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(54) Title: METHOD AND SYSTEM FOR OPTIMIZING AN ASSEMBLY LINE

(57) Abstract: A method of optimizing an assembly line is disclosed that includes receiving one or more process parameters corresponding to each of a plurality of process activities to be performed on the assembly line, based on which a digital assembly model is simulated. The digital assembly model may be divided into a plurality of sections corresponding to parts of the assembly line. The method further includes testing the digital assembly model on the simulation system and determining a tested working model corresponding to the inputted one or more process parameters, to minimize a changeover time from a first process activity to a second process activity. The method further includes determining one or more tested process parameters based on the tested working model and configuring the assembly line based on the determined one or more tested process parameters and the tested working model.

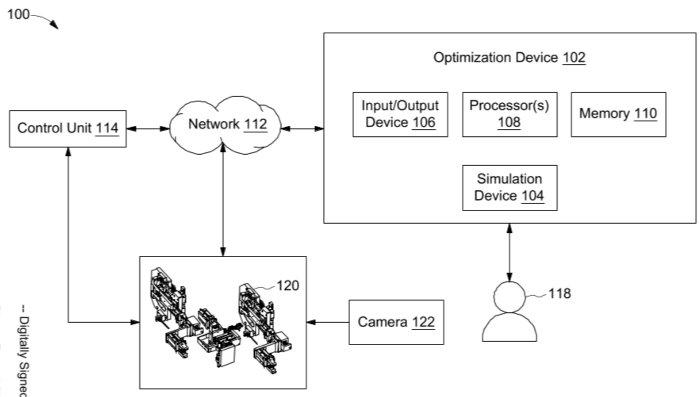

FIG. 1

FORM 2

THE PATENTS ACT 1970
(39 OF 1970)
&
The Patent Rules, 2003

Complete Specification

(See Section 10 and Rule 13)

1. TITLE OF THE INVENTION

METHOD AND SYSTEM FOR OPTIMIZING AN ASSEMBLY LINE

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification describes the invention and the manner in which it is to be performed

DESCRIPTION

Technical Field

[001] This disclosure relates generally to assembly lines, and more particularly to a system, a method, and a graphical user interface (GUI) for optimizing an assembly line.

BACKGROUND

[002] Presently, assembly lines are used in various industries for various processes related to manufacturing and packaging. Conventional assembly lines are manually controlled using electro-mechanical or mechanical systems. However, one assembly line may not be suitable for executing all kind of processes and requires customization based on a type of process or job it is used to implement or finish. Further, configuring a different assembly line for each process is capital intensive and also requires lot of space.

[003] Further, manual customization of an assembly line is performed when a change of job or process is required which is time consuming. The change of process is referred to as a changeover and the time consumed in enabling the changeover is referred herein as changeover time. The assembly lines are customized as per the requirements of a process by dividing the process into various steps which are performed by various workstations in a sequential manner to achieve a final output. Conventional methods may include an operator to monitor the assembly line manually to ensure when a changeover is required. The assembly line may then be manually configured for a new process. However, the manual changeover requires the assembly line to be emptied completely or run idle in order for the changeover to be done. This leads to increase in changeover time and reduction of efficiency of the assembly line. Thus, manually operated assembly lines lead to increased operation and waiting time, increased chances of error and an overall reduction in the efficiency.

[004] Some automation of assembly lines is performed in conventional systems by remotely monitoring the assembly line operations through a simulated model. However, such simulated model enables performing trivial operations remotely such as stopping, initiating, pausing, etc. without any manual intervention by the operator. Although, such remote access may save some time; however, lack of automatic configuration deployment during a changeover is a drawback for the manufacturers in terms of adaptation and efficiency.

[005] Therefore, there is a requirement to optimize an assembly line in order to maximize efficiency and minimize changeover time in a safe manner.

SUMMARY OF THE INVENTION

[006] In an embodiment, a system for optimizing an assembly line is disclosed. The system may include one or more processors in an optimizing device communicably connected to the assembly line and further comprising a display and a memory. The memory stores a plurality of processor-executable instructions, which upon execution by the processor, may cause the processor to receive, by the optimizing device, one or more process parameters corresponding to each of a plurality of process activities to be performed on the assembly line, based on which a digital assembly model is simulated on a simulation system communicably connected to the optimization device. The digital assembly model may include a plurality of sections, which may correspond to a part of the assembly line. The digital assembly model may be tested, by the optimization device, on the simulation system in order to determine a tested working model corresponding to the inputted process parameters to minimize changeover time for executing of the plurality of process activities. The system may changeover from a first process activity to a second process activity from the plurality of process activities upon completion of the first process activity during continuous operation of the assembly line. The system may determine one or more tested process parameters based on the tested working model and may configure the assembly line based on the determined one or more tested process parameters and the tested working model.

[007] In another embodiment, a method of optimizing an assembly line is disclosed. The method may include receiving, by an optimization device, one or more process parameters corresponding to each of a plurality of process activities to be performed on the assembly line, based on which a digital assembly model is simulated on a simulation system communicably connected to the optimization device. It is to be noted that the digital assembly model may be divided into a plurality of sections and each of the plurality of sections corresponds to a part of the assembly line. The method may include testing the digital assembly model, by the optimization device on the simulation system and determining a tested working model corresponding to the inputted process information to minimize changeover time in executing the plurality of process activities. The digital assembly model changeovers from a first process activity to a second process activity from the plurality of process activities upon detection of completion of the first process activity, during continuous operation of the assembly line. The method may then proceed to the optimization device determining one or more tested process parameters based on the tested working model and may configure the assembly line based on the determined one or more tested process parameters and the tested working model.

BRIEF DESCRIPTION OF THE DRAWINGS

[008] The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate exemplary embodiments and, together with the description, serve to explain the disclosed principles.

[009] **FIG. 1** is a block diagram of an assembly line optimization system for optimizing an assembly line, in accordance with an embodiment of the present disclosure.

[010] **FIG. 2** is a functional block diagram of the optimization device, in accordance with an embodiment of the present disclosure.

[011] **FIG. 3a** is an exemplary digital assembly line model of an assembly line running a process, in accordance with an embodiment.

[012] **FIG. 3b** is the digital assembly line model of **FIG**. **3a** undergoing a changeover, in accordance with an embodiment.

[013] **FIG. 3c** is the digital assembly line model of **FIG**. **3a** undergoing a changeover, in accordance with an embodiment.

[014] **FIG. 4a** is an exemplary digital three-dimensional (3D) simulation assembly line of an assembly line running a process, in accordance with an embodiment.

[015] **FIG. 4b** is a section of the digital 3D simulation assembly line of **FIG**. **4a** initiating a changeover, in accordance with an embodiment.

[016] **FIG. 4c** is a section the digital 3D simulation assembly line of **FIG**. **4a** undergoing a changeover, in accordance with an embodiment.

[017] **FIG. 5** is a flowchart of a method of optimizing an assembly line, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE DRAWINGS

[018] Exemplary embodiments are described with reference to the accompanying drawings. Wherever convenient, the same reference numbers are used throughout the drawings to refer to the same or like parts. While examples and features of disclosed principles are described herein, modifications, adaptations, and other implementations are possible without departing from the scope of the disclosed embodiments. It is intended that the following detailed description be considered as exemplary only, with the true scope being indicated by the following claims. Additional illustrative embodiments are listed.

[019] Presently, assembly lines are used in manufacturing and packing industry which are electrically and manually controlled using mechanical and sensor-based mechanisms. However, one assembly line is not suitable for executing all kind of processes and has to be customized based on a type of process or job it is used to implement or finish. The customization of the assembly line however is a mechanical process which consumes time when a change of job or process is required. The change of process is referred to as a changeover and the time consumed in enabling the changeover is referred herein as changeover time. However, during a changeover the configuration of the workstation(s) may be changed as per the new process to be performed on the assembly line. Therefore, the present invention provides an assembly line optimization system for optimizing an assembly line in order to maximize efficiency and minimize changeover time in a safe manner.

[020] The present disclosure provides methods and systems for optimizing an assembly line to perform various processes using a single assembly line. The assembly line optimization system comprises an optimizing device which is communicably connected to each other and an assembly line through a wireless or wired network. Therefore, information exchange between various parts of the assembly line such as machineries deployed at workstations, conveyors, gate stoppers and various sensors may be carried out via wired or wireless lines through programmable logic controllers (PLCs) enabled in a control unit. Further, the control unit may act as an administrator node and connects to multiple assembly lines over a wireless or wired network. The administrator node may be operated by a user (i.e. an operator or monitor of the assembly line) via a user device like a smartphone, tablet, computer for interacting with the assembly line, for example, for stopping the assembly line operation in case of an error in an operation by a workstation of the assembly line. Alternately, the control unit may provide a user interface or an input/output device for allowing the user to interact with the control unit in order to control the assembly line operations. The control unit may be enabled as a supervisory control and data acquisition interfaced with human machine interface which connect to programmable logic controllers connected to the assembly lines. The connectivity between the control unit and the optimization device may be provided through cloud servers, or directly connected over Internet. In an embodiment, the connectivity between the control unit and the optimization device may be implemented through open platform communication (OPC) protocols. A central camera may capture the assembly line using which a simulated digital assembly model representing the assembly line may be generated over a simulation environment of the simulation device of the optimization device. The digital assembly model may be used by the optimization device in order to control the assembly line by sending and receiving signals from the control unit.

[021] The control unit may identify each component of the assembly line and provide the identification information to the optimization device which may provide appropriate identifier to each component of the digital assembly model corresponding to the assembly line based on its type and function. The optimization device may further receive real time status parameters corresponding to each of the components of the assembly line based on which the digital assembly model is updated to depict the corresponding real-time status of the components. In an embodiment, one or more components would be represented by a plurality of sections in the digital assembly model.

[022] The control unit and the assembly line may perform an electric exchange and a data exchange (i.e. operational parameters such as speed, status, processing status, etc.). Further, the optimization device may perform a data exchange (i.e. of process information, section parameters, tested process parameters, etc.) with the control unit through open platform communication (OPC) protocols. In addition to this, the assembly line, control unit and the optimization device may further perform an exchange of software data (i.e. update package) and instructions.

