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(54) Title: MANUFACTURING PROCESS MONITORING AND CONTROL SYSTEM

(57) Abstract: A method and apparatus for controlling a manufacturing process (111). Statistical correlations (118) between a plurality of tasks (112) comprising the manufacturing process (111) are identified. The manufacturing process (111) is controlled using the statistical correlations (118).

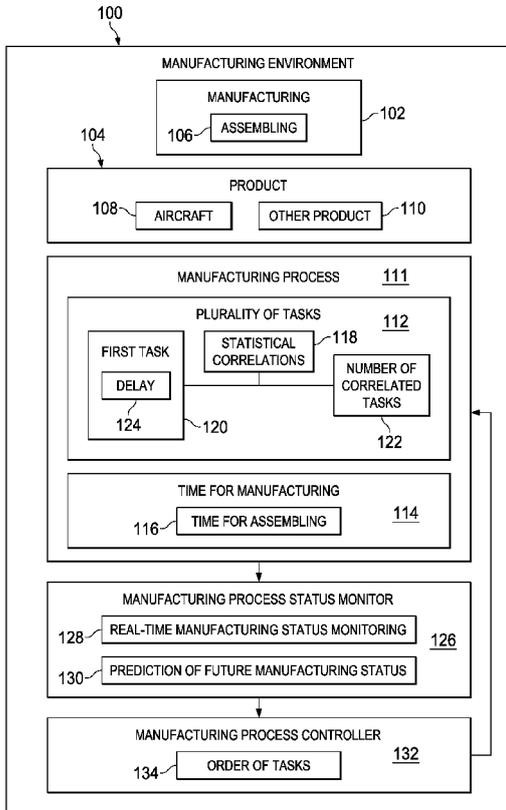


FIG. 1

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MANUFACTURING PROCESS MONITORING AND CONTROL SYSTEM**BACKGROUND INFORMATION**5 **1. Field:**

The present disclosure relates generally to systems and methods for monitoring and controlling a manufacturing process, such as a process for assembling an aircraft. More particularly, the present disclosure relates to identifying
10 statistical correlations between various tasks that comprise a manufacturing process and using the statistical correlations to improve the control of the manufacturing process.

2. Background:

15 A manufacturing process may be defined by a number of tasks. For example, a product may be made by a manufacturing process by completing the number of tasks. The number of tasks that comprise a manufacturing process may be defined in terms of resources that are needed to complete a task, the amount of time
20 that it takes to complete a task from the time that the task is started, and relationships between the tasks.

Controlling a manufacturing process may include scheduling the various tasks that comprise the process and allocating appropriate resources to those tasks in order to achieve desired
25 goals for completing the manufacturing process. For example, one such goal may be to complete the manufacturing process to make a product within a specified time period using specified available resources.

Controlling a manufacturing process also may include
30 monitoring the manufacturing process as tasks are completed and making any necessary adjustments to the task schedule. Controlling a manufacturing process also may include reallocating resources between tasks in response to changing conditions.

Many of the tasks in a manufacturing process may be interdependent. For example, some tasks may not be started until other tasks are completed. It may be desirable to understand the relationships among tasks in a manufacturing process. For example, it may be desirable to identify how the delay of some tasks in the manufacturing process may affect other tasks in the process.

In a large-scale manufacturing process there may be a great number of tasks to be performed. For example, the process of building an aircraft may involve thousands of specified tasks.

Effective control of a manufacturing process may be achieved if the relationships between the tasks comprising the manufacturing process are identified accurately. However, accurately identifying the relationships between the many tasks in a large-scale manufacturing process presents a technical problem.

Effective control of a manufacturing process may be achieved if the status of the manufacturing process may be identified accurately. Manufacturers currently may use various types of charts and other methods to track the status of a manufacturing process. The level of manual effort required to keep such charts updated throughout the manufacturing process may be undesirable.

Furthermore, current methods for monitoring the status of a manufacturing process may not identify the status of the process in a manner that may be used to improve control of the manufacturing process. For example, manufacturers may use the number of tasks behind schedule in a manufacturing process to identify the status of production of an aircraft or other system. Such current methods for identifying the status of a manufacturing process may not identify the status of the process accurately. Furthermore, current methods for monitoring the status of a manufacturing process may not be used to identify accurately the cause of delays in the manufacturing process.

Therefore, such current methods may not provide an effective tool for controlling the manufacturing process. Accurately identifying the status of a manufacturing process to improve control of the manufacturing process presents another technical
5 problem.

Accordingly, it would be beneficial to have a method and apparatus that takes into account one or more of the issues discussed above as well as possibly other issues.

10

SUMMARY

An illustrative embodiment of the present disclosure provides a method for controlling a manufacturing process. Statistical correlations between a plurality of tasks comprising
15 the manufacturing process are identified by a processor unit. The manufacturing process is controlled using the statistical correlations.

Another illustrative embodiment of the present disclosure provides an apparatus comprising a manufacturing process status
20 monitor and a manufacturing process controller. The manufacturing process status monitor is configured to identify statistical correlations between a plurality of tasks comprising a manufacturing process. The manufacturing process controller is configured to control the manufacturing process using the
25 statistical correlations.

Another illustrative embodiment of the present disclosure provides a method for controlling a process for assembling an aircraft. Statistical correlations between a plurality of tasks for assembling the aircraft are identified by a processor unit.
30 A first task from the plurality of tasks for assembling the aircraft is identified by the processor unit. A number of correlated tasks from the plurality of tasks for assembling the aircraft are identified by the processor unit using the statistical correlations. An effect of a delay in the first

task on the number of correlated tasks is identified by the processor unit using the statistical correlations.

The features, functions, and benefits may be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

10

The novel features believed characteristic of the illustrative embodiments are set forth in the appended claims. The illustrative embodiments, however, as well as a preferred mode of use, further objectives, and features thereof will best be understood by reference to the following detailed description of illustrative embodiments of the present disclosure when read in conjunction with the accompanying drawings, wherein:

Figure 1 is an illustration of a block diagram of a manufacturing environment in accordance with an illustrative embodiment;

Figure 2 is an illustration of a block diagram of a manufacturing process status monitor in accordance with an illustrative embodiment;

Figure 3 is an illustration of a user interface in accordance with an illustrative embodiment;

Figure 4 is an illustration of another user interface in accordance with an illustrative embodiment;

Figure 5 is an illustration of a flowchart of a process for controlling a manufacturing process in accordance with an illustrative embodiment; and

Figure 6 is an illustration of a block diagram of a data processing system in accordance with an illustrative embodiment.

DETAILED DESCRIPTION

The different illustrative embodiments recognize and take into account a number of different considerations. "A number,"
5 as used herein with reference to items, means one or more items. For example, "a number of different considerations" means one or more different considerations.

