation states of the machines, the names of these signals, and states of the signals. On the right side thereof, shown are a timing chart indicating states of the machines and the signals. A horizontal axis of the timing chart represents passage of time.

[0027] The operation of each apparatus in each process controlled by the sequence control using the single controller **110** is described below with reference to the operation timing chart shown in FIGS. **3**A to **3**B. First, when an input pallet **202** is set, the input unit **203** in the waiting state starts to operate. That is, the input unit **203** goes into an in-operation state. That is, the input unit **203** in the waiting state starts to operate. That is, the process A goes into an in-operation state. In FIG. **3**A, the states of the input unit of the process A has a transition from the waiting state (0) to the in-operation state (1) (**301** in FIG. **3**A). In response to this transition, a value 1 of a signal indicating that the process A is in the in-operation state and its start time are stored in a memory of the controller. In the present embodiment, the timing of the transition of the state of the process A from the waiting state to the in-operation state is given, by way of example, but not limitation, by the timing of setting the input pallet. Alternatively, for example, the transition of the state of the process A from the waiting state to the in-operation state may be made when a particular passage of time occurs from the transition of the state of the input unit from the in-operation state (1) to the waiting state (0).

[0028] When the process A (the input unit **203**) comes in the in-operation state, a command signal is issued to close a chuck C**1** disposed on the input unit **203** and functioning to hold a work (that is, the signal Y1 in FIG. **3**B changes from 0 to 1). At the same time, a signal value of 1 of the command signal Y1 and an issuing time of the command signal Y1 are stored in the memory of the controller. When the command signal Y1 to close the chuck C**1** is issued, the chuck C**1** closes and holds a work **201** on the pallet. The closed state of the chuck C**1** is detected by a sensor S**1** configured to detect the closed state of the chuck C**1**. That is, the signal code X1 of the signal of the sensor S**1**, the value of the signal indicating the states of the chuck C**1** (from 0 to 1 (OFF to ON)) indicating that the chuck C**1** is closed, and the detection time thereof are stored in the memory of the controller.

[0029] When the closed state of the chuck C**1** is detected, a command signal is issued to turn an X-shaft of a robot R**1** functioning as the input unit **203**. More specifically, a pulse signal changing from 0 to 1 functioning as the command signal with a code Y6 is issued, and the value 1 of this signal and the issuing time of this command signal are stored in the memory of the controller. In response to the issuing of the command signal, the robot R**1** turns and thus the work **201** is moved onto a conveyor **204**. A sensor S**6** (not shown) detects whether the turn position of the robot R**1** is correct or not. When the sensor S**6** detects that the turn position of the robot R**1** is correct (the sensor S**6** outputs the signal with a signal code X6 of a value of 1), the value 1 of the signal and the detection time thereof are stored in the memory of the controller. In response to detecting that the turn position of the robot R**1** is correct, a command signal to open the chuck C**1** is issued (a command signal with a code Y2, in the form of a pulse signal, changes from 0 to 1). Thus, the value 1 of the command signal and the issuing time of the command signal are stored in the memory of the controller. In response to the issuing of the command signal, the chuck C**1** opens and the work **201** is put on a conveyor **204**. When a sensor S**2**, provided to detect the open state of the chuck C**1**, detects that the chuck C**1** is open, the value of the signal with a signal code of X2 output by the sensor S**2** becomes 1, and the value 1 of the signal and the detection time thereof are stored in the memory of the controller. In response to detecting that the chuck C**1** is open, a sensor **205** of a work detection unit W1 detects whether the work **201** exists on the conveyor **204** or not. When the sensor **205** detects that a work **201** exists on the conveyor **204**, the value of the signal with a signal code X3 output by the sensor **205** becomes 1, and the value 1 of the signal and the detection time thereof are stored in the memory of the controller. In response to detecting the existence of the work **201**, a command signal is issued to turn the X-shaft of the robot R**1**. That is, the value of the command signal with a signal code Y5 in the form of a pulse signal changes from 0 to 1, and the value 1 of this signal and the issuing time of this command signal are stored in the memory of the controller. In response to the issued command signal, the robot R**1** turns until a return position is reached. A sensor S**5** (not shown) detects whether the return position of the robot

R**1** is correct or not. When the sensor S**5** detects that the return position of the robot R**1** is correct (the value of the signal with a signal code of X5 output by the sensor S**5** becomes 1), the value 1 of the signal and the detection time thereof are stored in the memory of the controller. In response to detecting that the return position of the robot R**1** is correct, the input unit **203** goes into the waiting state, and the value of a signal indicating the state of the input unit **203** becomes 0. This value and a detection time thereof are stored in the memory of the controller. That is, in FIG. **3**A, the state of the input unit of the process A has a transition from the in-operation state (1) to the waiting state (0) (**301** in FIG. **3**A).

[0030] When the sensor **205** of the work detection unit W1 detects the work **201** put on the conveyor, the conveyor **204** is driven to convey the work **201**. When a sensor **206** of a work detection unit W2 detects the work **201**, the value of a signal with a signal code X9 output from the sensor **206** becomes 1, and the conveyor stops. The value 1 of the signal and the detection time thereof are stored in the memory of the controller.