[023] A server or a database or a memory may be located in the cloud or connected via a communication channel to the optimization device. The server may create a database of assembly line components and their corresponding identifiers and security parameters, etc. As will be understood, this process may be carried out by the third-party entities acting as database service providers which may be accessed based on authentication. The server may authenticate an operator based on user identifier and a pre-defined password.

[024] An authenticated operator may input a process information from the optimization device and view the digital assembly model on a simulation device. The digital assembly model is tested on the simulation device to determine a tested working model corresponding the inputted process information to minimize changeover time in executing the plurality of process activities. The digital assembly model may be optimized to changeover from a first process activity to a second process activity from the plurality of activities based on a detection of completion of the first process activity in order to execute the plurality of process activities on the assembly line with maximum efficiency and minimum changeover time. The changeover from a first activity to a second activity is implemented by determining a target section of the plurality of sections at which the changeover is to take place. A time duration of halting of starting of the second activity at the target section is determined. The time duration corresponds to a time duration until the completion of the first activity at the target section. One or more tested parameters are determined based on the tested working model having minimum changeover time duration and transmitted to the control unit which may configure the assembly line based on the determined one or more tested process parameters and the tested working model.

[025] Referring now to **FIG. 1**, a block diagram indicating a network implementation of an assembly line optimization system 100 for optimizing an assembly line is illustrated, in accordance with an embodiment of the present disclosure. By way of an example, an assembly line 120 may include various machineries and conveyors installed in a workshop of a manufacturing unit or a production unit. In an embodiment, the assembly line 120 may be divided into various sections, wherein each section may include a workstation and one or more conveyors. Each section may include a gate stopper (not shown) at the end. Accordingly, an assembly line may include various sections, with each section comprising plurality of conveyors which may end with a gate stopper acting as a physical barrier created to prevent items from entering succeeding section.

[026] The system 100 may include an optimization device 102. By way of an example, the optimization device 102 may be implemented in any computing device which may be configured or operatively connected with a server (not shown). Further, one or more users 118 may communicate with the system 100 through one or more user input/output devices 106 provided in an optimization device 102. The optimization device 102 may be communicatively coupled to a control unit 114 through a wireless or wired communication network 112. In an embodiment, the user 118 may be a supervisor or monitor of the workshop comprising the assembly line 120. In an embodiment, user devices (not shown) can include a variety of computing systems, including but not limited to, a laptop computer, a desktop computer, a notebook, a workstation, a portable computer, a personal digital assistant, a handheld or a mobile device.

[027] In an embodiment, the user 118 may be authenticated by the optimization device 102 based on input of various authentication information including user name and password. In an embodiment, the user 118 may be provided access to the optimization device 102 based on a hierarchical user profile information such as expert operators, supervisors, junior level operators, testers, etc. In an embodiment, the access authorization of a user may be based on the hierarchical user profile information for example, an expert operator may be allowed full control access of the optimization device, wherein junior level operator may have only access to emergency control options of the optimization device 102.

[028] The optimization device 102 may include a processor 108 and a memory 110. The memory 110 may store instructions that, when executed by the processor 108, cause the processor 108 to perform optimization of the assembly line 120, as discussed in greater detail below. The memory 110 may be a non-volatile memory or a volatile memory. Examples of non-volatile memory may include, but are not limited to a flash memory, a Read Only Memory (ROM), a Programmable ROM (PROM), Erasable PROM (EPROM), and Electrically EPROM (EEPROM) memory. Examples of volatile memory may include but are not limited to Dynamic Random Access Memory (DRAM), and Static Random-Access memory (SRAM). The memory 110 may also store various assembly line operational parameters (e.g. section information, section parameters such as time information, emergency parameters, section parameters, speed parameters, status parameters, etc.) that may be captured, processed, and/or required by the system 100.

[029] In an embodiment, the communication network 112 may be a wired or a wireless network or a combination thereof. The network 112 can be implemented as one of the different types of networks, such as Common Industrial Protocol (CIP) network, DeviceNet network, ethernetIP network, intranet, local area network (LAN), wide area network (WAN), the internet, Wi-Fi, LTE network, CDMA network, and the like. Further, the network 106 can either be a dedicated network or a shared network. The shared network represents an association of the different types of networks that use a variety of protocols, for example, Common Industrial Protocol (CIP), Open Platform Communication (OPC) protocols, Hypertext Transfer Protocol (HTTP), Transmission Control Protocol/Internet Protocol (TCP/IP), Wireless Application Protocol (WAP), and the like, to communicate with one another. Further the network 112 can include a variety of network devices, including routers, bridges, servers, computing devices, storage devices, and the like.

[030] In an embodiment, the control unit 114 may be connected to various industrial controllers (not shown) which may be deployed throughout the assembly line 120 to monitor and control respective components of the assembly line 120. In an embodiment, the industrial controllers may execute one or more control algorithms to facilitate monitoring and control of the components such as, but not limited to, machines, workstation machines, conveyor systems of the assembly line 120. According to the current disclosure, the industrial controllers are optimized by the optimizing device 102 in order to efficiently and run the processes being performed by each of the components of the assembly line 120 with minimum changeover time and errors. Industrial controllers may include software executable controllers which may be implemented on hardware platform or a hybrid device that combines controller functionality and other functions such as visualization. The control software or algorithms executed by industrial controllers may include coding or algorithm to process input signal read from the industrial devices or components used in an assembly line 120. Industrial devices may include both input devices that input data for controlling the industrial devices which form part of the assembly line 120. Examples of such input devices may include, but are not limited to, telemetry devices (such as temperature sensors, flow meters, level sensors, pressure sensors, light sensors, etc.), manual operator control devices (e.g., push buttons, selector switches, etc.), safety monitoring devices (e.g., safety mats, safety pull cords, light curtains, etc.), and other such devices. Industrial devices may also include output devices such as but not limited to motor drives, pneumatic actuators, signalling, devices robot control inputs, valves, hydraulics machines, etc.

[031] In an embodiment, the assembly line may be configured to perform processes that relate to product manufacture, product packaging, machining, motion control, batch processing, material handling, etc. In an embodiment, a single assembly line may be configured to perform multiple processes by disabling or connecting various sections of the assembly line in a custom manner. In an exemplary embodiment, the assembly line for filling and packaging may be used for both filling and packaging process and may also be used for only filling or packaging process. In an exemplary embodiment, industrial controllers may be operated with hardwired inputs and outputs that communicate with the industrial devices forming the components of the assembly line 120 to effect control of the devices. The controller I/O can include digital I/O that may be transmitted and received as discrete voltage signals to and from the industrial devices, or analog I/O that transmits and receives analog voltage or current signals to and from the devices. The controller I/O can be received by the control unit 114 which may then be processed to covert from analog to digital or digital to analog signals in order to be read into and controlled by the control programs or the components using one or more analog to digital convertors or digital signal processing algorithms. In an embodiment, the control unit 114 may transmit the signals to the optimization device 102, which in turn may save the data in a memory 110. In an embodiment, the parameters detected corresponding to the assembly line may be categorized for each section or a component. The detected parameters may be categorized for each section or component of the assembly line based on which the control and monitoring is performed. In an embodiment, a section of the assembly line 120 may be detected based on detection of a workstation, preceded by one or more conveyors and terminating with a gate stopper. Accordingly, every section of an assembly line 120 may end with a gate stopper (not shown) which may act as emergency barrier during a changeover or an error.

[032] In an embodiment, the assembly line 120 may also include one or more sensors (not shown), such as, but not limited to, photo detectors, optical scanners, proximity sensors, heat sensors, weight sensors, speed sensors, liquid leakage sensors, video cameras, etc. In an embodiment, a workshop camera 122 may be installed in the workshop to capture images of the assembly line 120. In an embodiment, the workshop camera (not shown) may be a panoramic camera capable of capturing up to 360-degree view of the assembly line. The control unit 114 may provide the determined assembly line parameters to the optimization device 102 through the network 112.

[033] A simulation device 104 in the optimization device 102 may then realize interconnection and intercommunication of data and information, and real-time synchronization of real-time data of the assembly line, monitored data of the control unit 114 and the images captured by the camera 122. A three-dimensional digital assembly model of the assembly 120 may be realized using one or more simulation algorithms to obtain a three-dimensional digital assembly line model of the physical assembly line installed in a workshop. In an embodiment, the simulation algorithm may include, but not limited to, image processing tools such as CAD tool, etc. The simulation device 104 may visualize present states of the sections of the assembly line including industrial systems or their associated devices using graphical representations of the processes that display metered or calculated values, employ color or position animations based on state, render alarm notifications, or employ other such techniques for presenting relevant data to the user 118. Data presented in this manner is read from industrial controllers by control unit 114 and presented on one or more of the display screens of input/output device 106 according to preferred or selected display formats chosen by the operator (i.e. user 118).

[034] The control unit 114 and the optimization device 102 allow a user 118 to view relevant data values, alarms and statuses associated with the various machines and devices in a safe and remote manner. This prevents or avoids the requirements of the user 118 to be physically present near machines in order to view operational and status information of the machines of the assembly line 120. Moreover, displays of the optimization device 102 and controller programming tools of the control unit 114 provide a remote way of trouble-shooting or analysis in the event of a machine fault or other performance issue. The simulation device 104 present machine and device data to visually correlate the data presented on the screens with the user's own direct view of the relevant machines or devices of the assembly line 120.

[035] During a changeover or while diagnosing problems, the maintenance personnel (user 118) are often required to observe the assembly line 120 and the associated sources of information individually in person. Moreover, searching for information pertaining to a particular device or machine often requires an extensive knowledge of the overall industrial system in order to locate the data source to be searched (e.g., in order to locate the appropriate industrial controller or machine part), as well as to identify the relevant sensors, machine parts, and control program routines. Individually, searching each of these data sources in connection with optimizing the assembly line 120 for a changeover or for solving a system downtime issue or other problem can lead to delay, resulting in lost revenue and scheduling problems. Also, if an operator or maintenance person is not near the assembly line 120 at the time of a changeover, operational or maintenance issue, the user 118 may not be notified of the issue in a timely fashion.