The different illustrative embodiments recognize and take into account that the interdependence of tasks in a
10 manufacturing process may affect the status of the process. In particular, the different illustrative embodiments recognize and take into account that a delay of some tasks in the manufacturing process may affect other tasks in the manufacturing process and may affect the status of the
15 manufacturing process as a whole.

The different illustrative embodiments also recognize and take into account that relationships among tasks in a manufacturing process may be identified to improve control of the manufacturing process. For example, the identified
20 relationships between the tasks in a manufacturing process may be used to find the cause of delays in the manufacturing process, for resource planning, to prioritize tasks, or in another manner or various combination of manners for controlling the manufacturing process.

25 Illustrative embodiments provide a technical solution to the technical problem of identifying the relationships between tasks in a manufacturing process by identifying statistical correlations between a plurality of tasks comprising the manufacturing process. For example, without limitation,
30 illustrative embodiments may use engineering knowledge and statistical dependence concepts as well as measurements from historical manufacturing data to identify correlated tasks across a manufacturing process.

Illustrative embodiments provide a technical solution to the technical problem of identifying the status of a manufacturing process to improve control of the manufacturing process by controlling the manufacturing process using statistical correlations between the tasks comprising the manufacturing process. For example, without limitation, illustrative embodiments may use the statistical correlations between tasks to identify the effect of delayed tasks on other tasks in the manufacturing process and on the status of the manufacturing process as a whole.

Turning now to **Figure 1**, an illustration of a block diagram of a manufacturing environment is depicted in accordance with an illustrative embodiment. In this example, manufacturing environment **100** may include any environment for manufacturing **102** product **104**.

Manufacturing **102** may include any process for making product **104** or for making any part of product **104**. For example, without limitation, manufacturing **102** may include assembling **106**, any other portion of a manufacturing process, or various combinations of processes for making product **104**.

Product **104** may be any product that may be made in manufacturing environment **100**. For example, without limitation, product **104** may be aircraft **108** or other product **110**. Aircraft **108** may be any type of aircraft. For example, without limitation, aircraft **108** may be a commercial aircraft, a military aircraft, a fixed wing aircraft, a rotary wing aircraft, a lighter than air aircraft, a manned aircraft, or an unmanned aircraft. For example, without limitation, other product **110** may be a vehicle, such as an automobile or other land vehicle, a water vehicle, or any other type of product.

Product **104** may be made by manufacturing process **111**. Manufacturing process **111** may include any process for manufacturing **102** product **104**. For example, without limitation,

manufacturing process **111** may include a process for assembling **106** aircraft **108** or other product **110**.

Manufacturing process **111** may comprise plurality of tasks **112**. Plurality of tasks **112** may include various tasks that may
5 be performed to make product **104**. Plurality of tasks **112** also may be referred to as jobs, steps, or using other appropriate terminology.

Time for manufacturing **114** may refer to the amount of time that it may take to manufacture product **104** by manufacturing
10 process **111**. For example, time for manufacturing **114** may be the amount of time for completing number of tasks **112**. Time for manufacturing **114** also may refer to the time that it may take to perform a part of manufacturing process **111**. For example, without limitation, time for manufacturing **114** may include time
15 for assembling **116**.

Plurality of tasks **112** may be interrelated. For example, one or more of plurality of tasks **112** may not be started or completed until others of plurality of tasks **112** are started or completed. Delays in one or more of plurality of tasks **112** thus
20 may affect other ones of plurality of tasks **112**. Delays in one or more of plurality of tasks **112** also may affect time for manufacturing **114**.

In accordance with an illustrative embodiment, the relationships between plurality of tasks **112** may be defined by
25 statistical correlations **118**. For example, statistical correlations **118** may define the relationships between pairs of task in plurality of tasks **112**. Statistical correlations **118** also may define the relationships between groups of tasks in plurality of tasks **112**, between individual tasks and groups of
30 tasks in plurality of tasks **112**, or both.

For example, first task **120** in plurality of tasks **112** may be correlated with number of correlated tasks **122** in plurality of tasks **112**. The relationships between first task **120** and number of correlated tasks **122** may be defined by statistical

correlations **118**. Delay **124** in first task **120** may affect number of correlated tasks **122**. For example, delay **124** in first task **120** may cause delays in number of correlated tasks **122**. Delay **124** in first task **120** also may affect time for manufacturing **114** of product **104**. In accordance with an illustrative embodiment, the effect of delay **124** in first task **120** on number of correlated tasks **122**, on time for manufacturing **114**, or both may be identified using statistical correlations **118**.

In accordance with an illustrative embodiment, manufacturing process status monitor **126** may be configured to identify statistical correlations **118** between plurality of tasks **112**. As will be discussed in more detail below, statistical correlations **118** may be identified from historical information.

Manufacturing process status monitor **126** may be configured for monitoring the status of manufacturing process **111** using statistical correlations **118** between plurality of tasks **112**. For example, manufacturing process status monitor **126** may be used to identify the effect of delay **124** in first task **120** on number of correlated tasks **122**, on time for manufacturing **114**, or both using statistical correlations **118**.

Manufacturing process status monitor **126** may be used for real-time manufacturing status monitoring **128** using statistical correlations **118** between plurality of tasks **112**. Real-time manufacturing status monitoring **128** may include monitoring on-going tasks and future tasks in plurality of tasks **112** using statistical correlations **118**. Manufacturing process status monitor **126** also may be used for prediction of future manufacturing status **130**. Prediction of future manufacturing status **130** may be made based on the current status of manufacturing process **111** as identified by manufacturing process status monitor **126** and using statistical correlations **118** between plurality of tasks **112**.

In accordance with an illustrative embodiment, manufacturing process **111** may be controlled using statistical

correlations **118** between plurality of tasks **112** comprising manufacturing process **111**. For example, manufacturing process controller **132** may be configured to control manufacturing process **111** using statistical correlations **118** as identified by manufacturing process status monitor **126**. For example, without limitation, order of tasks **134** for performing manufacturing process **111** may be controlled using statistical correlations **118** between plurality of tasks **112**. Order of tasks **134** may define the order in which plurality of tasks **112** are performed to perform manufacturing process **111**. For example, without limitation, manufacturing process controller **132** may be configured to optimize order of tasks **134** using statistical correlations **118**.

Turning now to **Figure 2**, an illustration of a block diagram of a manufacturing process status monitor is depicted in accordance with an illustrative embodiment. In this example, manufacturing process status monitor **200** is an example of one implementation of manufacturing process status monitor **126** in **Figure 1**.

Manufacturing process status monitor **200** may include correlation identifier **202**. Correlation identifier **202** may be configured to identify correlated tasks **206** and statistical correlations **208** in a plurality of tasks comprising a manufacturing process. Statistical correlations **208** define the relationships between correlated tasks **206**.

