

## (12) Indian Patent Application

---

(21) Application Number: 202141045487

(22) Filing Date: 06/10/2021      (43) Publication Date: 14/04/2023

(71) Applicant(s): L&T TECHNOLOGY SERVICES LIMITED

(72) Inventor(s): Shah, Vishal Kamlesh Kumar  
Gohel, Aakash Bhailal

(51) International Classifications: G05B 19/418      G06F 30/20      G06N 20/00      H04L 9/32      G05B 23/02

(54) Title: TESTING AND OPTIMIZING THE PERFORMANCE OF MANUFACTURING LINE

(57) Abstract: A method of testing and optimizing performance of a manufacturing line is disclosed. The method may include creating a digital twin model for the physical manufacturing line based on data associated with the physical manufacturing line and automation data, interfacing one or more command input devices with the digital twin model via an interface device. The method may further include initiating the digital twin model to run a virtual assembly line corresponding to the physical manufacturing line and inputting in real-time, via the interface device, the control commands to the digital twin model, using the one or more command input devices. The method may include receiving, via the interface device, a feedback from the digital twin model in response to the control commands, and performing one or more operations to optimize the performance of the manufacturing line, based on the feedback.

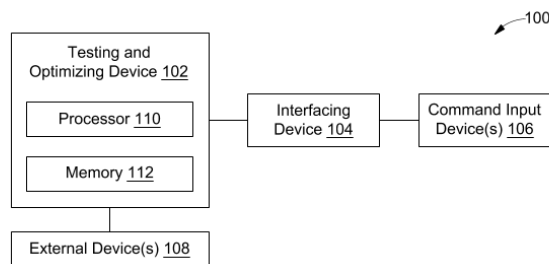


FIG. 1

# **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**

**TESTING AND OPTIMIZING THE PERFORMANCE OF MANUFACTURING  
LINE**

## **2. APPLICANT(S)**

- (a) NAME : **L&T TECHNOLOGY SERVICES LIMITED**  
(b) NATIONALITY : **INDIAN**  
(c) ADDRESS : **DLF IT SEZ Park, 2<sup>nd</sup> Floor – Block 3**  
**1/124, Mount Poonamallee Road,**  
**Ramapuram, Chennai – 600 089,**  
**INDIA.**

## **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 testing and optimizing performance of manufacturing line and more specifically to testing and optimizing the performance of manufacturing. using on digital twin technology.

### **BACKGROUND OF THE INVENTION**

[002] Designing and implementation of a new manufacturing solution is a time-consuming and costly process. Once the design has been finalized and the equipment has been installed, the industrial plant is commissioned during which controls are integrated, bugs are found and fixed, procedures are written, and operators are trained on new equipment, new processes, or revised procedures. The commissioning phase is difficult to plan and frequently overruns, thereby delaying production and possibly leading to late shipments and even lost businesses.

[003] Some methods for testing and optimizing manufacturing automation systems and processes are known. However, these methods suffer from various drawbacks. For example, in packaging lines or assembly lines, real-time testing occurs during physical start-up during which an engineer has to check the sequence and interlock of the line very thoroughly. As such, there are high chances of unpredictable issues coming in between and impacting the start-up schedule, which in turn increase the setup time and cost. Further, when testing trials start, it is possible that the schedule will prevent from checking the line in all worst-case and best-case scenarios.

[004] Furthermore, the conventional testing activities require physical assets and consumes a large volume of material - some of which eventually is scrapped, and sometimes lack of material creates testing bottlenecks. When it comes to manufacturing, utility costs are a major concern. As a result, costs for electricity, manpower, vendors, integrators, and other utilities rise as a result, thereby leaving a significant impact on project budget. Furthermore, when the line is handed over to operators after startup, due to lack of training, the operators spend most of their time resolving issues and have a difficult time figuring out how to operate the line and troubleshoot it. Conventional simulation with Programmable Logic Controller (PLC) or Human Machine Interface HMI controller may validate PLC or HMI code, because it is not linked to any 3D model of the line. Further, conventional testing with 3D model runs with

forced background scripting which fails to provide a complete picture of line operation. Some virtual commissioning methods may include sharing the system with technical support team via a Virtual Private Network (VPN). However, because physical assets are not in front of the support team, it is difficult to short out issues efficiently.