[0031] Furthermore, in response to detecting the work **201** by the sensor **206** of the work detection unit W2, the input unit **203** in the waiting state restarts to operate, and the value of the signal indicating the state of the input unit **203** changes from 0 to 1. That is, in FIG. **3**A, the state of the process A (the input unit) has a transition from the waiting state (0) to the in-operation state (1) (**302** in FIG. **3**A), and the value 1 of this signal and the detection time thereof (operation start time) are stored in the memory of the controller, and the operation described above is repeated.

[0032] Furthermore, the adhesive applying unit **207** in the waiting state starts to operate. That is, the process B goes into an in-operation state. That is, in FIG. **3**A, the state of the adhesive applying unit of the process code B has a transition from the waiting state (0) to the in-operation state (1) (**311** in FIG. **3**A). The value of a signal indicating the state of the process B (the adhesive applying unit **207**) becomes 1 to indicate that the process B is in the in-operation state, and the value 1 of this signal and the detection time thereof (the operation start time) are stored in the memory of the controller. Furthermore, in response to detecting the work **201**, a command signal is issued to move forward the dispenser of the adhesive applying unit **207** along the X-axis. That is, a signal with a value of 1 is output as the command signal with a signal code of Y7. Furthermore a command signal is issued to discharge an adhesive from the dispenser, that is, a signal with a value of 1 is output as the command signal with a signal code of Y9. The values of 1 of the command signals and the issuing time of the command signals are stored in the memory of the controller. As a result, the dispenser of the adhesive applying unit moves the X-shaft forward while discharging the adhesive thereby applying the adhesive to the work **201**. A sensor S**7** (not shown) provided to detect the forward movement position of the X-shaft detects the dispenser, and a signal with a value of 1 is output as the signal with a signal code X7 from the sensor S**7**. The value of 1 of this signal and the detection time thereof are stored in the memory of the controller. When the sensor S**7** detects the dispenser, the value of the command signal Y9 for controlling the discharging from the dispenser has a transition from 1 indicating that discharging is to be performed to 0 indicating that the discharging is to be stopped. When the value of the command signal changes from 1 to 0, the signal value of 0 and the time of transition to 0 are stored in the memory of the controller. Furthermore, a command signal is issued to move the X-shaft backward. That is, a signal with a value of 1 is output as the command signal with a signal code of Y8, and the value 1 of this signal and the issuing time of this command signal are stored in the memory of the controller. In response, the dispenser of the adhesive applying unit moves backward along the X-axis. When a sensor S**8** (not shown) provided to detect the backward position of the X-shaft detects the dispenser, a signal with a value of 1 is output as a signal with a signal code X8 from the sensor S**8**, and the value of 1 of this signal and the detection time thereof are stored in the memory of the controller. In response, the adhesive applying unit **207** goes into a waiting state, and the value a signal indicating the state of the adhesive applying unit **207** (the process B) becomes 0 to indicate that the adhesive applying unit **207** is in the waiting state. This value and the detection time thereof are stored in the memory of the controller. In FIG. **3**A, the state of the process B (the adhesive applying unit) has a transition from the in-operation state (1) to the waiting state (0) (**311** in FIG. **3**A).

[0033] When the process B and the process A both come into the waiting state, the conveyor **204** is driven to convey the work **201**. When a sensor **208** of a work detection unit W3 detects the work **201**, that is, when the value of the signal with a signal code of X13 output from the sensor **208** becomes 1, the value of 1 of this signal and the detection time thereof are stored in the memory of the controller. At the same time, the sensor **206** of the work detection unit W2 may also detect a work. If the sensor **206** detects the work, the value of the signal with the signal code X9 output from the sensor **206** becomes 1, and the value of 1 of this signal and the detection time thereof are stored in the memory of the controller. In response, the conveyor stops.

[0034] When the sensor **208** of the work detection unit W3 detects the work **201**, the process A in the waiting state restarts the operation. In FIG. **3**A, the state of the input unit of the process A has a transition from the waiting state (0) to the in-operation state (1) (**303** in FIG. **3**A). The value of 1 indicating that the process A (the input unit **203**) is in the in-operation state and the time thereof (the operation start time) are stored in the memory of the controller. The operation described above is repeated. As described above, the process A is operated repeatedly while having a waiting time between repetitions of the process A. That is, the operation is restarted after each waiting time.

[0035] In response, the process B in the waiting state starts to operation. That is, the adhesive applying unit **207** goes into the in-operation state. In FIG. **3**A, the state of the adhesive applying unit of the process code B has a transition from the waiting state (0) to the in-operation state (1) (**312** in FIG. **3**A). At the same time, the value 1 of this signal associated with the process B (the adhesive applying unit **207**) and the detection time thereof (operation start time) are stored in the memory of the controller, and the operation described above is repeated. As described above, the process B is performed repeatedly while having a waiting time between repetitions. That is, the operation is restarted after each waiting time.