Statistical correlations **208** between a plurality of tasks comprising a manufacturing process may be identified from historical information **210**. For example, without limitation, historical information **210** may include historical information for the manufacturing process for which statistical correlations **208** are being identified. Alternatively, or additionally, historical information **210** may include historical information for a manufacturing process that may be similar to the manufacturing process for which statistical correlations **208** are

being identified. Historical information **210** may be obtained and provided to manufacturing process status monitor **200** in any appropriate manner.

For example, without limitation, statistical correlations **208** may be automatically determined **212** from historical information **210**. Statistical correlations **208** that are automatically determined **212** may be manually adjusted **214**. For example, statistical correlations **208** may be manually adjusted in response to user input **215**.

Statistical correlations **208** may identify stochastic dependence **216** between the plurality of tasks comprising a manufacturing process. Statistical correlations **208** may be identified from historical information **210** using known techniques for measuring stochastic dependence **216**. For example, without limitation, statistical correlations **208** may be identified using global measures of dependence, local measures of dependence, other measures of dependence, or various measures of dependence in combination. Examples of global measures of dependence that may be used to identify statistical correlations **208** may include Pearson's rho, Kendall's tau, and Spearman's rho.

Manufacturing process status monitor **200** may include delay effect identifier **204**. Delay effect identifier **204** may be configured to identify effect of task delay on correlated tasks **218** using statistical correlations **208**. Effect of task delay on correlated tasks **218** may identify the effects of a delay of one task in a plurality of tasks comprising a manufacturing process on correlated tasks in the plurality of tasks. For example, without limitation, effect of task delay on correlated tasks **218** may include an indication of probabilities **220** that a delay of one of the plurality of tasks comprising a manufacturing process may affect other ones of the plurality of tasks.

Delay effect identifier **204** also may be configured to identify effect of task delay on time for manufacturing **222**

using statistical correlations **208**. Effect of task delay on time for manufacturing **222** may identify the effect of a delay of a number of tasks in a plurality of tasks comprising a manufacturing process on the time for manufacturing a product using the manufacturing process. Therefore, effect of task delay on time for manufacturing **222** may identify the effect of a delay of a number of tasks in a plurality of tasks comprising a manufacturing process on the manufacturing process as whole.

Manufacturing process status monitor **200** may include user interface generator **223**. User interface generator **223** may be configured to generate user interface **224** for manufacturing process status monitor **200**. For example, without limitation, user interface **224** may be a graphical user interface or other user interface.

User **226** may interact with user interface **224** via user interface devices **230**. User interface devices **230** may include any appropriate devices for displaying user interface **224** to user **226** and for receiving user input **215** from user **226**. For example, user interface **224** may be displayed to user **226** on display device **232**. User **226** may use input device **234** to provide user input **215** to user interface **224**.

User interface **224** may be configured to allow user **226** to interact with manufacturing process status monitor **200**. For example, user interface **224** may be configured to allow user **226** to provide user input **215** to manufacturing process status monitor **200** for controlling correlation identifier **202**, delay effect identifier **204**, or both. Effect of task delay on correlated tasks **218**, effect of task delay on time for manufacturing **222**, or both may be displayed to user **226** on user interface **224**.

The illustrations of **Figure 1** and **Figure 2** are not meant to imply physical or architectural limitations to the manner in which different illustrative embodiments may be implemented. Other components in addition to, in place of, or both in

addition to and in place of the ones illustrated may be used. Some components may be unnecessary in some illustrative embodiments. Also, the blocks are presented to illustrate some functional components. One or more of these blocks may be
5 combined or divided into different blocks when implemented in different illustrative embodiments.

Turning now to **Figure 3**, an illustration of a user interface is depicted in accordance with an illustrative embodiment. In this example, user interface **300** is an example of
10 one implementation of user interface **224** for manufacturing process status monitor **200** in **Figure 2**. In this example, user interface **300** is configured to allow a user to select a task from a plurality of tasks for assembling an aircraft.

User interface **300** may include a number of virtual buttons
15 **302** corresponding to various assembly areas for assembling the aircraft. The user may first select an assembly area from the displayed number of assembly areas. In this example, the user has selected virtual button **304** for the "Final Body Join" assembly area.

20 In response to selecting one of virtual buttons **302** corresponding to a selected assembly area, a list of milestones **306** corresponding to the selected assembly area may be displayed on user interface **300**. In this example, list of milestones **306** is a list of milestones corresponding to the selected "Final
25 Body Join" assembly area. The user then may select one of the listed milestones **306**. In this example, the user has selected "FWD Keel beam" **308** from list of milestones **306**.

In response to selecting one milestone from list of milestones **306**, job list **310** corresponding to the selected
30 milestone may be displayed on user interface **300**. Job list **310** also may be referred to as a list of installation plans or tasks for assembling the aircraft. In this example, job list **310** is a list of installation plans corresponding to the selected "FWD Keel beam" milestone. The user may select one of the

installation plans from job list **310** to display the effect of a delay in the selected installation plan on other installation plans in the process of assembling the aircraft.

Turning now to **Figure 4**, an illustration of another user interface is depicted in accordance with an illustrative embodiment. In this example, user interface **400** is an example of another implementation of user interface **224** for manufacturing process status monitor **200** in **Figure 2**. In this example, user interface **400** is an example of a user interface that may be displayed in response to selecting "DRILL KEEL BEAM SPLICE PLATE, STA 1035, LH" from the list of installation plans in user interface **300** in **Figure 3**.

In this example, user interface **400** is configured to show the correlation between a selected task and a number of correlated tasks. User interface **400** also is configured to show the probabilities that a delay in the selected task will affect the number of correlated tasks.

User interface **400** may include display **402** identifying the selected installation plan. User interface **400** may include display **404** identifying correlated installation plans **406** that are correlated to the selected installation plan, correlations **408** between the selected installation plan and each of correlated installation plans **406**, and delay probabilities **410** for each of correlated installation plans **406**. In this example, delay probabilities **410** indicate the probabilities that each of correlated installation plans **406** will be delayed if the selected installation plan is delayed.

Display **404** may include correction check boxes **412** for each of correlated installation plans **406**. Authorized users may select correction check boxes **412** to change manually the information presented in display **404** for corresponding installation plans **406**.

Turning now to **Figure 5**, an illustration of a flowchart of a process for controlling a manufacturing process is depicted in

accordance with an illustrative embodiment. For example, the process illustrated in **Figure 5** may be implemented in manufacturing environment **100** using manufacturing process status monitor **126** and manufacturing process controller **132** in **Figure**

5 **1**.

The process may begin by identifying statistical correlations between a plurality of tasks comprising a manufacturing process (operation **502**). Statistical correlations between the plurality of tasks may be identified using historical manufacturing information.

A first task from the plurality of tasks may be identified (operation **504**). A number of correlated tasks that are correlated to the first task may be identified using the statistical correlations (operation **506**). An effect of a delay in the first task on the number of correlated tasks may be identified using the statistical correlations (operation **508**). For example, without limitation, operation **508** may include identifying probabilities that a delay in the first task may affect the number of correlated tasks. An effect of the delay in the first task on a time for manufacturing also may be identified using the statistical correlations (operation **510**).