[036] In order to address these challenges, the simulation device 102 provides a visual digital presentation comprising various views of the assembly line 120. In an embodiment, the digital simulation of the assembly line may be in form of two- or three-dimensional views. In an embodiment, the digital simulation may include creation of augmented reality or virtual reality (AR/VR) presentation based on the videos captured by the camera 122. In an embodiment, the simulation device 104 may provide various views of the assembly line 120 in real time depicting various parameters of the assembly line such as status information of the sections of the assembly line, speed information of the processing of each section and the workstations and the conveyors of the assembly line 120. The optimization device 102 creates a virtual control network through a simulation platform which synchronizes the virtually created digital assembly line model and the physical assembly line 120 installed in the workshop. The simulated digital assembly line model may include displaying of superimposed operational and status information values over the corresponding sections and components of the assembly line 120. In an embodiment, the optimization device 102 can customize presentation of the simulated digital assembly line model based on the user's role, location, line of sight, type of operation, and/or other contextual information. In an embodiment, the user 118 may select a real-time line of sight by adjusting the camera 122 remotely by way of the optimization device 102. Once the camera 122 is set in a preferred viewing angle, the user 118 may give instructions to create the simulation of the assembly line corresponding to the view being captured by the camera 122. In an embodiment, different views of the assembly line 120 may be captured in order to create a panoramic digital assembly line model.

[037] In an embodiment, the optimization device 102 may automatically detect the process parameters defining the processes that are capable of being run of the assembly line

120. In an embodiment, the optimization device 102 may determine a sequence in which the processes selected by the user are to run on the assembly line. In an embodiment, the processes may be scheduled in a manner to minimize the changeover time while switching from one process to another. The optimization devise 102 may also detect an error and indicate the same on the simulated digital assembly line model by way of an alarm being sounded and display of an alert emphasizing the section and the component in which the error has been detected. In an embodiment, the alert may be displayed by changing the color of simulated digital model of the component or a displaying an indicator in form of an arrow or a rectangle enclosing the component in which the error has been detected.

[038] In an embodiment, the optimization device 102 may provide one or more options related to changeover control or emergency control in case of an erroneous component detected. The one or more changeover control or emergency control operations may vary from one component to another and enable an operator to temporarily control the assembly line 120 until the changeover or error can be implemented or resolved.

[039] In an embodiment, the simulation device 104 establishes a platform to realize a trial simulation operation corresponding to the physical assembly line 120 before the actual operation of the assembly line 120 in order to optimize the assembly line 120 in advance to complete the processes assigned efficiently, with minimum changeover time and no errors.

[040] In an embodiment, the trial simulation operation may be initiated based on an input of process information by a user 118 via a user input/output device 106. In an embodiment, the process information may provide details about one or more processes required to be performed by the assembly line in order to achieve one or more outputs. In an embodiment, the optimization device 102 may allow the user 118 to input the process information by way of selecting one or more processes using a graphic user interface (GUI) providing a list of processes the assembly line is configured to perform. For example, a filling and packaging assembly line may be configured to fill products of various sizes such as mineral water bottles of sizes 1 liter, 500 ml, and 250 ml. In an embodiment, the user may input process information regarding the required output of corresponding water bottle sizes, i.e. the process information may provide input regarding the batch size of each bottle size required. For example, 2 batches of 1000 bottles of 1000 ml, 2 batches of 1000 bottles of 500 ml, etc.

[041] On receiving the inputted process information, the optimization device 102 may determine a priority sequence of the processes to be performed in order to achieve highest efficiency and minimize the changeover time when switching from one process to another. In an embodiment, the processing time of each of the workstation of the section may be determined based on the previous running parameter detection of the assembly line 120. The trial simulation operation may be simulated based on the previously determined working parameters. The trial simulation is run to view the working three-dimensional digitized assembly line depicting the movement of input feeds on the conveyers and the workstations or sections. During the trial simulation, the changeover from one process to another may be done by determining a target section of the plurality of sections at which the changeover is to take place. A time duration of halting of starting of the second activity at the target section is determined. The time duration for which the target section is halted corresponds to a time taken by the target section for the completion of the first activity at the target section and the optimization of the target section for the next activity. In an embodiment, the integration of the control unit 114 with the digital assembly line model is based on establishing an instruction channel and an information channel for data interaction by a control network and configuration software of the control unit 114, and connection and data synchronization of the digital assembly line model with the optimization device 102 and the simulation device 104 are realized by a transmission and detection of information from the assembly line in real-time.

[042] In an embodiment, based on the trial simulation operation of the digital assembly line model a tested working model may be determined based on optimization of the digital assembly line model and tested parameters may be determined. The assembly line 120 may then be configured based on the tested working model and the tested parameters determined in the trial to achieve maximum efficiency and minimum changeover time and no errors.

[043] Referring now to **FIG. 2**, a functional block diagram 200 of the optimization device 102 is illustrated, in accordance with an embodiment of the present disclosure. In some embodiments, the optimization device 102 may include an authentication module 202, a simulation module 206, a synchronization module 204, a parameter detection module 208, a testing module 210 and other modules 212.

[044] The authentication module 202 may perform an authentication of the user 118 based on one or more authentication parameters such as a predefined user ID and a password. In an embodiment, the user 118 can register themselves directly with the system 102 using any or a combination of a mobile number, date of birth, place of birth, first name and last name, a biometric or any other such unique identifier-based input. On successful registration, the user 118 can be provided with a user name and password, which can be used for controlling the assembly line 120 via the optimization device 102. Once the user 118 is authenticated by the optimization device 102, the user 118 is provided an access to a user interface of the optimization device 102. In an embodiment, each user 118 may be responsible for monitoring one or various assembly lines of the workshop. The user interface of the optimization device 102 may display information related to all the assembly lines and their statuses for which the user 118 is responsible for.

[045] The synchronization module 204 may generate digital simulation models. The simulation device 104 of FIG. 1 may be configured by the simulation module to receive the parameters associated to the assembly lines 120 from the control unit 114. The control unit 114 may provide data that may be used for control decisions, including but not limited to measured or calculated values representing operational states of a controlled machine or process (e.g., operational status, tank levels, positions, alarms, etc.) or captured time series data that is collected during operation of the machines of the assembly line 120 (e.g., status information for multiple points in time, diagnostic occurrences, etc.). The parameters of the assembly line 120 may include, but not limited to, assembly line IDs, section IDs, conveyer IDs, speed information, status information, product detection information, error information, etc. Accordingly, the synchronization module 204 may synchronize both the digital and physical assembly lines simulated by the simulation module 206 in real time in order to create a real-time simulation of the assembly time 120. The simulated models of the assembly time enable a remote access for controlling the assembly line operations through the simulation device 102 in a user-friendly manner. The synchronization module once receiving an instruction from the testing module 210 (described later) may configure the operation of the assembly line 120 based on a tested and optimized digital assembly line model and implement the tested parameters.

[046] The simulation module 206 may include one or more digital simulation of the assembly line 120 displaying the real time parameters received from the synchronization module 204. The simulation module 206 may create different digital assembly line models in order to control the assembly line in real time through the digital simulation model of the assembly line 120 and to generate a trial simulation of the assembly line through a trial assembly line model.

[047] The parameter detection module 208 may detect operational statistics and parameters of each of the components and sections of the assembly line 120 in real time. The parameter detection module 208 may then calculate the processing time of each section and workstation based on the previous historical data saved in the memory 110 of the optimization device 102. Based on the parameters detected by the parameter detection module 208, the synchronization module 204 may synchronize the digital assembly line models simulated by the simulation module 206. The parameter detection module 208 may detect the real-time operational parameters based on the operational values and telemetry data captured by the control unit 114.

[048] The testing module 210 may implement a trial simulation of the test digital assembly line model simulated by the simulation module 206 based on processing information or parameters inputted by the user 118. The trial simulation is based on the historical operational parameters saved in the memory 110 such as the processing speed of the workstations, processing speed of each section of the assembly line, speed of conveyors, etc. and the current processing information or parameters inputted by the user 118. The objective of the trial simulation is to visualize the operation of the digital assembly line prior to actual operation of the assembly line to optimize the operation of the assembly line to achieve maximum efficiency and minimum changeover time with no errors.

[049] As will be understood by those skilled in the art, maximum efficiency of the assembly line may be determined based on maximum output generated by running all the processes in a continuous manner with minimum processing time. In order to achieve this, the delay caused during the operation of the assembly line in case of an error correction or changeover of process is to be minimized. In an embodiment, the process information may be input by the user 118 to input types of processes required to be run by the assembly line 180. The assembly line 180 may include filling and packaging assembly. For example, the processes required may require following processes to be performed: filling of bottles with soda and filling and packaging of bottles with mineral water. Further, the user 118 may define the process parameters corresponding each process such as number and capacity of bottled to be filled with soda and number and capacity of bottled to be filled and packed with mineral water. During a changeover, various components of the assembly line may be customized in order to generate the new output. A new input product may be required to be fed into the assembly line, which may require reconfiguration of the assembly line workstation in alignment with the new input product. For example, in order to fill the bottles with soda, only the filling assembly may be required and packaging assembly may not be disabled. Further, for filling the bottle of 1000 ml, a filling work station may require more time than while filling the bottles of 500 ml. Also, the input of bottles size may differ when filling 1000 ml bottles than when filling 500 ml bottles. Further, in another embodiment, the dispensing speed of water through the dispenser of the filling station may work at higher speed when filling 1000 ml bottle and the speed of the dispenser would be slowed when filling 500 ml bottles.

[050] Therefore, trial would be conducted to simulate a trial digital assembly line model by selecting different optimization options in order to achieve maximum efficiency, minimum changeover time and zero errors. The changeover time duration may be minimized by halting selected sections of the assembly line while continuously processing products of multiple processes on the assembly line. Once the trail simulation is completed, a report may be generated or presented to the user 118 depicting the various operational parameters used for each trial simulation and the results of each trial simulation in terms of efficiency, changeover time and errors occurred. Based on the reports generated the optimization device 102 may automatically select a best trial simulation and configure the assembly line based on the tested parameters and corresponding to the selected tested working model of the trial simulation. In an embodiment, the sequence in which the processed corresponding to multiple processes selected by the user may also be optimized or determined in order to reduce changeover time and maximize the efficiency. In another embodiment, the user 118 may be given an option to select one of the trial simulations based on the reports generated as the tested working model based on which the assembly line 180 may be configured. In another embodiment, the user 118 may overwrite the optimized trial simulation options and/or customize the trial simulation parameters by selecting one or more parameters manually.