5 [005] As such, an improved method of testing and optimizing the performance of a manufacturing line is required, which will reduce the cost of commissioning as well as the risk of errors during testing or manufacturing.

### **SUMMARY OF THE INVENTION**

10 [006] In an embodiment, a method of testing and optimizing performance of a manufacturing line is disclosed. The method may include creating a digital twin model for the physical manufacturing line based on data associated with the physical manufacturing line and automation data. The method may further include interfacing one or more command input devices with the digital twin model via interface devices. The one or more command input devices may be configured to input control commands to the physical manufacturing line. The  
15 method may further include initiating the digital twin model to run a virtual assembly line corresponding to the physical manufacturing line. The method may further include inputting control commands to the digital twin model in real-time, via the interface device. The method may further include receiving feedback from the digital twin model in response to the control commands, via the interface device. The method may further include performing one or more  
20 operations to optimize the performance of the manufacturing line, based on the feedback.

[007] In another embodiment, a system for testing and optimizing performance of a manufacturing line is disclosed. The system includes a processor and a memory storing a plurality of processor-executable instructions. The plurality of processor-executable instructions, upon execution by the processor, may cause the processor to create a digital twin  
25 model for the physical manufacturing line based on data associated with the physical manufacturing line and automation data, and interface one or more command input devices with the digital twin model via an interface device. The one or more command input devices may be configured to input control commands to the physical manufacturing line. The plurality of processor-executable instructions, upon execution, may further cause the processor to  
30 initiate the digital twin model to run a virtual assembly line corresponding to the physical manufacturing line, and input in real-time, via the interface device, the control commands to

the digital twin model, using the one or more command input devices. The plurality of processor-executable instructions, upon execution, may further cause the processor to receive, via the interface device, feedback from the digital twin model in response to the control commands and perform one or more operations to optimize the performance of the manufacturing line, based on the feedback.

### **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 a system for testing and optimizing performance of a manufacturing line, in accordance with an embodiment of the present disclosure.

[010] FIG. 2 is a block diagram of a memory of the testing and optimizing device, in accordance with some embodiments of the present

[011] FIG. 3 illustrates a digital twin architecture for testing and optimizing performance of a manufacturing line, in accordance with an embodiment of the present disclosure.

[012] FIG. 4 illustrates a flowchart depicting all the necessary steps carried out during the testing and optimization of a manufacturing line using digital twin technology, in accordance with an embodiment of the present disclosure.

### **DETAILED DESCRIPTION OF THE DRAWINGS**

[013] 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 spirit and scope of the disclosed embodiments. It is intended that the following detailed description be considered as exemplary only, with the true scope and spirit being indicated by the following claims. Additional illustrative embodiments are listed below.

[014] According to an embodiment, method and system for testing and optimizing performance of a manufacturing line are disclosed that use digital twins for scalable and model-based testing and optimization of manufacturing industry. The system may include a digital twin and a simulation platform. As will be understood, digital twins are digital models with  
5 bidirectional communication between the physical and virtual worlds. In a digital twin model, data flows in both directions from a physical asset to a digital asset. As a result, the digital model is synchronized with the physical asset's status, and the simulation's results can be used to optimize the physical asset directly, thereby boosting system reactivity. Therefore, using digital twin technology, mechanical and automation engineering is performed in parallel with  
10 the manufacturing readiness process, there allowing for identifying errors earlier and with little or no impact or cost.

[015] As will be further appreciated, digital twins can be used for a variety of tasks, including design modifications and diagnostics. Further, they can also be used to streamline and optimize the commissioning phase because they are accurate representations of physical assets. Instead  
15 of physically commissioning a new system, virtual commissioning entails creating a digital twin and then testing and verifying the model in a simulated virtual environment. This enables code testing and debugging in a virtual environment, simulation of packing line operation, identification of potential problems, rapid evaluation of alternative solutions, development of operating procedures, training of supervisors and equipment operators, and simulation of the  
20 impact of new machinery on the existing operation to identify choke points and space constraints so they can be addressed before installation.