The manufacturing process may be controlled using the statistical correlations (operation **512**), with the process terminating thereafter. For example, without limitation, operation **512** may include optimizing the order in which the plurality of tasks comprising the manufacturing process is performed.

Turning now to **Figure 6**, an illustration of a block diagram of a data processing system is depicted in accordance with an illustrative embodiment. In this example, data processing system **600** is an example of one implementation of a data processing system for implementing manufacturing process status monitor **126** or manufacturing process controller **132** in **Figure 1** or manufacturing process status monitor **200** in **Figure 2**.

In this illustrative example, data processing system **600** includes communications fabric **602**. Communications fabric **602** provides communications between processor unit **604**, memory **606**, persistent storage **608**, communications unit **610**, input/output (I/O) unit **612**, and display **614**. Memory **606**, persistent storage **608**, communications unit **610**, input/output (I/O) unit **612**, and display **614** are examples of resources accessible by processor unit **604** via communications fabric **602**.

Processor unit **604** serves to run instructions for software that may be loaded into memory **606**. Processor unit **604** may be a number of processors, a multi-processor core, or some other type of processor, depending on the particular implementation. Further, processor unit **604** may be implemented using a number of heterogeneous processor systems in which a main processor is present with secondary processors on a single chip. As another illustrative example, processor unit **604** may be a symmetric multi-processor system containing multiple processors of the same type.

Memory **606** and persistent storage **608** are examples of storage devices **616**. A storage device is any piece of hardware that is capable of storing information, such as, for example, without limitation, data, program code in functional form, and other suitable information either on a temporary basis or a permanent basis. Storage devices **616** also may be referred to as computer readable storage devices in these examples. Memory **606**, in these examples, may be, for example, a random access memory or any other suitable volatile or non-volatile storage device. Persistent storage **608** may take various forms, depending on the particular implementation.

For example, persistent storage **608** may contain one or more components or devices. For example, persistent storage **608** may be a hard drive, a flash memory, a rewritable optical disk, a rewritable magnetic tape, or some combination of the above. The media used by persistent storage **608** also may be removable. For

example, a removable hard drive may be used for persistent storage **608**.

Communications unit **610**, in these examples, provides for communications with other data processing systems or devices.

5 In these examples, communications unit **610** is a network interface card. Communications unit **610** may provide communications through the use of either or both physical and wireless communications links.

10 Input/output (I/O) unit **612** allows for input and output of data with other devices that may be connected to data processing system **600**. For example, input/output (I/O) unit **612** may provide a connection for user input through a keyboard, a mouse, and/or some other suitable input device. Further, input/output (I/O) unit **612** may send output to a printer. Display **614**
15 provides a mechanism to display information to a user.

Instructions for the operating system, applications, and/or programs may be located in storage devices **616**, which are in communication with processor unit **604** through communications fabric **602**. In these illustrative examples, the instructions
20 are in a functional form on persistent storage **608**. These instructions may be loaded into memory **606** for execution by processor unit **604**. The processes of the different embodiments may be performed by processor unit **604** using computer-implemented instructions, which may be located in a memory, such
25 as memory **606**.

These instructions are referred to as program instructions, program code, computer usable program code, or computer readable program code that may be read and executed by a processor in processor unit **604**. The program code in the different
30 embodiments may be embodied on different physical or computer readable storage media, such as memory **606** or persistent storage **608**.

Program code **618** is located in a functional form on computer readable media **620** that is selectively removable and

may be loaded onto or transferred to data processing system **600** for execution by processor unit **604**. Program code **618** and computer readable media **620** form computer program product **622** in these examples. In one example, computer readable media **620** may
5 be computer readable storage media **624** or computer readable signal media **626**.

Computer readable storage media **624** may include, for example, an optical or magnetic disk that is inserted or placed into a drive or other device that is part of persistent storage
10 **608** for transfer onto a storage device, such as a hard drive, that is part of persistent storage **608**. Computer readable storage media **624** also may take the form of a persistent storage, such as a hard drive, a thumb drive, or a flash memory, that is connected to data processing system **600**. In some
15 instances, computer readable storage media **624** may not be removable from data processing system **600**.

In these examples, computer readable storage media **624** is a physical or tangible storage device used to store program code **618** rather than a medium that propagates or transmits program
20 code **618**. Computer readable storage media **624** is also referred to as a computer readable tangible storage device or a computer readable physical storage device. In other words, computer readable storage media **624** is a media that can be touched by a person.

Alternatively, program code **618** may be transferred to data processing system **600** using computer readable signal media **626**. Computer readable signal media **626** may be, for example, a propagated data signal containing program code **618**. For
25 example, computer readable signal media **626** may be an electromagnetic signal, an optical signal, and/or any other suitable type of signal. These signals may be transmitted over communications links, such as wireless communications links, optical fiber cable, coaxial cable, a wire, and/or any other
30 suitable type of communications link. In other words, the

communications link and/or the connection may be physical or wireless in the illustrative examples.

In some illustrative embodiments, program code **618** may be downloaded over a network to persistent storage **608** from another device or data processing system through computer readable signal media **626** for use within data processing system **600**. For instance, program code stored in a computer readable storage medium in a server data processing system may be downloaded over a network from the server to data processing system **600**. The data processing system providing program code **618** may be a server computer, a client computer, or some other device capable of storing and transmitting program code **618**.

The different components illustrated for data processing system **600** are not meant to provide architectural limitations to the manner in which different embodiments may be implemented. The different illustrative embodiments may be implemented in a data processing system including components in addition to and/or in place of those illustrated for data processing system **600**. Other components shown in **Figure 6** can be varied from the illustrative examples shown. The different embodiments may be implemented using any hardware device or system capable of running program code. As one example, data processing system **600** may include organic components integrated with inorganic components and/or may be comprised entirely of organic components excluding a human being. For example, a storage device may be comprised of an organic semiconductor.

In another illustrative example, processor unit **604** may take the form of a hardware unit that has circuits that are manufactured or configured for a particular use. This type of hardware may perform operations without needing program code to be loaded into a memory from a storage device to be configured to perform the operations.

For example, when processor unit **604** takes the form of a hardware unit, processor unit **604** may be a circuit system, an

application specific integrated circuit (ASIC), a programmable logic device, or some other suitable type of hardware configured to perform a number of operations. With a programmable logic device, the device is configured to perform the number of
5 operations. The device may be reconfigured at a later time or may be permanently configured to perform the number of operations. Examples of programmable logic devices include, for example, a programmable logic array, a programmable array logic, a field programmable logic array, a field programmable gate
10 array, and other suitable hardware devices. With this type of implementation, program code **618** may be omitted, because the processes for the different embodiments are implemented in a hardware unit.