[051] In an embodiment, the other module(s) 212 may supplement the functionalities of other modules or the system 102 as required.

[052] Referring now to **FIG. 3a**, a simulated digital assembly line model 300 is illustrated, in accordance with an embodiment. In an exemplary embodiment, a digital assembly line model 300 for filling and packaging is digitally simulated on the simulation device 104 for a real-time simulation of the assembly line 120 or for trial simulation. In an embodiment, the user may specify the process information including the processed to be performed. In an exemplary scenario, the digital assembly line 300 is to be optimized to provide two types of outputs such as 1000 ml mineral water bottles and 500 ml mineral water bottles. A user input may further specify other parameters related to branding and number of bottles to be filled and packed. The assembly line 120 may therefore be optimized to produce the required outputs corresponding to two bottle sizes adhering to the required processing parameters with maximum efficiency and minimum changeover time over the digital assembly line 300 during trial.

[053] As shown in FIG. 3a, the digital assembly line 300 may include a simulation of each of the sections and a plurality of conveyor belts required to be included in the assembly line 120 in order to process the processes selected by the user such as filling and packing of

1000 ml bottles and 500 ml bottles. As shown in FIG. 3a, a plurality of sections such as (product section 302, labeler section 306, filler section 310, case former section 314, case packer section 316, case sealer section 320, palletizer section 323 and stretch wrapper section 326) are digitally reproduced or simulated corresponding to the assembly line 120. Further, each section such as product section 302 may be succeeded by a plurality of conveyor belts (EB1, EB2, EB3, and EB4 collectively referred as 304) and a gate stopper (not shown). Further, the simulated digital assembly line 300 may depict a status of each section and conveyor during the trial or real-time simulation.

[054] In an embodiment, the status of a conveyor belt may be depicted as 'stopped', signifying the conveyor belts as empty and not carrying any product and 'execute' signifying that the conveyor is under execution of a process. Further, the speed of each conveyor may be depicted and the type of product being carried by the conveyor may be depicted. In an embodiment, when the conveyor is processing input product related to first process which may be filling and packaging of 1000 ml bottles with mineral water or second process which may be filling and packaging of 500 ml bottles with mineral water. Also, the process parameters input may depict the volume of output products required for first process and second process. For example, the volume for first process may be 500 bottles and volume for second process may be 750 bottles. Further the status of conveyor belts may also depict if a conveyor belt is processing which process such as a first process or a second process.

[055] The status of product section 302 may be shown as ‘empty’ depicting that no input product is loaded or left on to the product section 302. The status ‘auto’ of the product section 302 may depict that the input feed or product are loaded and are fed to the succeeding section through the succeeding conveyors 304. The conveyors 304 may correspond to the product section 302 and the product section 302 may end with a gate stopper 330 (as shown in FIG. 3C) which may be used to stop the product section 302 processing by creating a physical barrier to prevent the output from the product section 302 to enter the subsequent labeler section 306 in case of a changeover or an error. Similarly, section parameters of each of the sections may be displayed on the digital assembly model 300. The section information may include, but not limited to, status, speed, condition of the section, etc.

[056] In an exemplary scenario, initiation of a trial simulation may include the product corresponding to first process i.e. 1000 ml bottles being loaded into the product section 302. Each section may have a capacity of product it may handle, for example, the product section 302 may be capable of loading 20 bottles at a time. The product section 302 may depict its status as: ‘reject’ if it is not capable of accepting more input of empty bottles.

[057] The labeler section 306 may be configured for labeling each of the 1000 ml bottles with corresponding labels. In an embodiment, the labeler section 306 may be optimized to select a particular label based on branding information, process information, process parameters, and tested parameters. During the actual processing of the assembly line 120, the digital assembly line model 300 may indicate the status of each of the sections and may further display plurality of process parameters which may indicate the speed of the labeler, the type of labels selected, the number of rejected products due to exceeding capacity, and so on.

[058] The processing may now proceed towards the filler section 310 through a plurality of conveyor belts EB5 and EB6 collectively referred as 308. The conveyor belts EB5 and EB6 may be represented as ‘execute’, signifying the conveyor belts running into auto mode for proceeding the products towards the filler section. The filler section 310 may further comprise of a plurality of process parameters which may indicate the type of beverage to be filled, speed of dispenser for filling the bottle with the selected beverage, the speed of the filler section 310, and the number of rejected products, etc.

[059] The process may now proceed towards the case packer section 316 through a plurality of conveyor belts FB1, FB2, FB3, and FB4, which may be represented as 312. As shown in FIG. 3a, the case packer section 316 may receive a second input from case former section 314. In an embodiment, the case former section 314 may provide the cases such as bottle caps, lids, etc. The bottle caps provided by the case former section 314 may be used to cap the filled bottles in the case packer section 316.

[060] The capped and filled bottles, upon processing through case packer section 316, may proceed towards the case sealer section 320 through conveyor belts FC1 and FC2 collectively referred as 318, where the bottles may be sealed. The conveyor belts FC1 and FC2 318 may depict 'execute', signifying the conveyor belts running in an auto mode for proceeding the products towards the case sealer section 320. The case sealer section 320 may further include a plurality of section parameters which may indicate the type of sealer used, number of products sealed by the case sealer section 320 in a predefined time interval, the quality of the processed products, and the number of rejected products through the case sealer 320.

[061] Further upon execution by the case sealer section 320, the sealed bottles may now proceed towards the palletizer section 324 wherein the sealed bottles are palletized with predefined number of bottles in a pallet. In an embodiment, the section parameters may include the number of bottles to be included in a pallet, size and shape of the pallet, etc. Thereafter, the pallets of the bottles are sent to be stretch wrapped in the stretch wrapper section 326 through the conveyor belts FC3 and FC4 collectively referred as 322. The conveyor belts FC3 and FC4 may depict 'execute', signaling the conveyor belts running in an auto mode for proceeding the products from the palletizer section 324 towards stretch wrapper section 326. The stretch wrapper section may be configured based on section parameters comprising number stretch wrap folds, type of stretch wrap used, branding information, etc.

[062] The digital assembly line model 300 as shown in FIG. 3a further provides a plurality of operational switches 328 to control the trial simulation of the digital assembly line model 300 during optimization and testing. In an embodiment, the operational switches may include a start switch which may switch on the simulation trial of the digital assembly line model; a stop switch which may stop the simulation trial operations; a reset switch which may reset the inputted process information, process parameters, section parameters, etc.; a clear switch which may direct clearing of the digital assembly line model; a hold switch which may hold or pause the digital assembly line model simulation, an un-hold switch which may un-pause the simulation of the digital assembly line model simulation which may have been paused previously; an abort switch which may be used to abort the trial simulation.

[063] Now referring to **FIG. 3b**, a digital assembly line model 300a is depicted in which a changeover may be initiated during a real-time digital simulation or a digital testing simulation (e.g. when the input of bottles of 1000 ml capacity may become empty in the product section 302). Once, the product input in product section is detected as empty, the product section 302 is stopped and a changeover is initiated as shown in FIG. 3a. As the product input to the conveyors 304 is not detected, the conveyors 304 are also stopped. The corresponding status of the conveyors is updated in the digital assembly line model 300. In the meantime, the product corresponding to the second process i.e. 500 ml bottles may be loaded onto the product section 302. The time required for the loading of the input product for the second process is called idle time which may be used to compute the changeover time.

[064] **FIG. 3c** depicts the digital assembly line model 300b undergoing a changeover, in accordance with an embodiment. During the changeover the gate stopper 330 corresponding to product section 302 may be activated to prevent the 500 ml bottles from entering the subsequent sections still processing the first process i.e. 1000 ml bottles. During the changeover, the labeler section 306 may be selected as a target section to undergo changeover during which the filler section 310 may become empty and hence the status of filler section 310 becomes ‘stopped’. The cumulatively time duration for which each of the sections are stopped to delay the initiation of the second process on each section is determined as the changeover delay. During the changeover, the gate stopper 332 corresponding to the labeler section 306 is activated in order to prevent any movement of product of second process to mix with the products of the first process being processed by subsequent sections which are processing the first process. Therefore, the digital assembly line model 300 is simulated and optimized to enable the assembly line 120 to run two processed in a simultaneous manner to enhance the efficiency of the assembly line 120 with minimum changeover time.

[065] In another embodiment, the digital assembly line model 300 once optimized and tested may be implemented as a finalized working model to configure and control the working of the assembly line 120 as per the tested parameters.

[066] Referring now to **FIG. 4a**, an exemplary digital three-dimensional (3D) assembly line model 400 of an assembly line is illustrated, in accordance with an embodiment of the current disclosure. The 3D assembly line model 400a may depict a 3D simulation of the assembly line with a plurality of sections, plurality of conveyors belts and stopping gates. It may be noted that the simulation model thus generated may be based on a real-time simulation or a trial simulation of the assembly line. In an exemplary embodiment, the 3D digital assembly line model 400 may be simulated for a filling and packaging assembly line. The 3D digital assembly line model 400 may be configured to run a first process and a second process with maximum efficiency and minimum changeover time and zero errors. The 3D digital assembly line model 400 may include sections such as unscrambler section 402, labeler section 404, filler section 406, case packer section 408, case former section 410, case sealer section 412. In an embodiment, the status of the sections may be shown as ‘execute’, ‘stopped’, ‘changeover’. During a real-time simulation of the assembly line 120, the status of the section may be shown as under ‘production’ or ‘empty product’. The 3D digital assembly line model 400 may be first optimized based on trial simulations and then configured based on tested parameters as final working model. The simulation working of the 3D digital assembly line model 400 may be initiated by feeding an input corresponding to a first process and processing the input at various sections 402-424 based on the process parameters inputted by the user 118. The completion of the processing of the first process is detected based on no detection of product input in the unscrambler section 402 corresponding to the first process.

