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**Singh et al.**

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(54) **PROCESS EVOLUTION FOR ROBOTIC  
PROCESS AUTOMATION AND WORKFLOW  
MICRO-OPTIMIZATION**

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This patent is subject to a terminal dis-  
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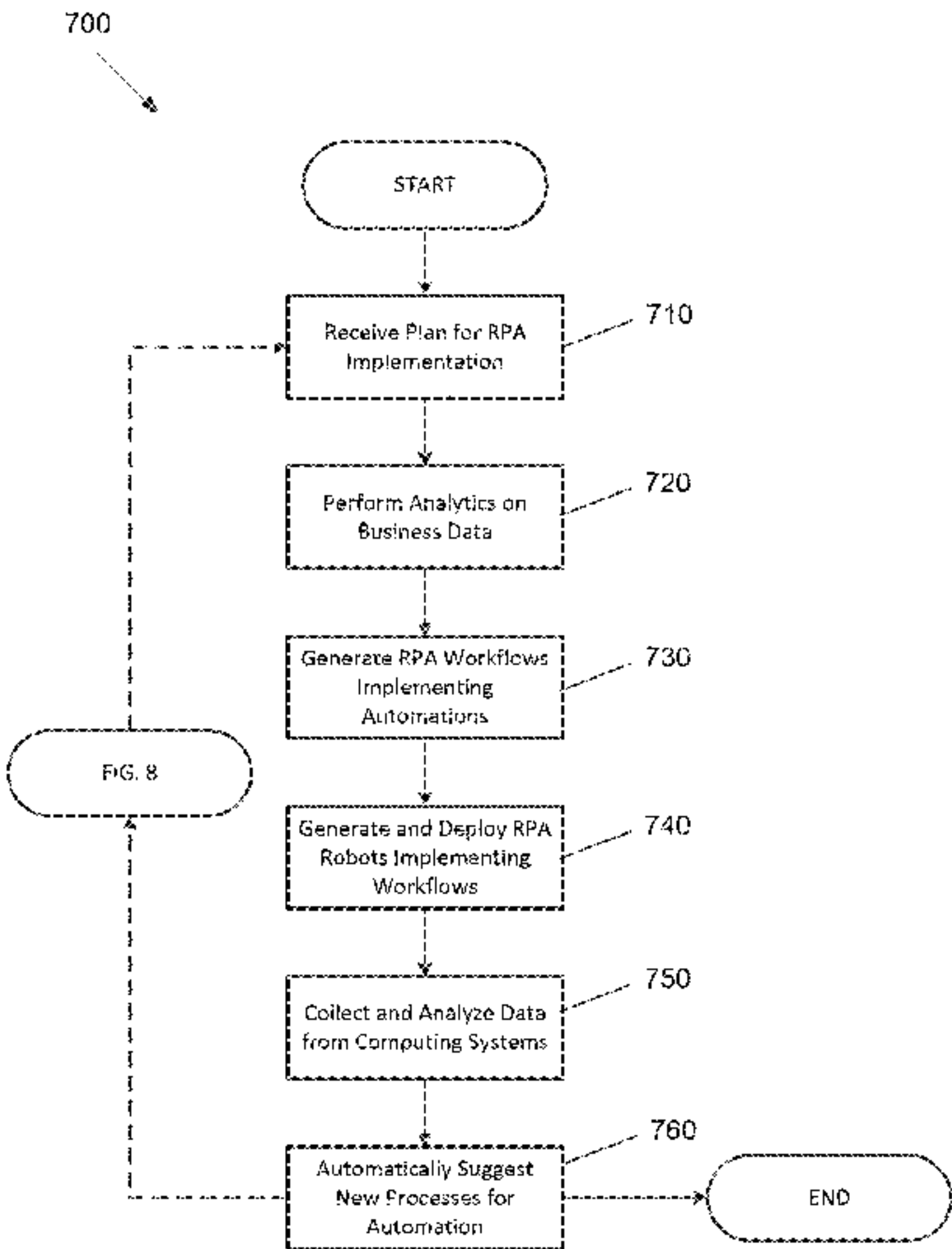
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(57) **ABSTRACT**

Process evolution for robotic process automation (RPA) and  
RPA workflow micro-optimization are disclosed. Initially,  
an RPA implementation may be scientifically planned,  
potentially using artificial intelligence (AI). Embedded ana-  
lytics may be used to measure, report, and align RPA  
operations with strategic business outcomes. RPA may then  
be implemented by deploying AI skills (e.g., in the form of  
machine learning (ML) models) through an AI fabric that  
seamlessly applies, scales, manages AI for RPA workflows  
of robots. This cycle of planning, measuring, and reporting  
may be repeated, potentially guided by more and more AI,  
to iteratively improve the effectiveness of RPA for a busi-  
ness. RPA implementations may also be identified and  
implemented based on their estimated return on investment  
(ROI).