In still another illustrative example, processor unit **604**
15 may be implemented using a combination of processors found in computers and hardware units. Processor unit **604** may have a number of hardware units and a number of processors that are configured to run program code **618**. With this depicted example, some of the processes may be implemented in the number of
20 hardware units, while other processes may be implemented in the number of processors.

In another example, a bus system may be used to implement communications fabric **602** and may be comprised of one or more buses, such as a system bus or an input/output bus. Of course,
25 the bus system may be implemented using any suitable type of architecture that provides for a transfer of data between different components or devices attached to the bus system.

Additionally, communications unit **610** may include a number of devices that transmit data, receive data, or both transmit
30 and receive data. Communications unit **610** may be, for example, a modem or a network adapter, two network adapters, or some combination thereof. Further, a memory may be, for example, memory **606**, or a cache, such as that found in an interface and

memory controller hub that may be present in communications fabric
602.

In variations of the preceding illustrative examples, a method for controlling a process for assembling an aircraft (108) can
5 also include identifying, by a processor unit (604), (i) statistical correlations (118) between a plurality of tasks (112) for assembling the aircraft (108), (ii) identifying, by the processor unit (604), a first task (120) from the plurality of tasks (112) for assembling the aircraft (108), (iii)
10 identifying, by the processor unit (604), a number of correlated tasks (122) from the plurality of tasks (112) for assembling the aircraft (108) using the statistical correlations (118), and (iv) identifying, by the processor unit (604), an effect of a delay (124) in the first task (120) on the number of correlated
15 tasks (122) using the statistical correlations (118).

In further variations, the method may also the identifying the effect of the delay (124) in the first task (120) on the number of correlated tasks (122), can further include identifying probabilities (220) that the delay (124) in the
20 first task (120) will result in a delay (124) in the number of correlated tasks (122).

The flowcharts and block diagrams described herein illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer
25 program products according to various illustrative embodiments. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function or functions. It should also be
30 noted that, in some alternative implementations, the functions noted in a block may occur out of the order noted in the figures. For example, the functions of two blocks shown in succession may be executed substantially concurrently, or the

functions of the blocks may sometimes be executed in the reverse order, depending upon the functionality involved.

The description of the different illustrative embodiments has been presented for purposes of illustration and description
5 and is not intended to be exhaustive or to limit the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different illustrative embodiments may provide different benefits as compared to other illustrative embodiments. The
10 embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use
15 contemplated.

CLAIMS:

What is claimed is:

- 5 1. A method for controlling a manufacturing process (111),
comprising:
identifying, by a processor unit (604), statistical
correlations (118) between a plurality of tasks (112) comprising
the manufacturing process (111); and
10 controlling the manufacturing process (111) using the
statistical correlations (118).
2. The method of claim 1, wherein controlling the
manufacturing process (111) comprises controlling an order in
15 which the plurality of tasks (112) are performed using the
statistical correlations (118).
3. The method of claim 1, wherein identifying the statistical
correlations (118) comprises identifying the statistical
20 correlations (118) using historical information (210) for the
manufacturing process (111); and
manually adjusting the statistical correlations (118).
4. The method of claim 1, wherein the statistical
25 correlations (118) identify stochastic dependence (216) between
the plurality of tasks (112).
5. The method of claim 1 further comprising:
identifying, by the processor unit (604), an effect of a
30 delay (124) in a first task (120) in the plurality of
tasks (112) on a number of correlated tasks (122) in the
plurality of tasks (112) using the statistical
correlations (118); and

wherein identifying the effect of the delay (124) in the first task (120) on the number of correlated tasks (122) comprises identifying probabilities (220) that the delay (124) in the first task (120) will result in a delay (124) in the number of correlated tasks (122).

6. The method of claim 1 further comprising:
identifying, by the processor unit (604), an effect of a delay (124) in a first task (120) in the plurality of tasks (112) on a time for manufacturing (114) a product (104) using the manufacturing process (111).

7. The method of claim 1, wherein the manufacturing process (111) comprises a process for assembling an aircraft (108).

8. An apparatus, comprising:
a manufacturing process status monitor (126) configured to identify statistical correlations (118) between a plurality of tasks (112) comprising a manufacturing process (111); and
a manufacturing process controller (132) configured to control the manufacturing process (111) using the statistical correlations (118).

9. The apparatus of claim 8, wherein the manufacturing process controller (132) is configured to control an order in which the plurality of tasks (112) is performed using the statistical correlations (118).

10. The apparatus of claim 8, wherein the manufacturing process status monitor (126) is configured to identify the statistical correlations (118) using historical information (210) for the manufacturing process (111); and

wherein the manufacturing process status monitor (126) is configured to receive user input (215) from a user (226) and to adjust the statistical correlations (118) responsive to the user input (215).

5

11. The apparatus of claim 8, wherein the statistical correlations (118) identify stochastic dependence (216) between the plurality of tasks (112).

10 12. The apparatus of claim 8, wherein the manufacturing process status monitor (126) is configured to identify an effect of a delay (124) in a first task (120) in the plurality of tasks (112) on a number of correlated tasks (122) in the plurality of tasks (112) using the statistical correlations (118); and

15 wherein the manufacturing process status monitor (126) is configured to identify probabilities (220) that the delay (124) in the first task (120) will result in a delay (124) in the number of correlated tasks (122).

20 13. The apparatus of claim 8, wherein the manufacturing process status monitor (126) is configured to identify an effect of a delay (124) in a first task (120) in the plurality of tasks (112) on a time for manufacturing (114) a product (104) using the manufacturing process (111).

25

14. The apparatus of claim 8, wherein the manufacturing process (111) comprises a process for assembling an aircraft (108).