[067] **FIG. 4b** illustrates magnified view of sections of the digital 3D simulation assembly line 400a during initiation of a changeover. When the unscrambler section 402 is detected as empty, a changeover to second process is initiated. During the initiation of the changeover, the unscrambler section 402 is reset, the gate stopper 416 is closed, and the product input corresponding to the second process is inputted in the unscrambler section 402. **FIG. 4c** illustrates magnified view of sections of the digital 3D simulation assembly line 400b undergoing the changeover. The status of the unscrambler section 402 is shown as ‘changeover’ during changeover and the gate 416 is closed. Further, based on no detection of product in the labeler section 404, the status of the labeler section 404 is changed to ‘stopped’. Accordingly, the status of the labeler section 404 is switched to ‘changeover’ and the gate 418 may then be closed. In the same fashion or sequence, the changeover is implemented until input product of the second process is inputted in the unscrambler section 402 and each section begins the processing of second process.

[068] Further, the status of the conveyors of each section may be depicted using arrows indicating the direction of the processing. It may further be noted that a gate, which may be positioned between each consecutive sections, may depicted as 'gate close' for avoiding any intermixing of the first batch of products with the second batch of products. Further, the working simulation of the 3D assembly line model 400a may be viewed based on color-based simulation depicting the progression of the process activities depicting the progression of a first product of the first process by a red color and a second product of the second process by a blue color. Further, depiction of status of each section may also be depicted based on change of color as depicted by shaded section 402 in FIG. 4B which is being reset during a changeover.

[069] Referring now to **FIG. 5**, a method 500 of optimizing an assembly line is disclosed via a flowchart 500 in accordance with an embodiment. FIG. 5 is explained in conjunction with FIGS. 1-4. Each step of the flowchart 500 may be executed by various modules (same as the modules of the system 100).

[070] At step 502, one or more process parameters corresponding to each of a plurality of process activities to be performed on the assembly line may be received by the optimization device 102, based on which a digital assembly model is simulated on a simulation device 104 communicably connected to the optimization device 102. The process parameters may be inputted through a user using a user input interface.

[071] At step 504, the wherein the digital assembly model is divided into a plurality of sections and wherein each of the plurality of sections correspond to a part of the assembly line. At step 506, the digital assembly model may be tested, by the optimizing device 102, on the simulation device 104 and a tested working model may be determined corresponding to the inputted one or more process parameters to minimize changeover time for executing the plurality of process activities.

[072] At step 508, the tested working model may be tested corresponding to the inputted process parameters to minimize changeover time by implementing a changeover from a first process activity to a second process activity from the plurality of process activities upon detection of completion of the first process activity during continuous execution of the assembly line. Further, at step 510, one or more tested process parameters may be determined based on the tested working model. Thereafter, at step 512, the assembly line may be configured based on the determined one or more tested process parameters and the tested working model.

[073] It is intended that the disclosure and examples be considered as exemplary only, with a true scope of disclosed embodiments being indicated by the following claims.

WE CLAIM:

1. A method of optimizing an assembly line, the method comprising:

receiving, by an optimizing device, one or more process parameters corresponding to each of a plurality of process activities to be performed on the assembly line, based on which a digital assembly model is simulated on a simulation system communicably connected to the optimization device,

wherein the digital assembly model is divided into a plurality of sections, and wherein each of the plurality of sections correspond to a part of the assembly line,

testing, by the optimizing device, the digital assembly model on the simulation system and determining a tested working model corresponding to the inputted one or more process parameters to minimize changeover time for executing the plurality of process activities,

wherein the changeover is from a first process activity to a second process activity from the plurality of process activities, upon detection of completion of the first process activity, during continuous operation of the assembly line;

determining, one or more tested process parameters based on the tested working model; and

configuring the assembly line based on the determined one or more tested process parameters and the tested working model.

2. The method as claimed in claim 1, wherein the changeover from the first process activity to the second process activity comprises:

determining a target section of the plurality of sections at which the changeover is to take place; and

determining a first time duration of halting starting of the second activity at the target section, wherein the first time duration corresponds to a time duration until the completion of the first activity at the target section, wherein the first activity is associated with a first batch of products and the second activity is associated with a second batch of products.

3. The method as claimed in claim 2, wherein each of the plurality of sections are arranged in a predefined sequence corresponding to position of each part of the assembly line, wherein the assembly line comprises a gate stopper associated with each part of the

assembly line, and wherein the gate stopper is configured to halt starting of the second activity at the target section.

4. The method as claimed in claim 1, wherein the completion of the first process activity is detected based on no input feed corresponding to the first process activity in at least one of the plurality of sections.

5. The method as claimed in claim 4, further comprises:

generating a closing signal during the changeover, for closing at least one of a plurality of gate stoppers to restrict progression of the input feed corresponding to the second process activity into the target section processing the input feed corresponding to the first process activity.

6. The method as claimed in claim 5, further comprises:

optimizing the section parameters of the sections preceding the section processing the input feed corresponding to the first process activity to section parameters corresponding to the second process activity during the changeover.

7. The method as claimed in claim 1, wherein the tested working model is determined by scheduling and prioritizing the plurality of process activities in order to minimize the changeover time.

8. A system for optimizing an assembly line comprising:

one or more processors in an optimizing device communicably connected to the assembly line and comprising a display and a memory, wherein the memory stores a plurality of processor-executable instructions which upon execution cause the one or more processors to:

receive, by the optimizing device, one or more process parameters corresponding to a plurality of process activities to be performed on the assembly line, based on which a digital assembly model is simulated on a simulation system communicably connected to the optimization device,

wherein the digital assembly model is divided into a plurality of sections, and wherein each of the plurality of sections correspond to a part of the assembly line, test, by the optimization device, the digital assembly model on the simulation system and determining a tested working model corresponding to the inputted one or more process parameters to minimize changeover time during execution of the plurality of process activities,

wherein the changeover is from a first process activity to a second process activity from the plurality of process activities based on detection of completion of the first process activity during continuous operation of the assembly line;

determine, one or more tested process parameters based on the tested working model; and

configure the assembly line based on the determined one or more tested process parameters and the tested working model.

9. The system as claimed in claim 8, wherein the changeover from the first process activity to the second process activity is based on:

determination of a target section of the plurality of sections at which the changeover is to take place; and

determination of a first time duration of halting starting of the second activity at the target section, wherein the first time duration corresponds to a time duration until the completion of the first activity at the target section, wherein the first activity is associated with a first batch of products and the second activity is associated with a second batch of products.

10. A graphical user interface (GUI) client for publishing a digital assembly model created in a simulated environment running on an optimizing device, the GUI client configured to:

receive, by the optimizing device, one or more process parameters corresponding to a plurality of process activities to be performed on the assembly line, based on which a digital assembly model is simulated on a simulation system communicably connected to the optimization device,

wherein the digital assembly model is divided into a plurality of sections, and wherein each of the plurality of sections correspond to a part of the assembly line,

test, by the optimization device, the digital assembly model on the simulation system and determining a tested working model corresponding to the inputted one or more process parameters to minimize changeover time during execution of the plurality of process activities,

wherein the changeover is from a first process activity to a second process activity from the plurality of process activities based on detection of completion of the first process activity during continuous operation of the assembly line;

determine, one or more tested process parameters based on the tested working model; and

configure the assembly line based on the determined one or more tested process parameters and the tested working model.

Dated this 21st day of July 2022

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ABSTRACT

METHOD AND SYSTEM FOR OPTIMIZING AN ASSEMBLY LINE

A method of optimizing an assembly line is disclosed that includes receiving one or more process parameters corresponding to each of a plurality of process activities to be performed on the assembly line, based on which a digital assembly model is simulated. The digital assembly model may be divided into a plurality of sections corresponding to parts of the assembly line. The method further includes testing the digital assembly model on the simulation system and determining a tested working model corresponding to the inputted one or more process parameters, to minimize a changeover time from a first process activity to a second process activity. The method further includes determining one or more tested process parameters based on the tested working model and configuring the assembly line based on the determined one or more tested process parameters and the tested working model.