[0036] When the sensor **208** of the work detection unit W3 detects a work, the process C (the output unit **209**) in a waiting state starts to operate. A value of a signal indicating that the process C (the output unit **209**) is in operation (1 in the present embodiment) and the time thereof (the operation start time) are stored in the memory of the controller.

[0037] In response, the output unit **209** in a waiting state starts to operate. That is, the process C comes into the in-operation state. In FIG. **3**A, the state of the output unit **209** of the process code C has a transition from the waiting state (0) to the in-operation state (1) (**321** in FIG. **3**A), and the value of 1 of a signal indicating the state of the process C and the detection time thereof are stored in the memory of the controller. Furthermore, a command signal is issued to close the chuck C**2** of the output unit **209**. That is, a signal with a value of 1 is issued as the command signal with a signal code of Y10, and the value 1 of the signal and the detection time thereof are stored in the memory of the controller. In response, the chuck C**2** closes and holds the work **201** on the conveyor. When a sensor S**10** provided to detect the closed state of the chuck C**2** detects that the chuck **2** is in the closed state, the value of the signal, denoted by a signal code X10, output from the sensor S**10** becomes 1 and the value 1 of the signal and the detection time thereof are stored in the memory of the controller. Furthermore, a command signal is issued to turn an I-shaft of a robot R**2** functioning as the output unit **209**. That is, a signal with a value of 1 is issued as the command signal denoted by a signal code Y13, and the value 1 of this signal and the issuing time of this command signal are stored in the memory of the controller. In response, the I-shaft of the robot R**2** turns to move the work **201** onto an output pallet **210**. When a sensor S**15** (not shown), provided to detect whether the turn position of the robot R**2** is correct or not, detects that the turn position is correct, the value of a sensor signal denoted by a signal code X15 becomes 1, and the value of 1 of this signal and the detection time thereof are stored in the memory of the controller. In response, a command signal to open the chuck C**2** is issued. That is, a signal with a value of 1 is issued as the command signal denoted by a signal code Y11, and the value 1 of this signal and the issuing time of this command signal are stored in the memory of the controller. In response, the chuck C**2** opens and thus the work **201** is put on the output pallet **210**. When the open state of the chuck C**2** is detected by a sensor S**11** provided to detect the open state of the chuck C**2**, the sensor S**11** outputs a signal with a value of 1 as a sensor signal denoted by a signal code of X11, and the value 1 of the signal and the detection time thereof are stored in the memory of the controller. In response, a command signal is issued to turn the I-shaft of the robot R**2**. That is, a signal with a value of 1 is issued as the command signal denoted by a signal code Y12, and the value 1 of this signal and the issuing time of this command signal are stored in the memory of the controller. In response, the I-shaft of the robot R**2** turns until the return position is reached. When a sensor S**14** (not shown) provided to detect whether the return position of the robot R**2** is correct or not detects that the return position is correct, the sensor S**14** outputs a signal with a value of 1 as a sensor signal denoted by a signal code X14, and the value 1 of the signal and the detection time thereof are stored in the memory of the controller. In response, the process C (the output unit **209**) goes into a waiting state. That is, in FIG. **3**A, the state of the output unit **209** of the process code C has a transition from the in-operation state (1) to the waiting state (0) (**321** in FIG. **3**A), and the value of 0 indicating the state of the associated with the process C (the output unit **209**) and the detection time thereof are stored in the memory of the controller.

[0038] In the present embodiment, one cycle denotes a period in which each process (the process A, the process B, the process C) performs adhesion or conveying on a part (work) of an article to be produced.

[0039] When the production line starts the operation in a state in which there is no work on the conveyor, only the process A (the input unit **203**) operates in a first cycle. In a second cycle, the process A (the input unit **203**) and the process B (the adhesive applying unit **207**) operate. In a third cycle, all units and processes including the process A (the input unit **203**), the process B (the adhesive applying unit **207**), and the process C (the output unit **209**) operate.

[0040] In cycles after the third cycle, all units operate until there is no more work in the input pallet **202**. When no more work exists in the input pallet **202** in a certain cycle, the input unit **203** no longer operates (the waiting time becomes longer than a predetermined value). In a next cycle, no work is supplied to the adhesive applying unit **207**, and thus the adhesive applying unit **207** does not operate. In a further next cycle, no work is supplied to the output unit **209**, and the output unit **209** does not operate (the waiting time becomes longer than a predetermined value).

[0041] In a case where there is initially N works in the input pallet, an N-cycle operation is performed until no work exists in the input pallet and no unit is in operation (the waiting time becomes longer than a predetermined value). That is, each apparatus in each process is operated repeatedly while having a waiting time between repetitions. In other words, each apparatus in each process restarts the operation after each waiting time.