[016] According to the present invention, the method comprises testing of the digital twin operational model. The testing phase entails a thorough and offline examination for possible failures, as well as the conversion to robust software, early identification of bottlenecks,  
25 operator training, and staffing plan estimation. As a result, business is faster and smoother, with consistent production and low utility and material costs. And with digital twin technology best production rate is obtained throughout the life cycle.

[017] Referring to **FIG. 1**, a system for testing and optimizing performance of a manufacturing line is illustrated, in accordance with an embodiment of the present disclosure.  
30 In an embodiment, the system 100 may include a testing and optimizing device 102 and an interfacing device 104. The testing and optimizing device 102 may have processing capability to test and optimize performance of a manufacturing line. Examples of the testing and

optimizing device 102 may include, but are not limited to a server, a desktop, a laptop, a notebook, a net book, a tablet, a Smartphone, or a mobile phone.

5 [018] The testing and optimizing device 102 may further include a processor 110, which may be communicatively coupled to a memory 112. The memory 112 may store process instructions, which when executed by processor 110 may cause the processor 110 to test and optimize performance of a manufacturing line. The memory 112 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). Moreover, the testing and optimizing device 102 may be communicatively coupled to a database that may include data (e.g. automation data, sensors data, etc.). Additionally, the testing and optimizing device 102 may be communicatively coupled to an external device 108 for sending and receiving various data. Examples of the external device 108 may include, but is not limited to, a remote server, digital devices, and a computer system.

[019] The interfacing device 104 may interface one or more command input devices 106 with the digital twin model. For example, the one or more command input devices 106 may include a human machine interface (HMI) device and a Programmable Logic Controller (PLC) device. 20 The one or more command input devices 106 may be configured to input control commands to the physical manufacturing line. The interfacing device 104 may be configured to enable inputting in real-time the control commands to the digital twin model, using the one or more command input devices 106. The interfacing device 104 may be further configured to enable receiving feedback from the digital twin model in response to the control commands.

25 [020] Referring now to **FIG. 2**, a block diagram of the memory 112 of the testing and optimizing device 102 is illustrated, in accordance with some embodiments of the present disclosure. The testing and optimizing device 102 may include various modules within the memory 112 configured to work together. In an embodiment, the memory 112 may include a digital twin model creating module 202, an interfacing module 204, a virtual assembly line initiating module 206, a control commands inputting module 208, a feedback module 210, and 30 an optimizing module 212.

[021] The digital twin model creating module 202 may create a digital twin model for the physical manufacturing line based on data associated with the physical manufacturing line and automation data. Alternately, the digital twin model creating module 202 may receive the digital twin model for the physical manufacturing line. For example, the digital twin model  
5 may be created using a PlantSim platform. The data associated with the physical manufacturing line and automation data may include manufacturing line control data, automation components data, sensor data, actuator data, PLC data, and HMI data.

[022] The interfacing module 204 may interface the one or more command input devices 106 with the digital twin model via the interface device 104. The one or more command input  
10 devices 106 may be configured to input control commands to the physical manufacturing line. As mentioned above, the one or more command input devices 106 may include the human machine interface (HMI) device and/or a Programmable Logic Controller (PLC) device.

[023] The virtual assembly line initiating module 206 may initiate the digital twin model to run a virtual assembly line corresponding to the physical manufacturing line. The control  
15 commands inputting module 208 may input in real-time, via the interface device 104, the control commands to the digital twin model, using the one or more command input devices. The feedback module 210 may receive, via the interface device 104, feedback from the digital twin model in response to the control commands. The optimizing module 212 may perform  
20 one or more operations to optimize the performance of the manufacturing line, based on the feedback. The one or more operations may include checking line logic functionality, tuning the manufacturing line, determining and adjusting sensor response time and location, calculating demand and throughput, determining optimum machine or conveyor speed, analysing high level machine functionality, testing the manufacturing line at different speeds and for different recipes, determining accumulation and backup of products at different locations in the  
25 manufacturing line, planning machine and operator utilization, or eliminating or reducing utilization of physical prototypes.