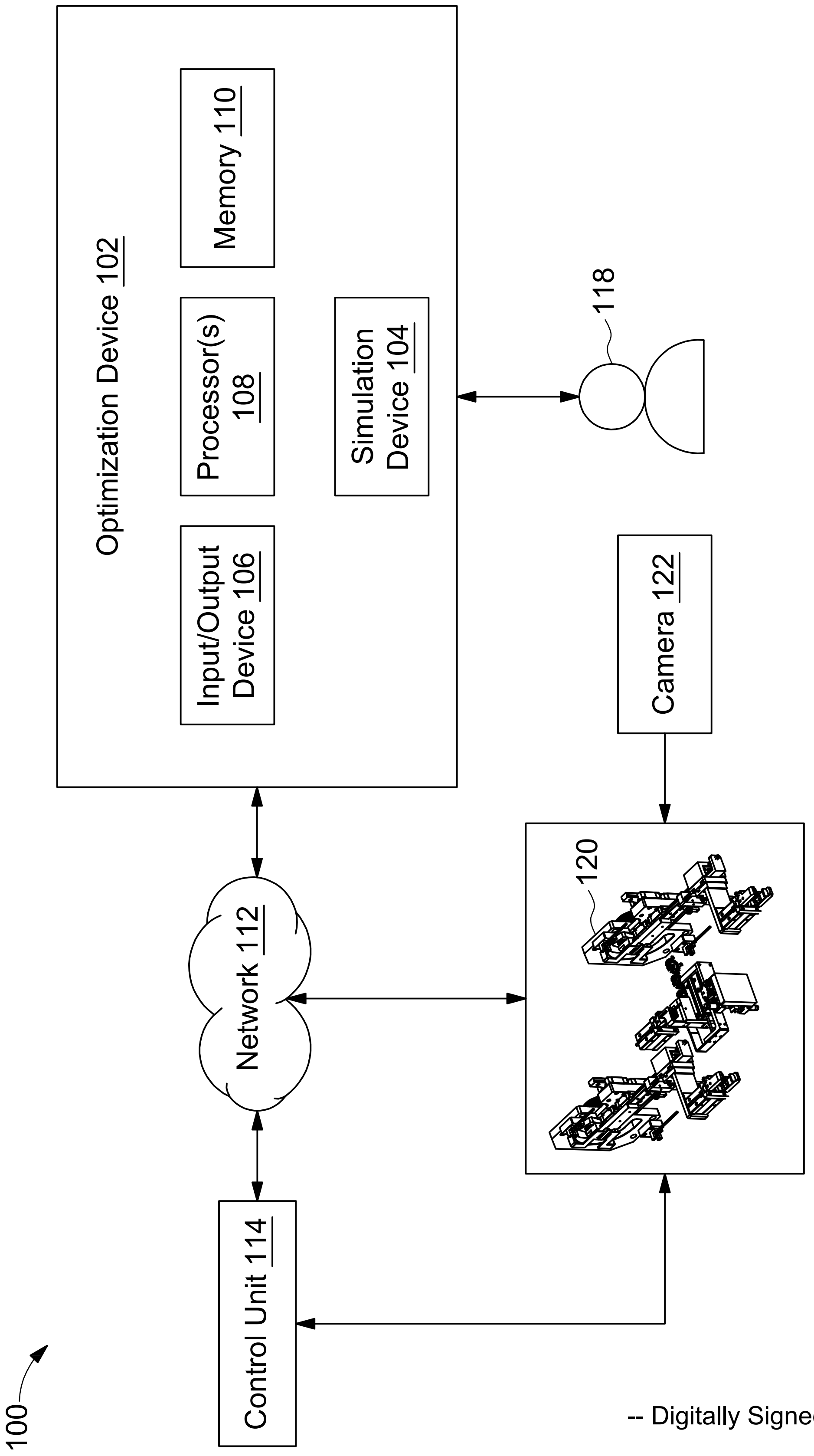

FIG. 1

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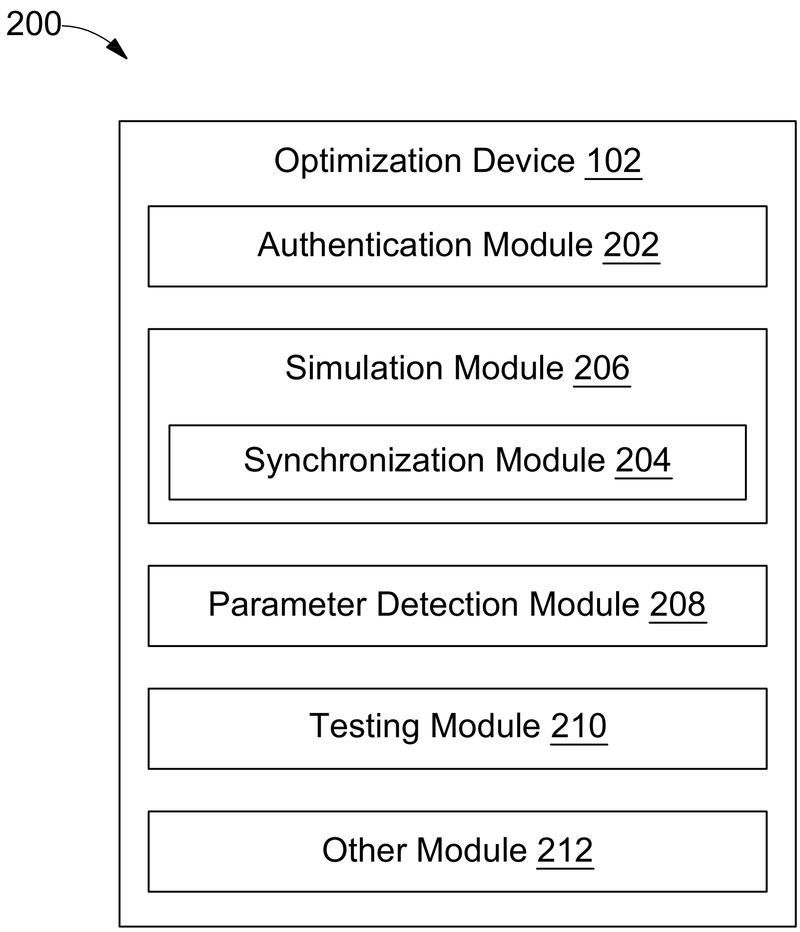

FIG. 2

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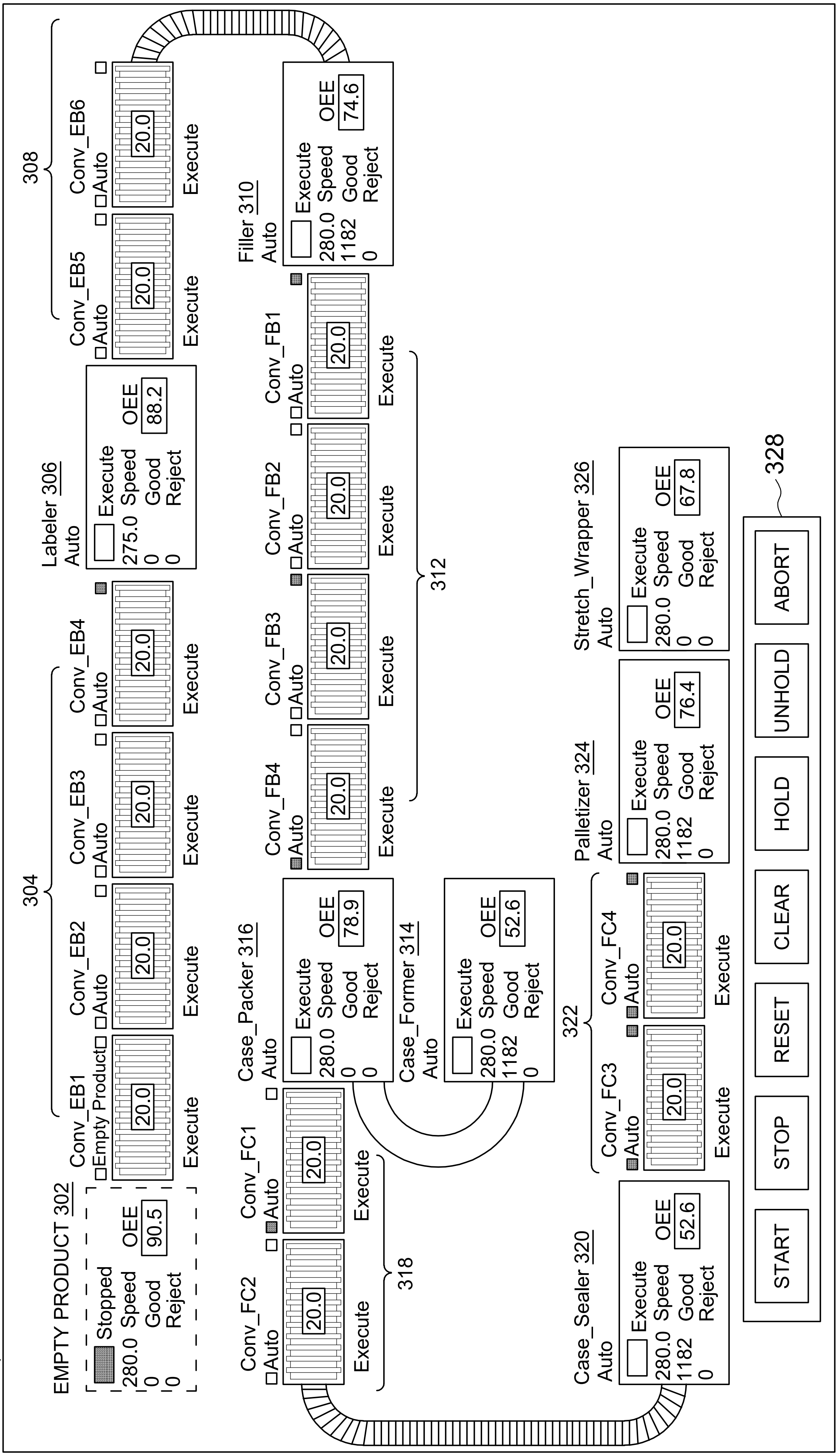

FIG. 3A

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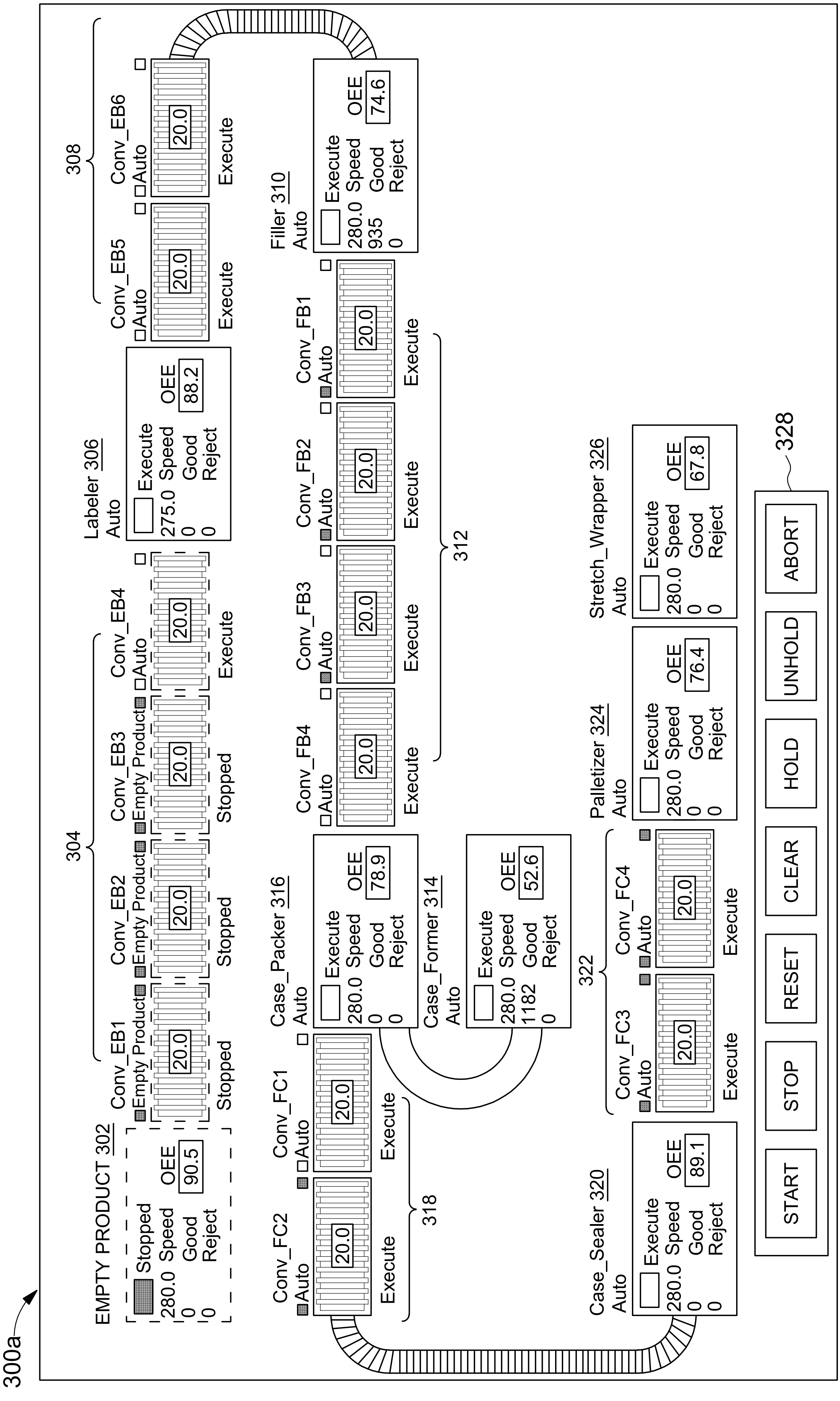