[0042] The record processing unit **114** of the controller **110** reads out a value of a signal indicating an operation state and a value of a signal associated with each apparatus in each process from memory of the controller **110** synchronization with the operation clock of the controller **110**, and transmits the read signals to the monitoring apparatus. The monitoring apparatus receives the transmitted operation state signal and the signal associated with each apparatus in each process and stores, in the storage unit, as the operation state **131** or the signal **132**. In the production line shown in FIG. **2**, the input pallet is set in a state in which there is no work on the conveyor **303**. The operation state **131** and the signal **132** associated with each apparatus in each process are recorded until no more work exists in the input unit and any unit no longer operates (the waiting time becomes longer than the predetermined value).

[0043] Using the recorded operation state **131** and the signal **132** associated with each process, the monitoring apparatus **120** monitors the machines as described below with reference to FIG. **1**, FIG. **2**, and FIGS. **3**A to **3**C.

[0044] The monitoring apparatus **120** has a program to produce a condition of monitoring the machine of each apparatus in each process and a program to monitor the machine of each apparatus in each process. First, the program for producing the condition of monitoring the machine of each apparatus in each process is described. The program for producing the condition of monitoring the machine of each apparatus in each process includes an analysis unit **141** and a judgment condition generation unit **142**.

[0045] The role of the analysis unit **141** is to automatically determine which signal is used by the machine in each apparatus in each process in the production line. More specifically, from the operation state **131** and the signal **132** associated with each apparatus in each process stored in the storage unit of the monitoring unit, the analysis unit **141** automatically determines the signal used in each apparatus in each process in the in-operation state in the production line **100**, and the analysis unit **141** stores a result as a signal in use list **133**.

[0046] In the production line, operations are sequentially performed on works, and thus the number of machines which start to operate increases stepwise and progressively until works arrive at all machines having no works before. That is, using the fact that when machines sequentially start to operation, the values of signals corresponding to the machines sequentially change from a value indicating a waiting state to a value indicating an operation state, signals used in each apparatus in each process are detected.

[0047] First, for example, when an operator inputs an instruction to the monitoring apparatus **120** using an input unit (not shown), the analysis unit **141** starts to operate. First, the analysis unit **141** prompts the operator to input an analysis period. In this situation, for example, a work is input to the production line which has no works yet and in which all apparatuses in processes are in the waiting state (as indicated by signals associated with the respective processes), and the operator inputs a value specifying a period including a period till a time when a completed article is output. The analysis unit **141** reads out the operation state **131** and the signal **132** associated with each apparatus in each process for the specified period, and extracts necessary data and starts analysis.

[0048] When an operation state **131** of an apparatus in a process has a constant value over a particular period, the analysis unit **141** determines that the process is in a particular operation state in this particular period. FIGS. **3**A to **3**C are graphs indicating recorded values of the operation state **131** and the signal **132** associated with each apparatus in each process. More specifically, process codes and signal codes are plotted along a vertical axis, and time is plotted along a horizontal axis, and signals of the respective process codes and signals of the respective signal codes are plotted time-sequentially.

[0049] In FIGS. **3**A to **3**C, **301**, **302**, and **303** represent time periods in which an input unit of a process code A is in an in-operation state. **301** represents a first-time operating time period, **302** represents a second-time operating time period, and **303** represents a third-time operating time period. Similarly, **311** and **312** represent time periods in which an adhesive applying unit of a process code B is in an in-operation state. **311** represents a first-time operating time period, and **312** represents a second-time operating time period. **321** represent a time period in which an output unit of a process code C is in an in-operation state. **321** represents a first-time operating time period. Note that the operating time period is a period from a time at which a transition occurs from the waiting state (0) to the in-operation state (1) to a time at which a transition occurs from the in-operation state (1) to the waiting state (0).

[0050] The analysis unit **141** extracts a signal whose value indicating the operation state changes between the ON (1) and the OFF (0) in the same operating time period for the same process code, and employs a signal code of the extracted signal as a signal code used in this process. Thus, the analysis unit **141** produces a signal in use list **133** such as that shown in FIG. **4**.

[0051] When all processes (process codes A to C) are in operation as in the case of the first-time operating time period **321** of the process code C (the output unit) shown in FIG. **3**A, it may not be easy to detect, from signals associated with the respective processes, a signal of a machine used in a particular process. However, using the fact that a progressive and stepwise increase occurs in the number of machines used in processes that start to operate, it is possible to correctly detect a signal code of a signal associated with the particular process.