[024] Referring to **FIG. 3**, a digital twin architecture 300 for testing and optimizing performance of a manufacturing line is illustrated, in accordance with an embodiment of the present disclosure. At step 302, a virtual line is created. For example, in a packaging industry,  
30 the virtual line may correspond to a virtual packaging line. As such, the virtual line may be an exact replica of the physical line and may be created using a “PlantSim” or “Plant Simulation” platform. As will be appreciated by those skilled in the art, the PlantSim, is a manufacturing

plant simulation software tool that assists in the creation of digital models of production line systems in order to investigate their characteristics and optimize their performance through the evaluation of various manufacturing scenarios. To this end, the PlantSim, platform may be provided with the knowledge needed to make sound decisions during the planning stages of production line optimization.

[025] At step 304, data connectivity of the virtual line with PLC/HMI controls may be established. In other words, the virtual packing line or the digital twin may be provided with real time live PLC and HMI connectivity with the help of digital twin operating model. The model may capture sensor data from physical, operating system, and may perform offline testing of controls by disconnecting them from the critical path. As such, the model may lower operational risk. It may be noted that information may be fed into the simulation model with real-time live PLC and HMI connectivity customized with original equipment manufacturer (OEM). The PLC may connect to a simulation three-dimensional model of the physical manufacturing line. The PLC may take the input consisting of data from the sensors from the human machine interface (HMI) and generate codes, which may further be tested through interactions within the virtual model before the physical system (produced with the assistance of OEM) has been installed. As will be understood, this real-time emulation solution allows for operator training and staffing calculations, as well as the ability to test various scenarios. These scenarios may include checking line logic functionality, line tuning, determination and adjustment of sensor response time and location, demand vs throughput calculation, identification of optimum machine/conveyor speed, high level machine functionality, trial and testing of entire packaging line at different speeds and for different recipes, determination of accumulation/backup of product at different locations, machine/operator utilization, and elimination/reduction of costly physical prototypes.

[026] At step 306, various scenarios may be induced by running virtual line to verify the response of the developed digital twin architecture. The information developed in the physical-cyber interface may form specifications for the changes that are implemented in the specific phase at a virtual level and then into the original manufacturing system. This aids in the proactive optimization of the production line, avoiding unplanned downtime and cost.

[027] Referring to **FIG. 4**, a flowchart of a method 400 of testing and optimizing performance of a manufacturing line is illustrated, in accordance with an embodiment of the present disclosure. At step 402 a digital twin model for the physical manufacturing line may be created

based on data associated with the physical manufacturing line and automation data. In some embodiments, the digital twin model may be created using a PlantSim platform. It may be understood that the any other technique may be used for creating the digital twin model as well without limiting the scope of the present subject matter. Further, it may be noted that the data associated with the physical manufacturing line and automation data may include manufacturing line control data, automation components data, sensor data, actuator data, PLC data, and HMI data.

**[028]** At step 404, one or more command input devices may be interfaced with the digital twin model via an interface device. The one or more command input devices may be configured to input control commands to the physical manufacturing line. In some embodiments, the one or more command input devices may include a human machine interface (HMI) device and a Programmable Logic Controller (PLC) device. At step 406, the digital twin model may be initiated to run a virtual assembly line corresponding to the physical manufacturing line. At step 408, the control commands may be inputted to the digital twin model, using the one or more command input devices. The control commands may be inputted in real-time, via an interface device.

**[029]** At step 410, feedback may be received from the digital twin model in response to the control commands. The feedback may be received via the interface device. At step 412, one or more operations may be performed to optimize the performance of the manufacturing line, based on the feedback. For example, the one or more operations may include checking line logic functionality, tuning the manufacturing line, determining and adjusting sensor response time and location, calculating demand and throughput, determining optimum machine or conveyor speed, analysing high level machine functionality, testing the manufacturing line at different speeds and for different recipes, determining accumulation and backup of products at different locations I the manufacturing line, planning machine and operator utilization, or eliminating or reducing utilization of physical prototypes.