FIG. 3B

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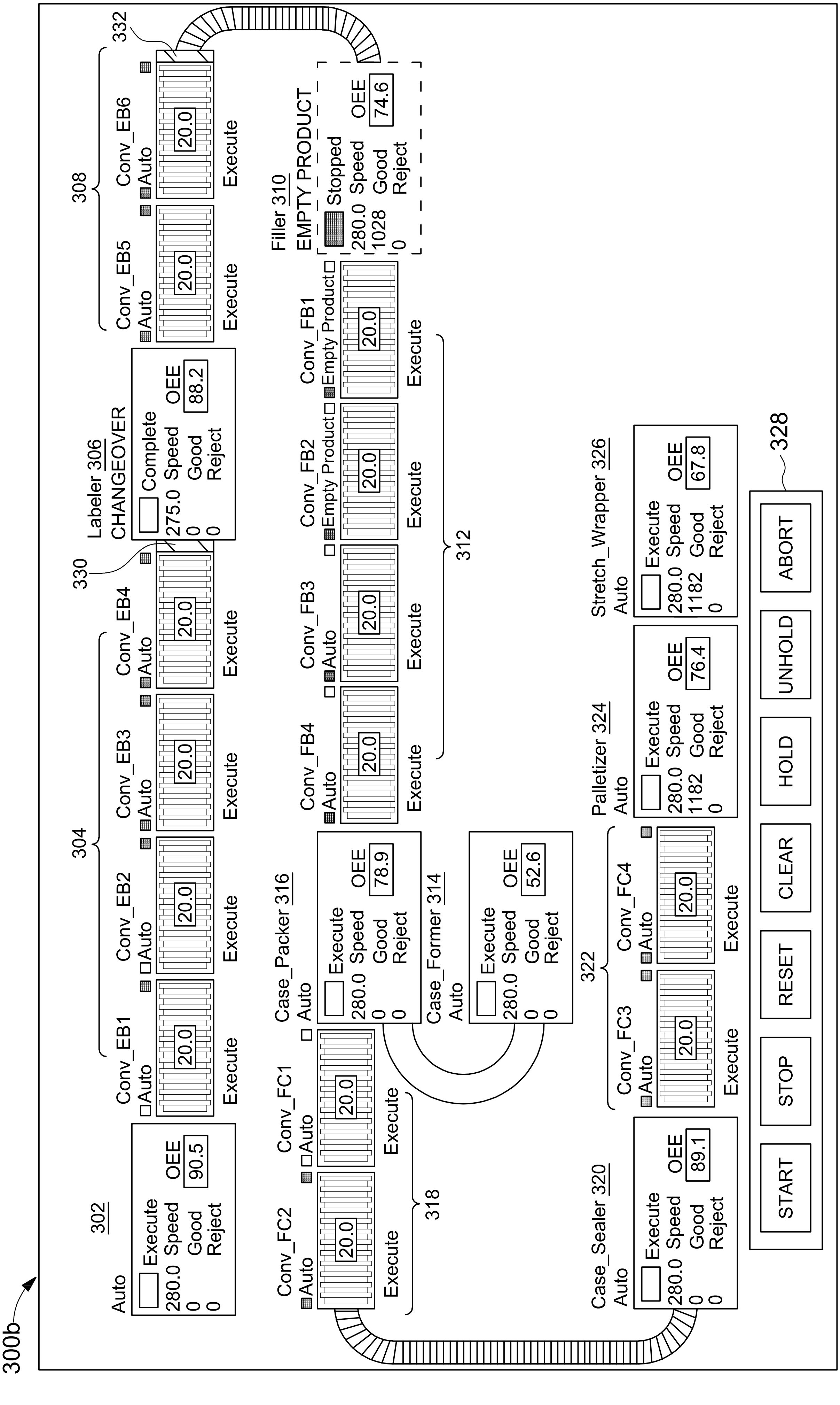

FIG. 3C

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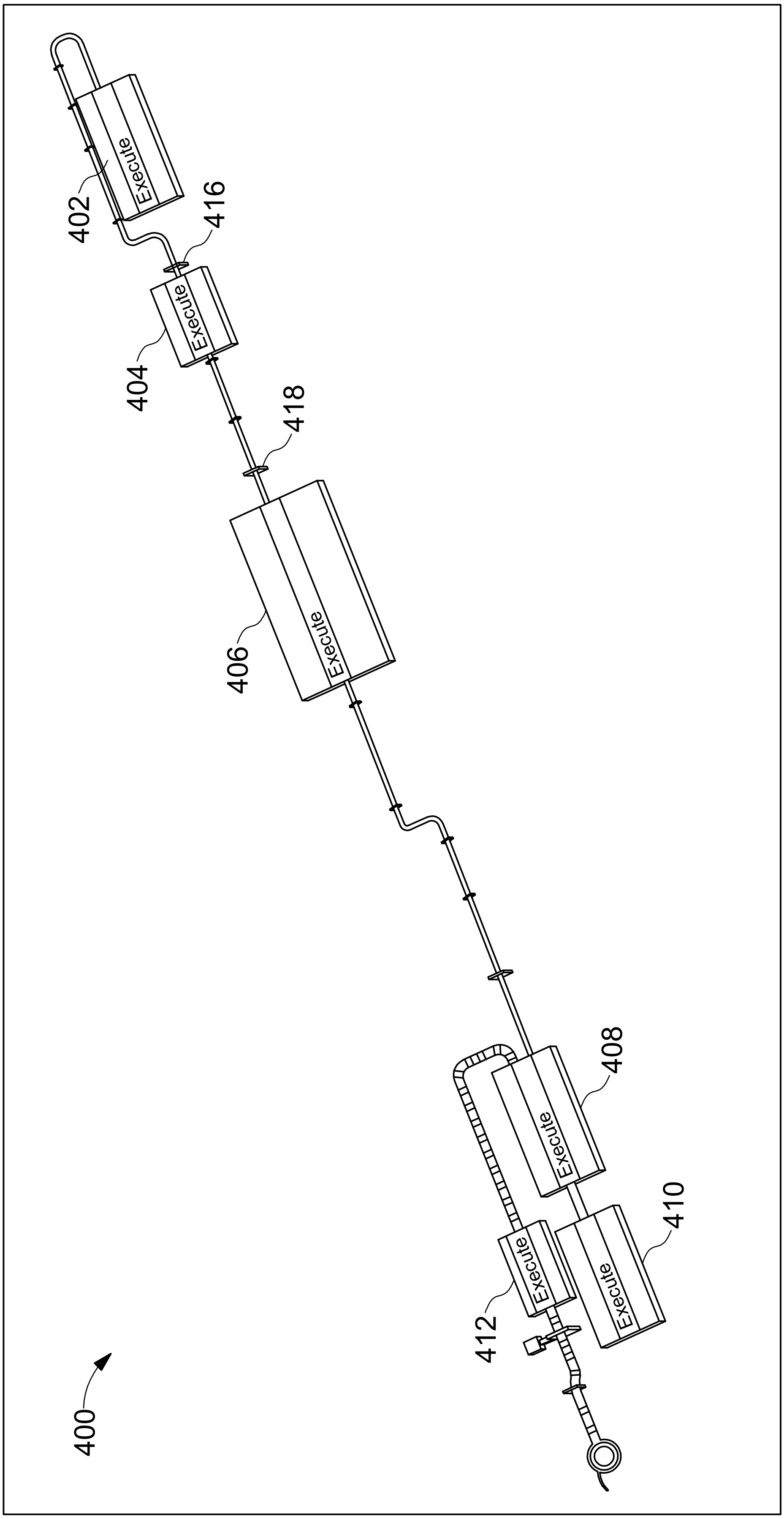