[0052] More specifically, for example, in the first-time operating time period of the process code A (the input unit **203**) denoted by **301** in FIG. **3**A, only the process code A (the input unit) is in operation. When a particular signal is detected to change in value between ON (1) indicating the in-operation state and OFF (0) indicating the waiting state in this period, it can be determined that this particular signal is a signal associated with the input unit. A change in signal value indicating the operation state between ON (1) and the OFF (0) in the first-time operating time period **301** of the process code A (the input unit) in FIG. **3**A occurs in a zone **304** (FIG. **3**A) and a zone **305** (FIG. **3**B). That is, it can be determined that signals with signal codes X1, X2, X3, X5, X6, Y1, Y2, Y5, and Y6 are signals used in the process A (the input unit **203**). In the second-time operating time period of the process code A (the input unit) denoted by **302**, not only the process A (the input unit **203**) but also the process B (the adhesive applying unit **207**) is in operation. Based on differences from the first-time operating time period **301** in which only the process code A (the input unit **203**) is in operation, it is possible to detect signals used in the process code B (the adhesive applying unit **207**) as follows. That is, signals to be detected have no change in signal value between ON (1) and OFF (0) in the operating time period **301**, but the signals have a change in value indicating the operation state between ON (1) and OFF (0) in the operating time period **311**. It can be determined that these detected signals are signals used in the process code B (the adhesive applying unit **207**). That is, such signals are detected in a zone **313** and a zone **314**. Thus, signals with signal codes X7, X8, X9, Y7, Y8, and Y9 are signals associated with the adhesive applying unit **207**.

[0053] Similarly, based on differences in signal between the first-time operating time period **321** of the process code C (the output unit) and the second-time operating time period **302** of the process code A (the input unit), it is possible to detect signals used in the process code C (the output unit **209**). More specifically, by detecting signals having no change in value indicating the operation state between ON (1) and OFF (0) in the operating time period **302** but having a change between ON (1) and OFF (0) in the operating time period **321**, it is possible to detect signals used in the process code C (the output unit **305**). That is, signals whose value indicating the operation state changes between ON (1) and OFF (0) are found in a zone **322** and a zone **323**, and thus signals with signal codes X10, X11, X13, X14, X15, Y10, Y11, Y12, and Y13 are detected.

[0054] The relationship, determined in the above-described manner, between the operation state of the processes and signals are stored as the signal in use list **133**. FIG. **4** illustrates an example of a signal in use list **133** according to the present embodiment.

[0055] As described above, signals used by the machines in the in-operation state are detected based on the fact that the number of machines operating in the production line increases progressively and stepwise, and a signal used for a particular machine has a change in signal value between ON and OFF only when this particular machine is in operation.

[0056] Alternatively, the period specified by the operator and input to the analysis unit **141** may a period from a state in which all processes of the production line are in operation (all processes have their works) to a state in which all works have been output. In this case, the number of machines in operation decreases stepwise and progressively in a period from the state in which all processes of the production line are in operation (all processes have their works) to a state in which all works have been output via states in which inputting of works to the processes is successively stopped. By using data acquired in this period, it is also possible to detect signals associated with the respective apparatus used in corresponding processes as in the case where data is acquired in the manner described above with reference to FIGS. **3**A to **3**C. Thus, as described above, the operator may input values to the analysis unit **141** to specify the period from a state in which all processes of the production line are in operation (all processes have their works) to a state in which all works have been output after inputting of works is stopped.

[0057] In the production line, in some cases, a plurality of machines may operate at the same

timing. For example, this situation may occur in a case where the production line includes not only one but two adhesive applying units **304**, and adhesives are applied to one work at the same time by the two adhesive applying units **304**. In this case, the method described above allows it to detect a signal is used by a first adhesive applying unit or a second adhesive applying unit. However, the method does not allow it to determine whether the signal is used by the first adhesive applying unit or the second adhesive applying unit.
[0058] In such a case where a plurality of machines operate at the same timing, signals may be detected correctly, for example, by a method described below.
[0059] There can be a slight difference in ON/OFF timing among sensors (S**1**, S**2**, **205**, S**5**, S**6**, S**7**, S**8**, **206**, S**10**, S**11**, **208**, S**14**, and S**15**) due to various factors such as a response speed, a control signal transmission time, a sliding friction of a machine, and/or the like. Even the same machine does not necessarily operate at the same timing. When machines operate using signals, ON-OFF transitions in the operation states of the machines occur in response to ON signals of sensors. Therefore, in general, the difference between the end timing of an in-operation state and a signal ON timing is rather small. This allows it to narrow down candidate machines. A time period denoted by **331** in FIG. **3**A, that is, a time period from a time at which a signal turns on to a time at which an in-operation state ends is measured for a plurality of cycles, and it is determined that a machine indicating a smallest deviation in the measured time period is a machine using the signal. This makes it possible to correctly detect signals used by respective machines based on the operation states of the respective machines even when the operation timings are similar among the machines.
[0060] Next, a method of producing a monitoring condition for a machine is described below with reference to FIG. **1**, FIG. **4**, FIG. **5**, and FIGS. **6**A and **6**B.
[0061] When an operator issues a judgment condition generation instruction to the judgment condition generation unit **142** shown in FIG. **1**, the monitoring condition starts to generate a monitoring condition. The judgment condition generation unit **142** refers to the signal in use list such as that shown in FIG. **4** and generates the judgment condition such as that shown in FIGS. **7**A and **7**B. The process of generating the judgment condition is described in further detail below.
[0062] A plurality of judgment conditions may be defined in each row of the signal in use list. An example of a method of judging whether a signal is normal or abnormal is described below. In this method, the judgment condition is defined using an ON timing and an OFF timing of a signal according to the present embodiment.
[0063] The ON timing and the OFF timing of a signal refer to a time from the beginning of an operation of a process (1) to a transition to ON (1) or OFF (0) of the signal. FIG. **5** is an operation timing chart regarding signals extracted from the charts shown in FIGS. **3**A to **3**C, that is, only signals with signal codes used by the process code A (the input unit **203**) over a plurality of cycles. In FIG. **5**, t1, t2, and tn each indicate an ON timing, and T1, T2, and Tn each indicate an OFF timing. More specifically, in FIG. **5**, t1 indicates an ON timing of a signal X1 in a first cycle, and tn indicates an ON timing of the signal X1 in an n-th cycle. In FIG. **5**, T1 indicates an OFF timing of the signal X1 in the first cycle, and Tn indicates an OFF timing of the signal X1 in the n-th cycle.
[0064] There can be a slight difference in ON or OFF timing among sensors due to various factors such as a response speed, a control signal transmission time, a sliding friction of a machine, and/or the like. Therefore, values are measured for a plurality of cycles, and measured values are statically processed to determine a judgment threshold value defining an allowable variation in a normal state.
[0065] When the judgment condition generation unit **142** shown in FIG. **1** starts to generate the monitoring condition, the judgment condition generation unit **142** prompts an operator to input an analysis period. In response, the operator specifies a period including a plurality of cycles, such as those shown in FIG. **5**, over which processes have been performed normally. The judgment condition generation unit **142** reads the operation state **131** and the signal **132** in the specified