**[030]** The above disclosure provides one or more techniques for testing and optimizing performance of a manufacturing line. For example, the techniques allow manufacturers to create a valuable tool in the form of a dynamic digital twin by combining a mechanical three-dimensional (3D) simulation model with real control system logic. When compared to traditional testing techniques, this dynamic digital twin can enable comprehensive and accurate testing at a lower cost, reducing commissioning time earlier in the project cycle, adding

efficiency, assisting manufacturers in meeting rising customer expectations, handling more complex products and variants with mass customization, and becoming more competitive and profitable. Another significant business benefit of virtual commissioning is accelerated time to market. This further allows manufacturers to market faster, produce economically, and offer more variations during market windows and gain first-mover market advantage, and thereby build a larger market share, and be more profitable.

[031] Furthermore, digital twins created with sophisticated software represent physical production systems in both design and operation, including controls, automation components, sensors and actuators, PLCs and HMIs. Engineers can conduct a wide range of simulations using such a comprehensive virtual representation to evaluate their various automation approaches and find the best one much earlier in the process. Critical line operations can be easily validated using a digital twin. With the digital twin, the validation process can take place in parallel with production engineering, thereby saving time and lowering the risks associated with traditional production engineering and set-up. Using a digital twin to complete the engineering and validation stages of automation and mechatronics can serve as the foundation for both documentation and operator and maintenance technician training which can take weeks or months without the digital twin.

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

**WE CLAIM:**

**1.** A method of testing and optimizing performance of a manufacturing line, the method comprising:

creating a digital twin model for the physical manufacturing line based on data associated with the physical manufacturing line and automation data;

interfacing one or more command input devices with the digital twin model via an interface device, wherein the one or more command input devices are configured to input control commands to the physical manufacturing line;

initiating the digital twin model to run a virtual assembly line corresponding to the physical manufacturing line;

inputting in real-time, via the interface device, the control commands to the digital twin model, using the one or more command input devices;

receiving, via the interface device, a feedback from the digital twin model in response to the control commands; and

performing one or more operations to optimize the performance of the manufacturing line, based on the feedback.

**2.** The method as claimed in claim 1, wherein the digital twin model is created using PlantSim platform.

**3.** The method as claimed in claim 1, wherein the one or more command input devices comprise a human machine interface (HMI) device and a Programmable Logic Controller (PLC) device.

**4.** The method as claimed in claim 1, wherein the one or more operations comprise:

checking line logic functionality;

tuning the manufacturing line;

determining and adjusting sensor response time and location;

calculating demand and throughput;

determining optimum machine or conveyor speed;

analysing high level machine functionality;

testing the manufacturing line at different speeds and for different recipes;

determining accumulation and backup of products at different locations I the manufacturing line;

planning machine and operator utilization; or

eliminating or reducing utilization of physical prototypes.

5. The method as claimed in claim 1, wherein the data associated with the physical manufacturing line and automation data comprises: manufacturing line control data, automation components data, sensor data, actuator data, PLC data, and HMI data.

6. A system for testing and optimizing performance of a manufacturing line, the system comprising:

a processor; and

a memory storing a plurality of processor-executable instructions, wherein the plurality of processor-executable instructions, upon execution by the processor, cause the processor to:

create a digital twin model for the physical manufacturing line based on data associated with the physical manufacturing line and automation data;

interface one or more command input devices with the digital twin model via an interface device, wherein the one or more command input devices are configured to input control commands to the physical manufacturing line;

initiate the digital twin model to run a virtual assembly line corresponding to the physical manufacturing line;

input in real-time, via the interface device, the control commands to the digital twin model, using the one or more command input devices;

receive, via the interface device, a feedback from the digital twin model in response to the control commands; and

perform one or more operations to optimize the performance of the manufacturing line, based on the feedback.

Dated this 8<sup>th</sup> Day of September 2022

**-- Digitally Signed--**

Bhanu Prasad  
(INPA No: **3253**)  
Manager, IPR Dept.,  
L&T Technology Services Limited,  
DLF 3rd Block, 2nd Floor,  
Manapakkam, Chennai - 600089.