FIG. 4A

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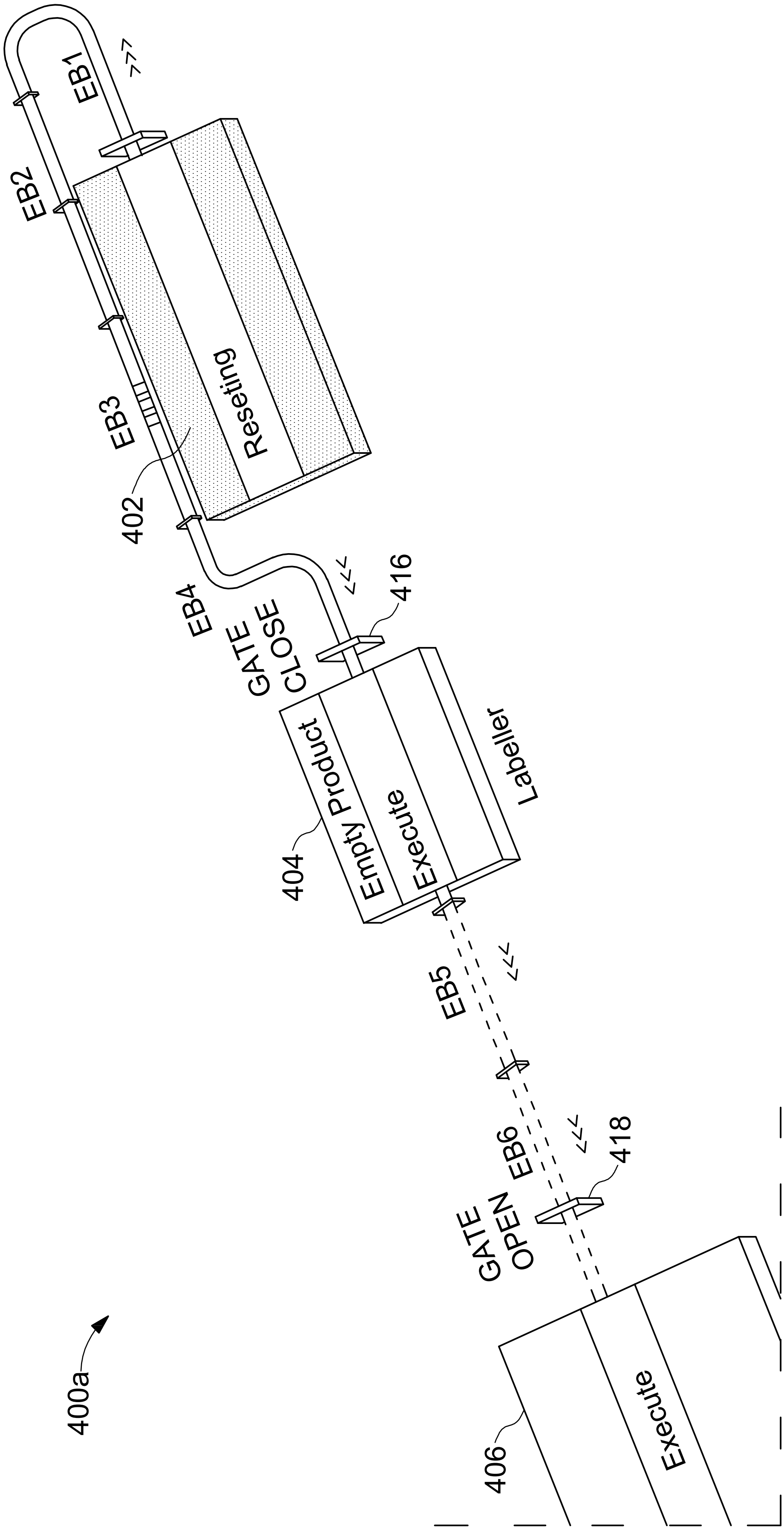

FIG. 4B

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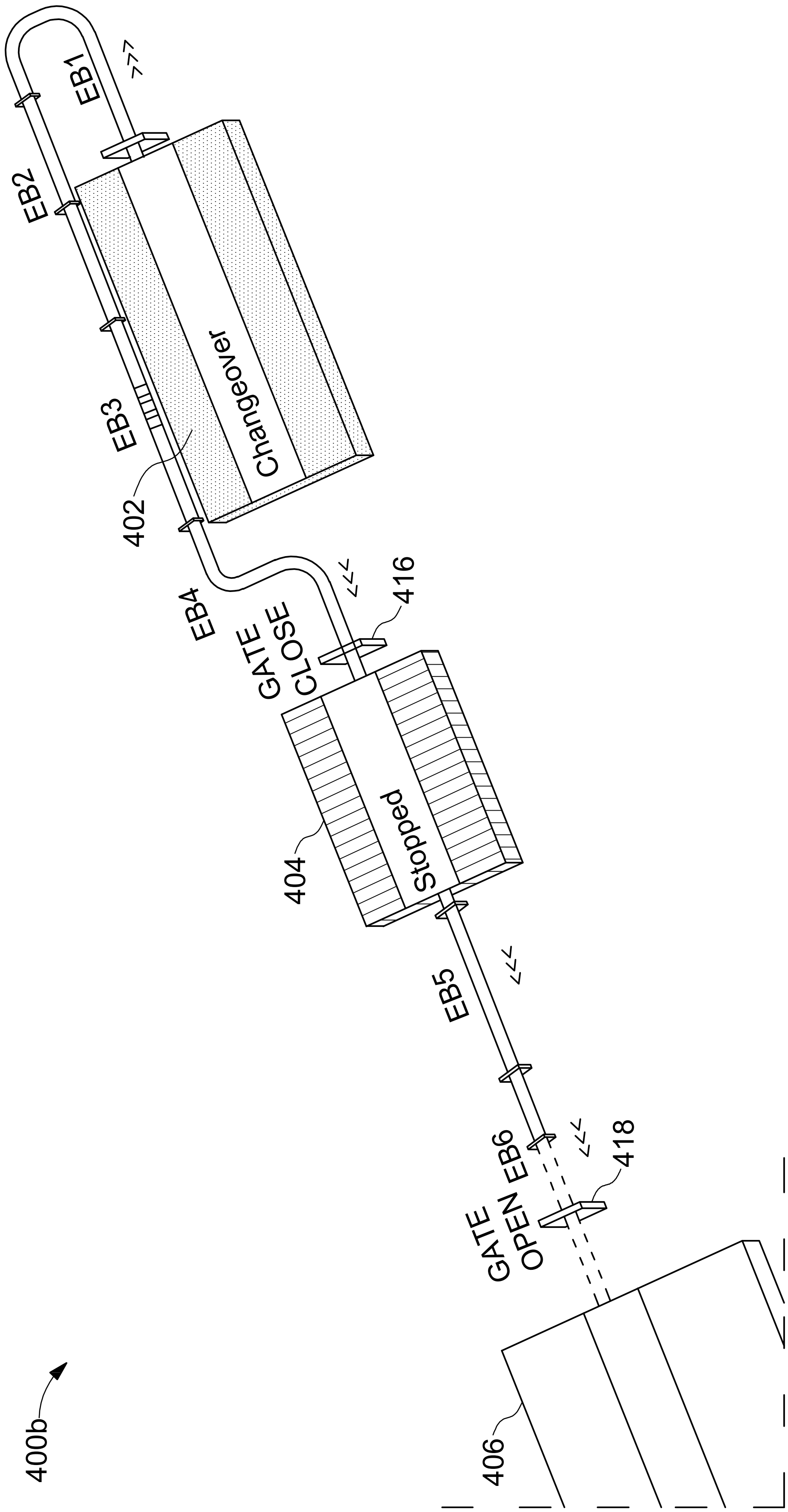

FIG. 4C

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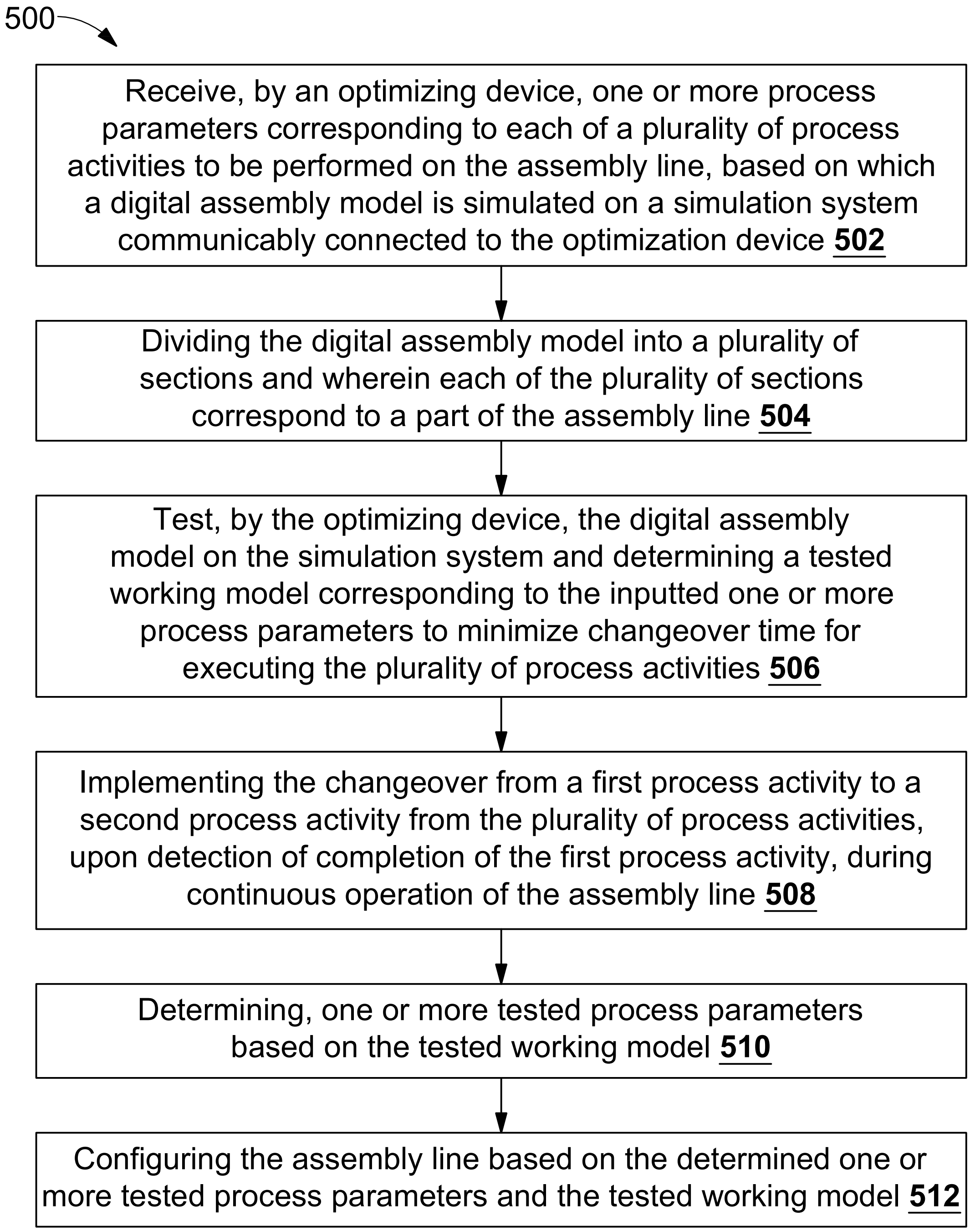

FIG. 5

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