**21 Claims, 8 Drawing Sheets**



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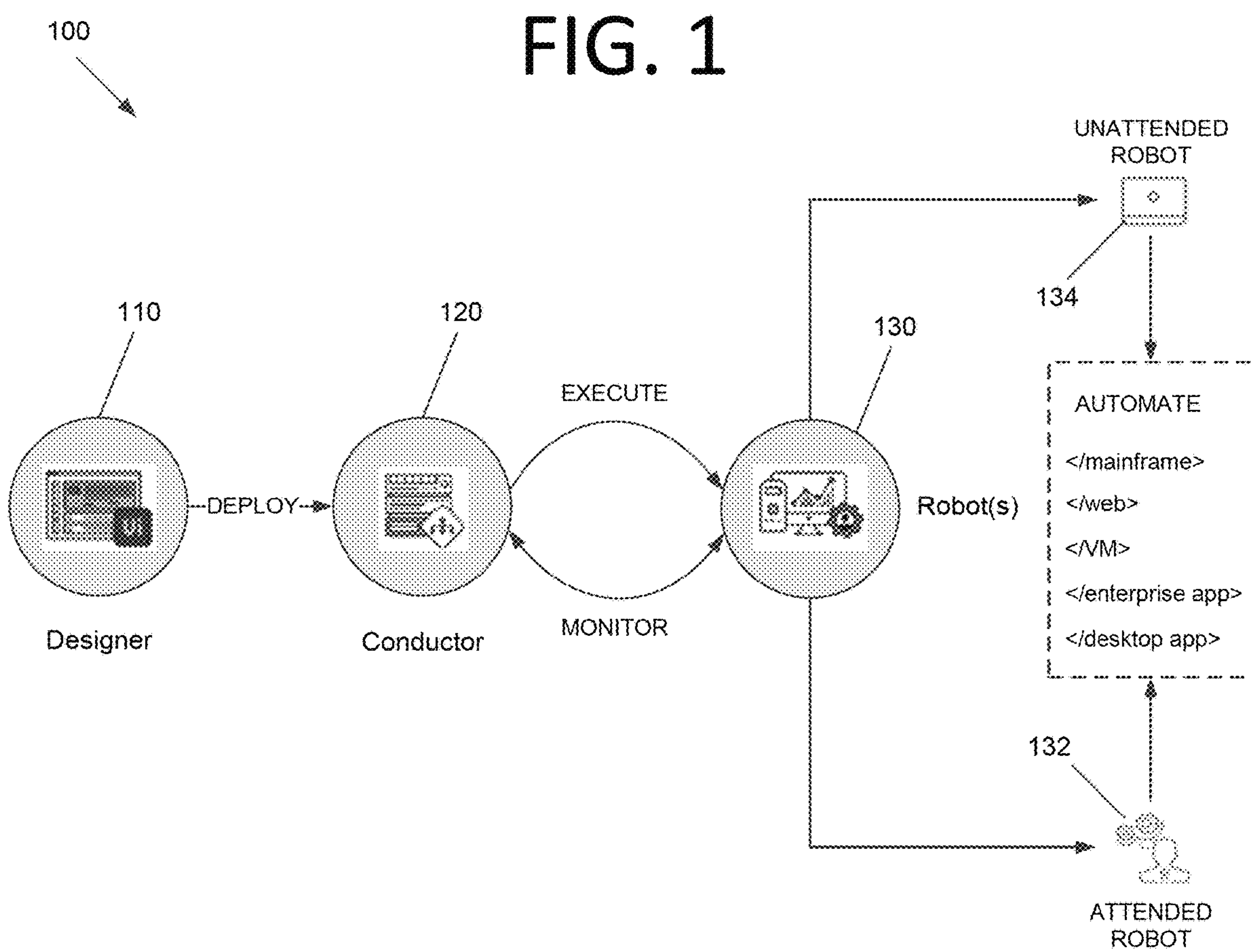
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