30

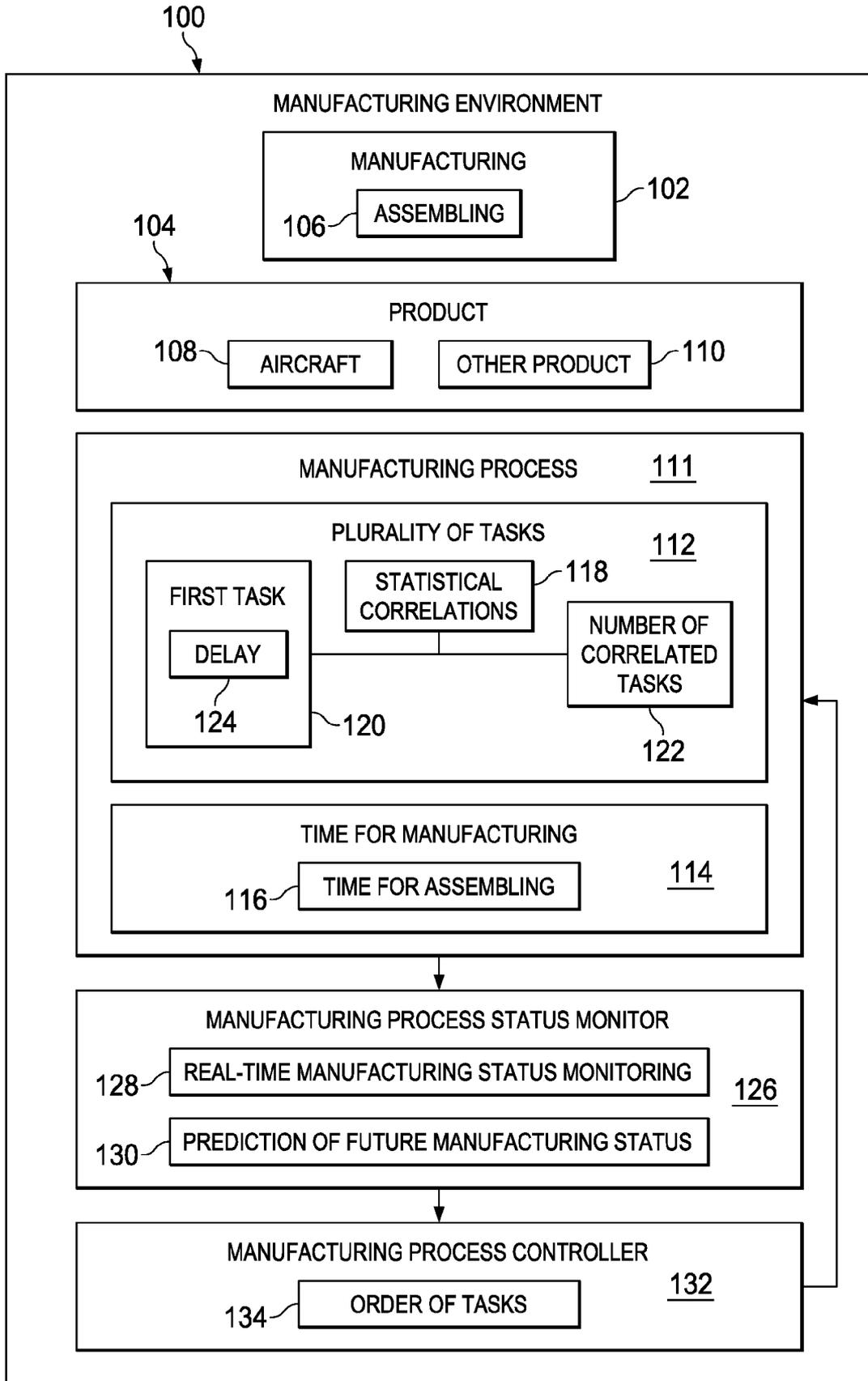
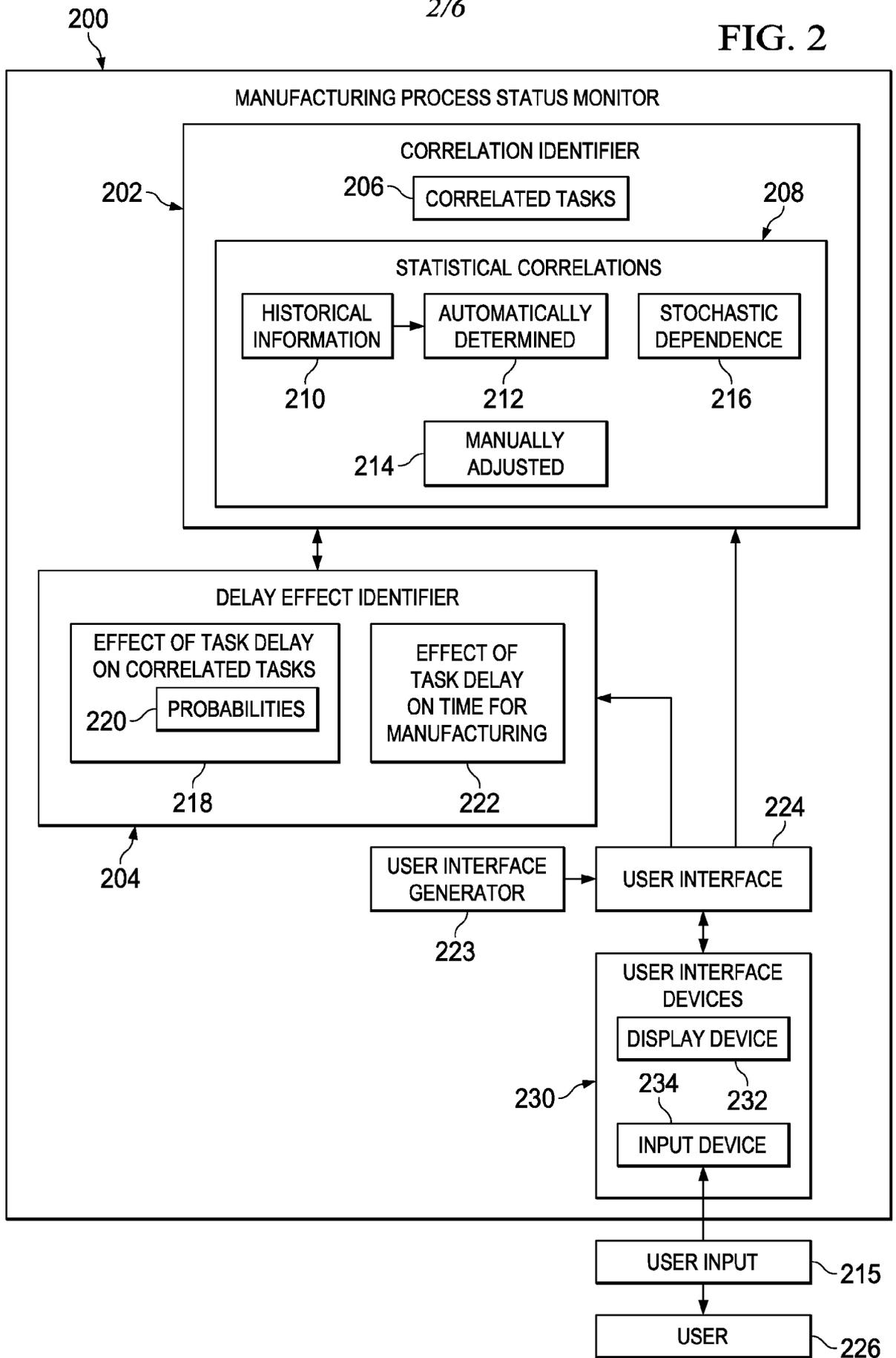