period.

[0066] As an example, a first row of the signal in use list shown in FIG. **4** is explain. A signal with a signal code X1 is described in the first row. As can be seen from the signal in use list, the signal with the signal code X1 is used in the process A (the input unit). Thus, ON timings t1, t2, . . . , tn and OFF timings T1, T2, . . . , Tn are determined from the operation state and the signal read as indicated in FIG. **5**. More specifically, a time from the beginning of the operation to each transition to ON and a time from the beginning of the operation to each transition to OFF are determined. FIGS. **6**A and **6**B illustrate a result of the determination. In FIGS. **6**A and **6**B, a first row indicates ON timings and OFF timings of the signal X1 shown in FIG. **4** over a plurality of cycles.

[0067] The average value taken over all cycles and the deviation are calculated separately for each the ON timing and the OFF timing and separately for each of items. Next, the upper and lower limits of the threshold value are calculated, for example, as the average value±6×the deviation. When timings are within the range described above, signals are recorded as normal signals, but otherwise signals are recorded as abnormal signals. After threshold values are calculated for all items of the signal in use list, resultant judgment conditions and judgment threshold values are described in a list, for example, as shown in FIGS. **7**A and **7**B. The judgment condition and the judgment threshold value described in the list in FIGS. **7**A and **7**B may be employed as the judgment condition **134** in FIG. **1**.

[0068] In the present embodiment, the operation state of each apparatus in each process is represented by one of two values such that when an operation is performed on a work by a machine during a period, the signal has a value of 1, while when a machine is waiting for a work to arrive in a waiting state, the signal value has a value of 0. However, signals may take other values depending on operation patterns of respective apparatuses in corresponding processes. For example, in a case where a plurality of models of articles are produced in one production line, operation states may be defined and represented by values for each type, for example, such that when an operation is performed on a model A, the operation state is represented by a value of 1, when an operation is performed on a model B, the operation state is represented by a value of 2, while when a waiting state in which a machine is waiting for a work to arrive is represented by a value of 0. This makes it possible to easily set monitoring states for each operation pattern of machines even in a case where the operation patterns of machines vary depending on models, that is, ON/OFF timings of signals vary depending on models.

[0069] Next, a program for monitoring a production line, the judgment unit **143**, and the display processing unit **144** are described below.

[0070] When the judgment condition **134** is produced, the judgment unit **143** automatically starts to operate. When a new operation state **131** or signal **132** is recorded in the monitoring apparatus **120**, the judgment unit **143** judges the signal based on the judgment condition **134**. When a threshold value is exceeded, the signal is determined as an abnormal signal, and an occurrence time of the abnormality and a signal code of the signal having the abnormality are recorded as a history (an abnormality occurrence history) **135** in the storage unit.

[0071] The display processing unit **144** has a role of notifying an operator of an occurrence of an abnormality. When the abnormality occurrence history **135** is updated, the display processing unit **144** edits the abnormality occurrence history **135**, the process operation state **131**, the signal **132**, and the judgment condition **134** into a visually easily understandable chart, and displays the resultant chart on the display unit **160**.

[0072] Next, a method of monitoring a production line is described below with reference to FIG. **1** and FIG. **8**.

[0073] When the judgment condition **134** shown in FIG. **1** is recorded in the monitoring apparatus **120**, the monitoring apparatus **120** starts to monitor the signal **132**. The judgment unit **143** operates periodically to judge the signal **132** based on the judgment condition **134**. If the signal **132** exceeds the threshold value, a time of occurrence of exceeding the threshold value, a process code, and a signal code are recorded as the abnormality occurrence history **135**.