## **ABSTRACT**

### **TESTING AND OPTIMIZING THE PERFORMANCE OF MANUFACTURING LINE**

A method of testing and optimizing performance of a manufacturing line is disclosed. The method may include creating a digital twin model for the physical manufacturing line based on data associated with the physical manufacturing line and automation data, interfacing one or more command input devices with the digital twin model via an interface device. The method may further include initiating the digital twin model to run a virtual assembly line corresponding to the physical manufacturing line and inputting in real-time, via the interface device, the control commands to the digital twin model, using the one or more command input devices. The method may include receiving, via the interface device, a feedback from the digital twin model in response to the control commands, and performing one or more operations to optimize the performance of the manufacturing line, based on the feedback.

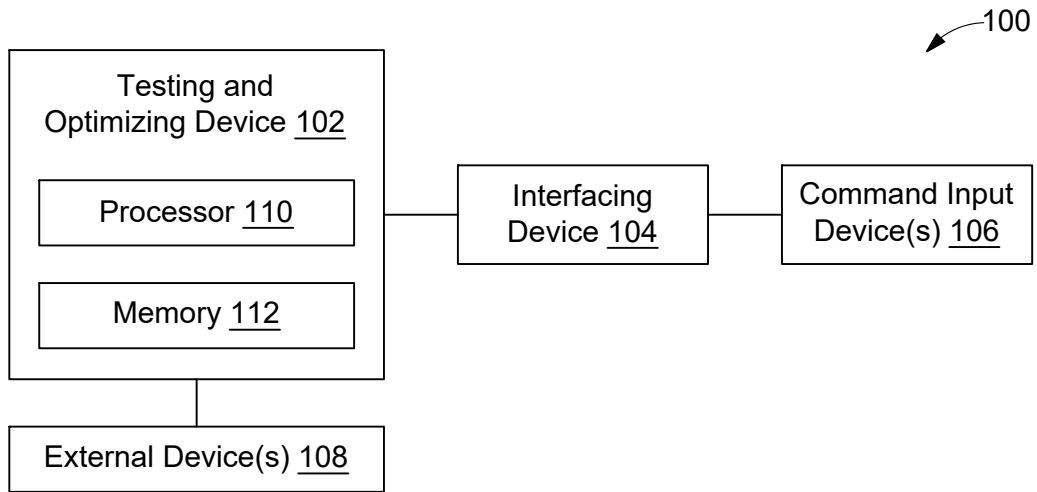


FIG. 1

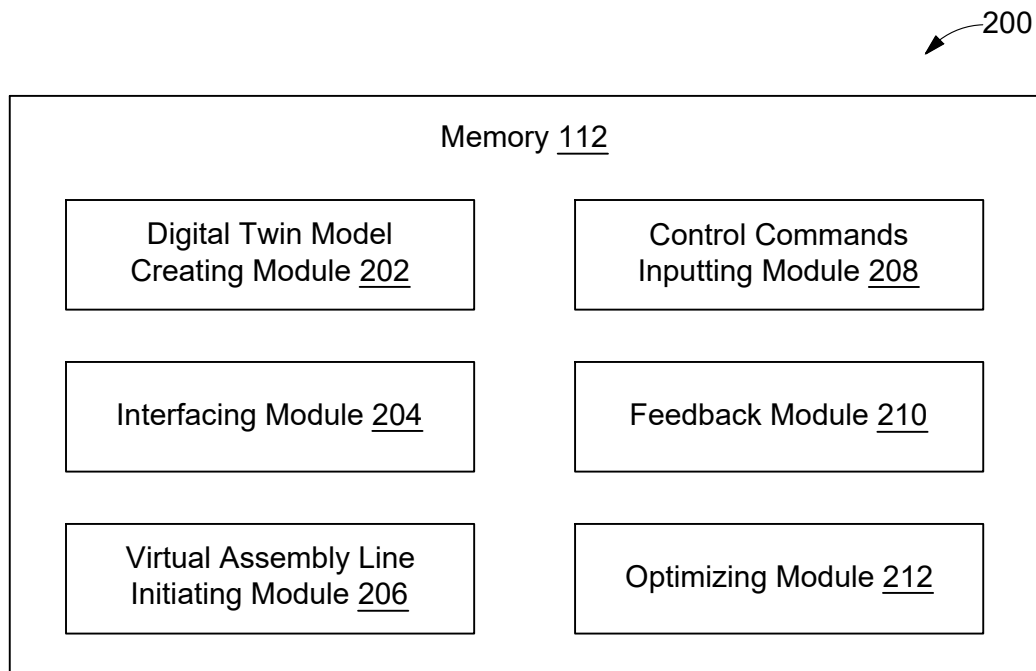


FIG. 2

-- Digitally Signed--  
Bhanu Prasad  
(INPA No: 3253)  
Manager, IPR Dept.,  
L&T Technology Services Limited,  
DLF 3rd Block, 2nd Floor,  
Manapakkam, Chennai - 600089.