FIG. 1

FIG. 2



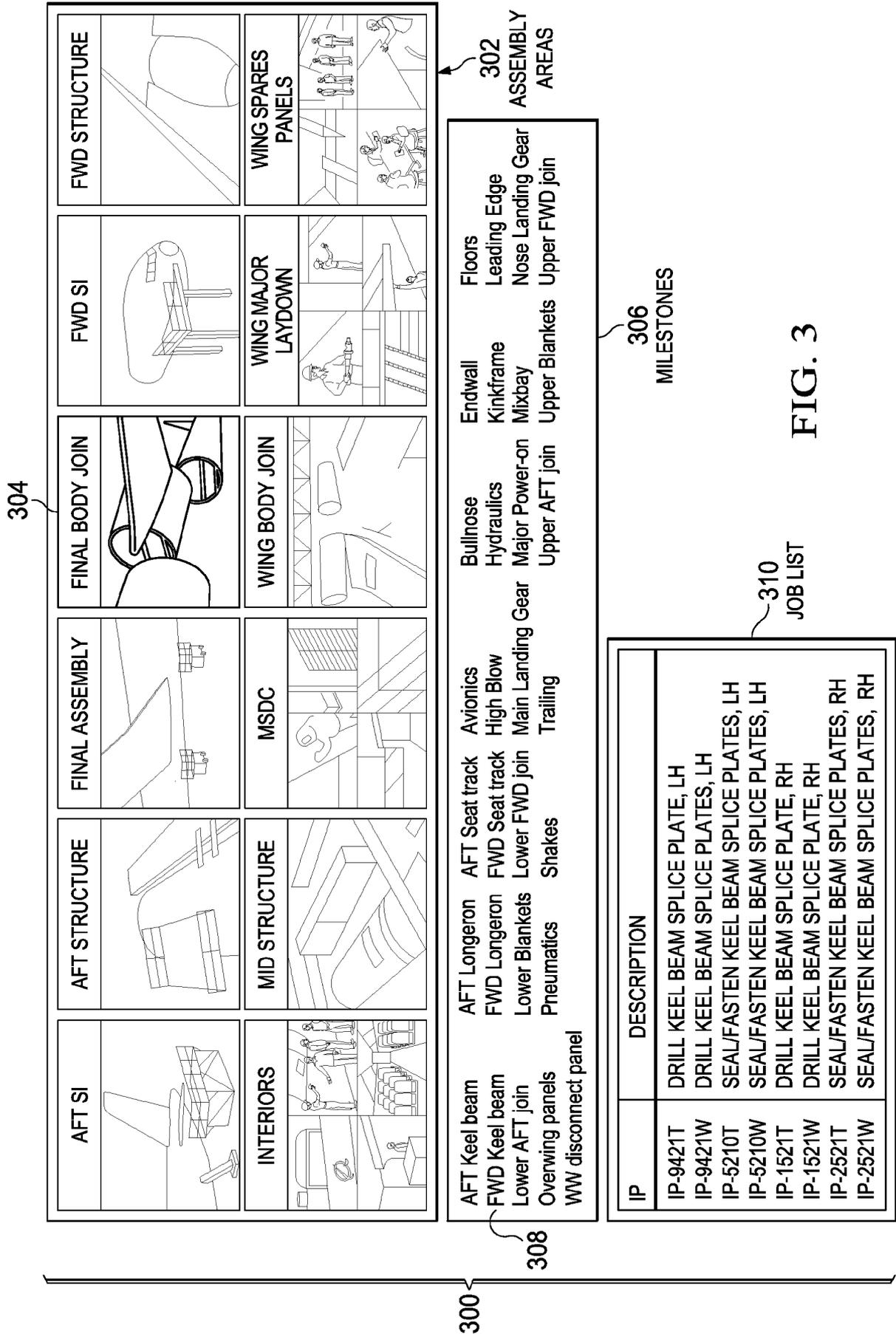


FIG. 3

400

SELECTED JOB INFORMATION
 Assembly Area: Final Body Join
 Milestone: Fwd Keel beam
 Ip: IP-9421T
 DRILL KEEL BEAM SPLICE PLATE, LH
 Select Different Job
402

JOB OPTIONS

Downstream [Final Assembly, Interiors]
 Upstream [FWD SJ]

Correlation Threshold
 Delay Prob Threshold
 Show Checked Only

FILTER BY LINE:

913 914 915 916 917 918 919
 920 921 922 923 924 925 926
 927 928 929 930 931 932 933
 934 935 936 937 938 939 940
 941 942 943 944 945 946 947
 948 949 950 951 952 953 954

404

Associated Jobs 406

IP	Area/Selection	Milestone	Correlation 408	Delay Probability 410	Correction Check 412	Description
IP-1521T	Final Body Join	FWD Keel beam	0.95	0.65	<input checked="" type="checkbox"/>	DRILL KEEL BEAM SPLICE PLATE, RH
IP-40294W	Final Body Join	Pneumatics	0.86	0.85	<input checked="" type="checkbox"/>	INSTALL PACK AIR SUPPLY DUCTING, RH
IP-30294W	Final Body Join	Pneumatics	0.85	0.73	<input checked="" type="checkbox"/>	INSTALL PACK AIR SUPPLY DUCTING, LH
IP-40111T	Final Body Join	Hydraulics	0.84	0.81	<input checked="" type="checkbox"/>	INSTALL AND PERMASWAGE HYDRAULIC TUBES, PASSENGER FLOOR
IP-5371T	Final Body Join	AFT Keel beam	0.84	0.65	<input checked="" type="checkbox"/>	DRILL KEEL BEAM SPLICE, L AND R
IP-41294W	Final Body Join	Pneumatics	0.84	0.81	<input checked="" type="checkbox"/>	ECS/HP, INSTALL AIR SUPPLY DUCTS AND VALVES, A/C PACK BAY