[0074] The display processing unit **144** displays the updated abnormality occurrence history **135** on the screen of the display unit **160** thereby notifying an operator of the occurrence of the abnormality. FIG. **8** illustrates an example of a screen displayed on the display unit **160** by the display processing unit **144**. In FIG. **8**, **801** denotes a period of an abnormality occurrence history displayed currently. In the present embodiment, the abnormality occurrence history in a particular period (for example, one week) from a date/time where the screen is updated is displayed. In FIG. **8**, **802** denotes the abnormality occurrence history **135** displayed in the form of a table n the display period specified by **801**.

[0075] An operator can get to know the occurrence of the abnormality and the state of the abnormality from the abnormality occurrence history **802**. The operator then may select a specific abnormality occurrence history **802** more detailed information of which is to be displayed. In response to the selecting by the operator, the operation state and signals as of the occurrence of the abnormality are displayed in the form of a chart in a lower area of the screen. In FIG. **8**, **803** denotes a selection element (for example, a tab) displayed on the screen to allow for selecting an apparatus in each process displayed in the chart form. In FIG. **8**, **804** represents operation states of respective processes in the form of a bar chart, in which no bar parts each indicate a waiting state (0). In FIG. **8**, **805** represents signals in the ON state (1) in the form of a bar chart, in which no bar parts each indicate the OFF state (0). In FIGS. **8**, **806** and **807** are visual representations of threshold values (judgment threshold values) of the judgment condition **134** shown in FIG. **1**. More specifically, a broken line denoted by **806** in FIG. **8** represents a normal range of the ON timing of the signal, a broken line denoted by **807** in FIG. **8** represents a normal range of the OFF timing of the signal. In FIG. **8**, **808** represents a range where the ON timing of the signal is out of the normal range represented by the broken line and thus the signal is regarded as an abnormality. For easier understanding of the abnormality, the abnormal range **808** may be represented in a color different from that of the normal range. In response to selecting a selection element displayed on the screen thereby selecting an apparatus in a process, a signal code and a signal name associated with the apparatus in the process and/or a corresponding bar chart are displayed. In FIG. **8**, by way of example, tabs are used as the selection elements for selecting apparatuses in processes. However, the selection elements are not limited to the tabs. For example, a selection may be made from a pull-down menu.

[0076] By displaying the abnormality occurrence history in the form of table as described above, it becomes possible for the operator to easily notice the occurrence of the abnormality. By displaying the operation states and the signals of the respective apparatuses in processes in the form of a chart, it becomes possible to get to know the abnormality occurrence status and to easily narrow down candidate causes.

[0077] Furthermore, the operator is allowed to easily build the monitoring apparatus simply by operating the production line in a usual manner and specifying a period in which signals used by machines are detected by the monitoring apparatus and specifying a period in which judgment threshold values are determined, even in a case where the number of machines or the number of signals is increased.

[0078] The disclosed techniques may be used in a production system in a production line used in a factory or the like.

Other Embodiments

[0079] Embodiment(s) of the present disclosure can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-transitory computer-readable storage medium') to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described

embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)™), a flash memory device, a memory card, and the like.
[0080] While the present disclosure has been described with reference to exemplary embodiments, the scope of the following claims are to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

Claims

1. An information processing method of acquiring information regarding a first apparatus and a second apparatus, the first apparatus and the second apparatus being controlled by a control apparatus, a processing unit being configured to execute: acquiring a first period in which the first apparatus is operating and the second apparatus is not operating, a second period in which the second apparatus is operating, a signal communicated between the first apparatus and the control apparatus, and a signal communicated between the second apparatus and the control apparatus; and identifying a signal communicated during the first period as a first signal associated with the first apparatus, and identifying, among signals communicated during the second period, a signal excluding the first signal as a second signal associated with the second apparatus.
2. The information processing method according to claim 1, wherein the second period is after the first period.
3. The information processing method according to claim 1, wherein the signal communicated between the first apparatus and the control apparatus and the signal communicated between the second apparatus and the control apparatus include a sensor signal outputted from a sensor provided on the first apparatus and from a sensor provided on the second apparatus in accordance with operation of the first apparatus and operation of the second apparatus.
4. The information processing method according to claim 3, wherein the sensor signal includes a signal outputted by switching of the sensor from an OFF state to an ON state, a signal outputted by switching of the sensor from an ON state to an OFF state, or both.
5. The information processing method according to claim 1, wherein the signal communicated between the first apparatus and the control apparatus and the signal communicated between the second apparatus and the control apparatus include a control signal outputted from the control apparatus for the control apparatus to control the first apparatus and the second apparatus.
6. The information processing method according to claim 1, wherein the processing unit acquires the first period on a basis of information that varies while the first apparatus is operating and acquires the second period on a basis of information that varies while the second apparatus is operating.
7. The information processing method according to claim 1, wherein the processing unit compares a first timing that is a timing at which the first signal or the second signal is outputted with a threshold, and, based on a difference between the first timing and the threshold, displays abnormality information indicating occurrence of abnormal status on a display unit.
8. The information processing method according to claim 7, wherein the processing unit displays a