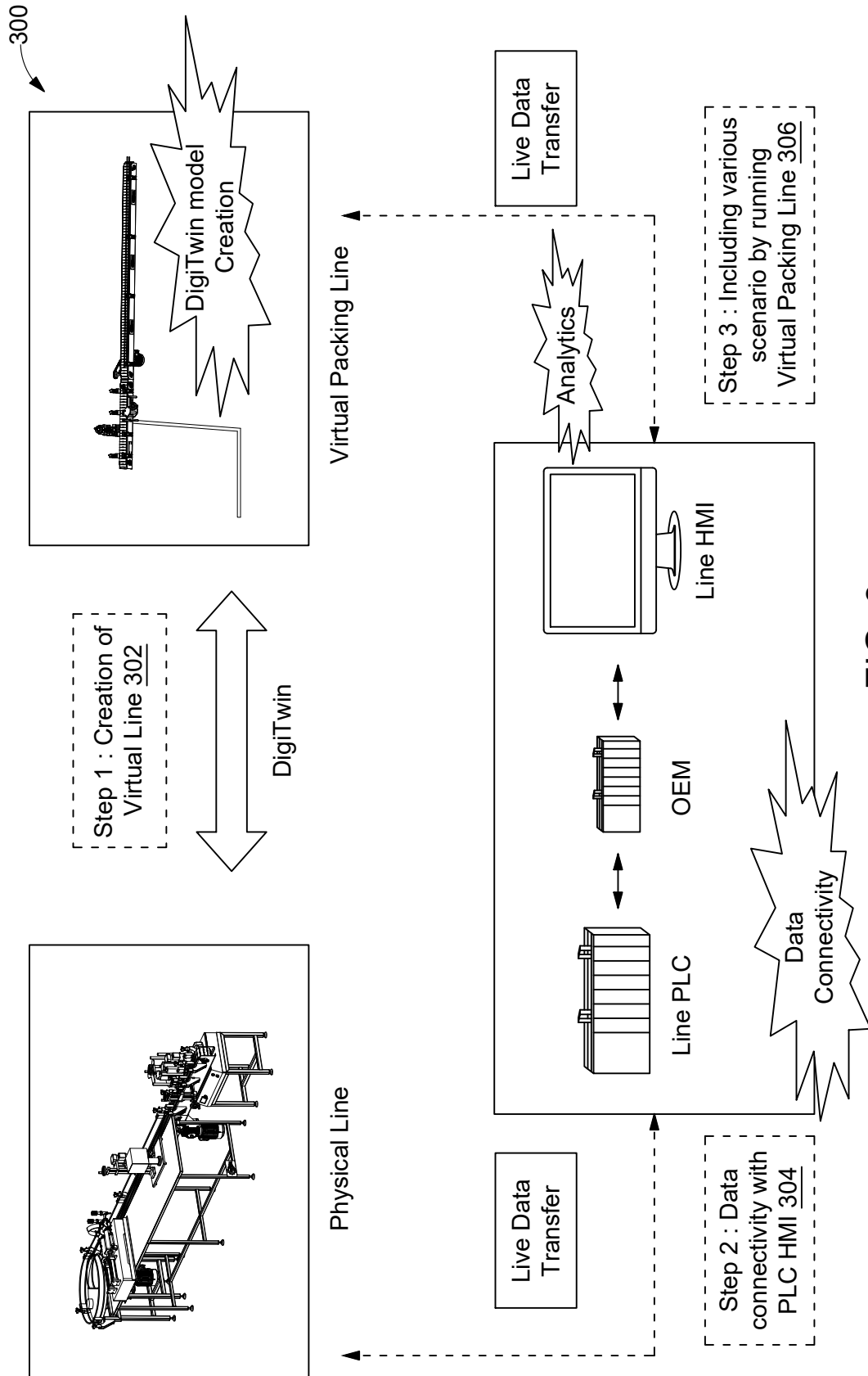


FIG. 3

-- Digitally Signed--  
**Bhanu Prasad**  
 (INPA No: 3253)  
 Manager, IPR Dept.,  