FIG. 4

5/6

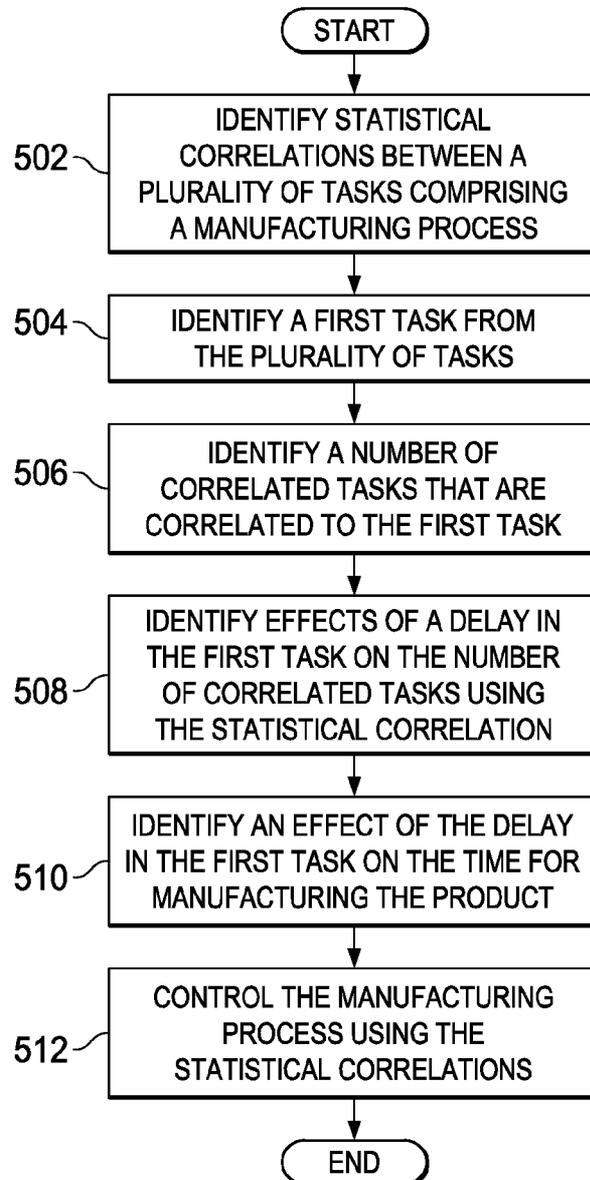
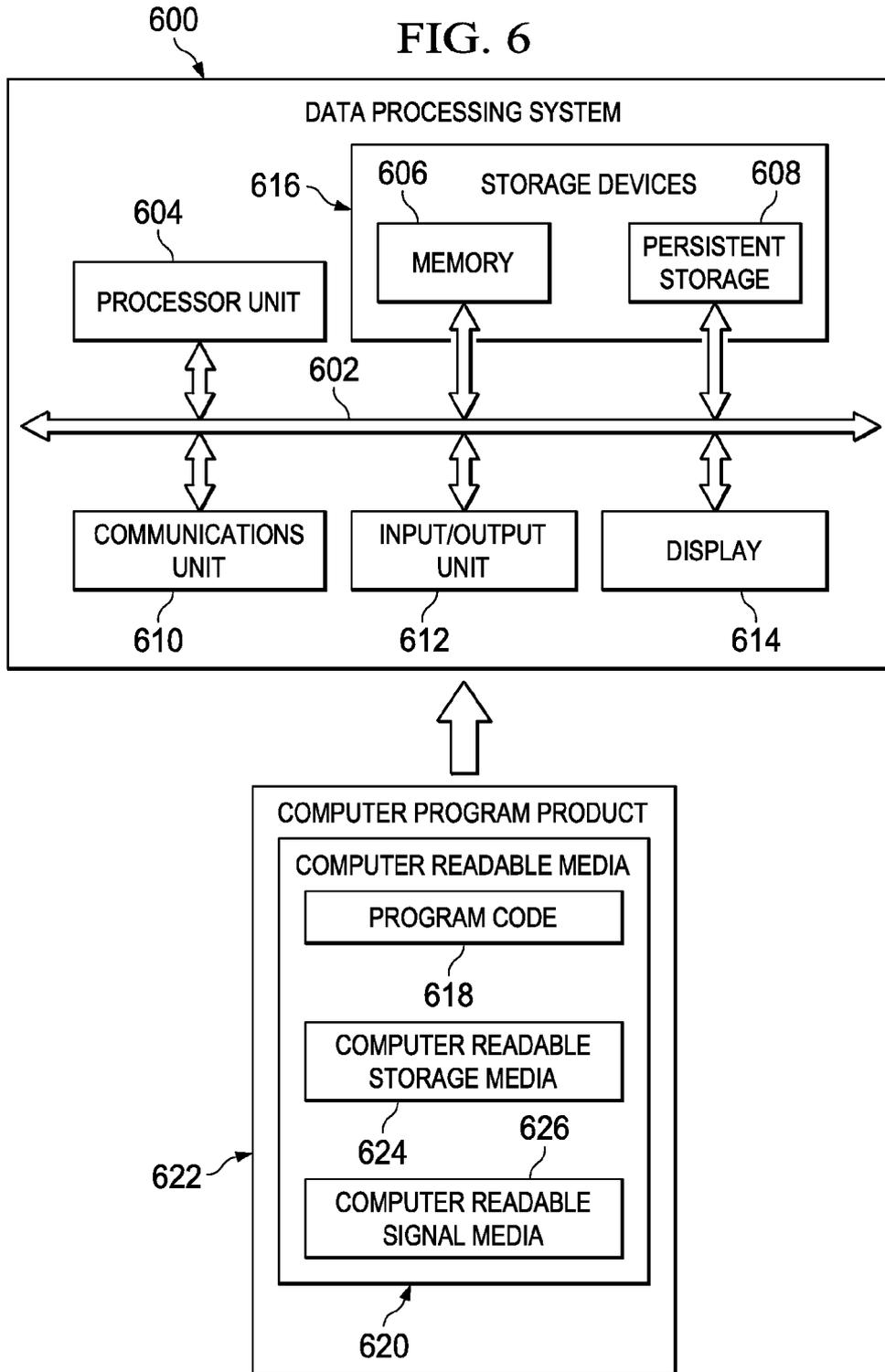


FIG. 5

FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 13/68445

A. CLASSIFICATION OF SUBJECT MATTER
 IPC(8) - G06F 19/00 (2014.01)
 USPC - 700/100; 706/58
 According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 700/100; 706/58 (keyword limited)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
 700/28, 31, 40, 44, 47, 48, 95, 100-105; 706/45 (keyword limited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
 PatBase, ProQuest Dialog, Google Patents, Google Scholar.
 Search Terms used: manufacturing process control, statistical correlation, stochastic dependence, effect, impact, delay, wait

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X — Y	US 2010/0198776 A1 (Wang et al.) 05 August 2010 (05.08.2010), entire document, especially Fig. 3, 4, 8; para [0004]-[0005], [0045]-[0046], [0049]-[0050], [0056], [0088]-[0095]	1-3, 5-10, 12-14 ----- 4, 11
Y	US 2006/0079979 A1 (Giebels et al.) 13 April 2006 (13.04.2006), entire document, especially para [0035]	4, 11
X	US 2011/0040596 A1 (Chen et al.) 17 February 2011 (17.02.2011), entire document, especially Abstract, para [0037], [0062]-[0078]	1, 3, 6, 8, 10, 13
A	US 2006/0191993 A1 (Markham et al.) 31 August 2006 (31.08.2006)	1-14
A	US 2007/0220344 A1 (Bett et al.) 20 September 2007 (20.09.2007)	1-14
A	US 2003/0078683 A1 (Hartman et al.) 24 April 2003 (24.04.2003)	1-14
A	US 2006/0167825 A1 (Sayal) 27 July 2006 (27.07.2006)	1-14

Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance	“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
“E” earlier application or patent but published on or after the international filing date	“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
“O” document referring to an oral disclosure, use, exhibition or other means	“&” document member of the same patent family
“P” document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 21 April 2014 (21.04.2014)	Date of mailing of the international search report 12 MAY 2014
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Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774
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