range of the threshold together with the first signal or the second signal.
9. The information processing method according to claim 7, wherein the processing unit stores the first timing and a second timing into a storage unit, and the second timing is a timing at which operation of the first apparatus or the second apparatus starts.
10. The information processing method according to claim 9, wherein the threshold is determined based on the first timing and the second timing.
11. The information processing method according to claim 1, wherein the processing unit displays the first signal or the second signal on a display unit in response to selection of the first apparatus or the second apparatus.
12. The information processing method according to claim 1, wherein the processing unit associates the first apparatus with the first signal automatically, and associates the second apparatus with the second signal automatically.
13. The information processing method according to claim 1, wherein the processing unit generates a list showing a first correspondence between the first apparatus and the first signal and a second correspondence between the second apparatus and the second signal.
14. The information processing method according to claim 1, wherein the processing unit displays, on a display unit, the first period or the second period in a form of a first bar chart and the first signal or the second signal in a form of a second bar chart.
15. The information processing method according to claim 14, wherein the second bar chart shows a state in which the first signal or the second signal is outputted.
16. The information processing method according to claim 14, wherein the processing unit displays, on the display unit, in a manner of display different from a manner of display of the second bar chart, a threshold regarding a first timing that is a timing at which the first signal or the second signal is outputted.
17. The information processing method according to claim 16, wherein the processing unit displays, on the display unit, the threshold in a manner of superposition using a broken line on a part of the second bar chart.
18. The information processing method according to claim 8, wherein the processing unit displays the abnormality information on the display unit such that a manner of display of the threshold when the first timing is not included in the range and a manner of display of the threshold when the first timing is included in the range are different from each other.
19. The information processing method according to claim 1, wherein the processing unit displays, on the display unit, a name of the first apparatus or the second apparatus, a name of operation performed by the first apparatus or the second apparatus, a name of a command for causing the first apparatus or the second apparatus to operate, and a signal code that is a code representing the first signal or the second signal.
20. The information processing method according to claim 13, wherein the processing unit records the first signal into the list in the first period, and, based on the list, identifies the second signal in the second period.
21. The information processing method according to claim 1, wherein when a plurality of apparatuses including the first apparatus and the second apparatus is operated, based on a stepwise increase in the apparatuses, the processing unit identifies the first signal and the second signal.
22. The information processing method according to claim 1, wherein when a plurality of apparatuses including the first apparatus and the second apparatus is operated, based on a stepwise decrease in the apparatuses, the processing unit identifies the first signal and the second signal.
23. The information processing method according to claim 1, wherein the processing unit allows a user to designate the first period and the second period.
24. The information processing method according to claim 7, wherein the processing unit acquires the first timing in the first signal or the second signal plural times, and acquires a difference in the first timing acquired the plural times.

25. The information processing method according to claim 7, wherein the processing unit acquires the first timing in the first signal or the second signal plural times, and, based on a statistical amount of the first timing acquired the plural times, acquires the threshold.

26. The information processing method according to claim 1, wherein based on a period from a timing at which the first apparatus or the second apparatus goes into an operating state from a waiting state to a timing at which the first apparatus or the second apparatus goes into a waiting state from an operating state, the processing unit acquires the first period or the second period.

27. The information processing method according to claim 1, wherein the control apparatus causes the first apparatus only to operate in the first period and causes the first apparatus and the second apparatus to operate in the second period.

28. A method of producing an article by using a first apparatus and a second apparatus whose information is acquired using an information processing method of acquiring the information regarding the first apparatus and the second apparatus, the first apparatus and the second apparatus being controlled by a control apparatus, a processing unit executing the information processing method being configured to execute: acquiring a first period in which the first apparatus is operating and the second apparatus is not operating, a second period in which the second apparatus is operating, a signal communicated between the first apparatus and the control apparatus, and a signal communicated between the second apparatus and the control apparatus; and identifying a signal communicated during the first period as a first signal associated with the first apparatus, and identifying, among signals communicated during the second period, a signal excluding the first signal as a second signal associated with the second apparatus, and the control apparatus being configured to execute: producing an article by using the first apparatus and the second apparatus whose information is acquired.

29. An information processing apparatus configured to acquire information regarding a first apparatus and a second apparatus, the first apparatus and the second apparatus being controlled by a control apparatus, a processing unit being configured to execute: acquiring a first period in which the first apparatus is operating and the second apparatus is not operating, a second period in which the second apparatus is operating, a signal communicated between the first apparatus and the control apparatus, and a signal communicated between the second apparatus and the control apparatus; and identifying a signal communicated during the first period as a first signal associated with the first apparatus, and identifying, among signals communicated during the second period, a signal excluding the first signal as a second signal associated with the second apparatus.

30. A non-transitory computer-readable storage medium storing a program that enables a computer to execute the information processing method according to claim 1.