 L&T Technology Services Limited,  
 DLF 3rd Block, 2nd Floor,  
 Manapakkam, Chennai - 600089.

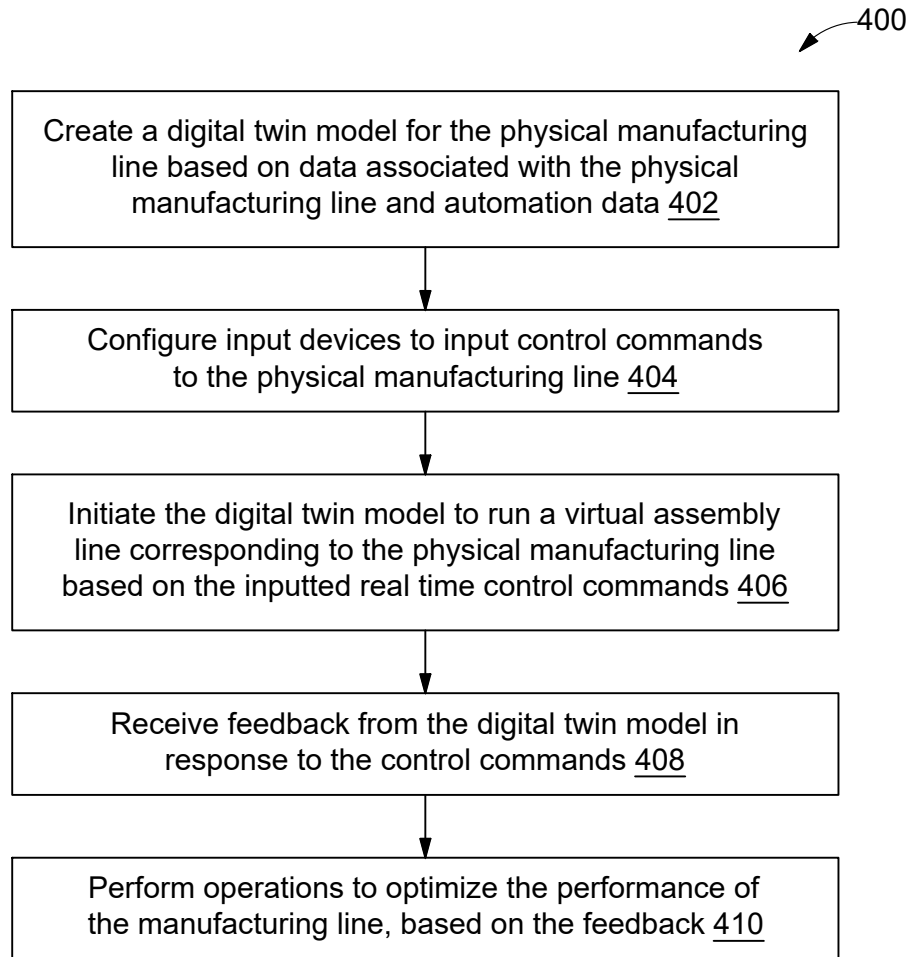


FIG. 4