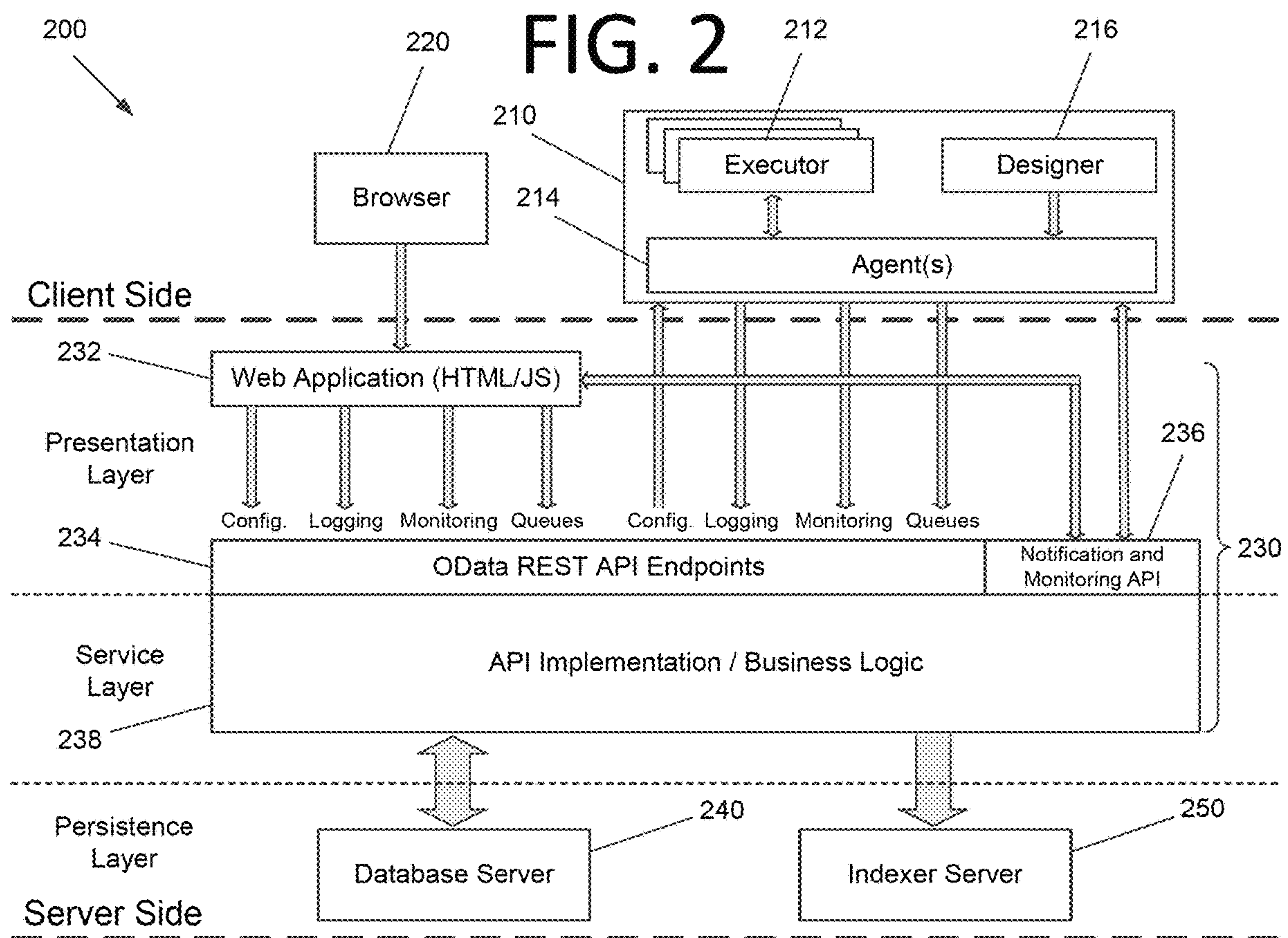
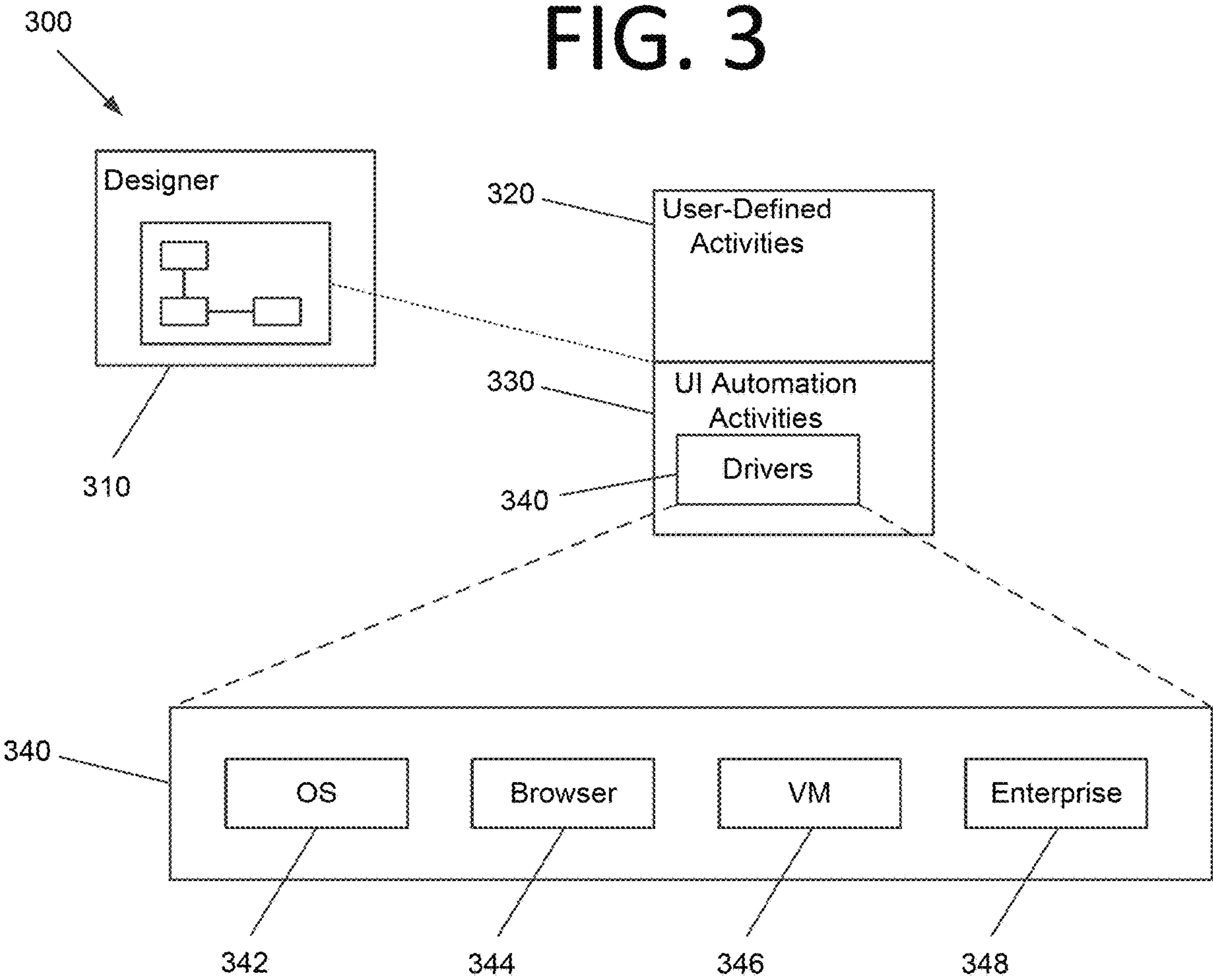
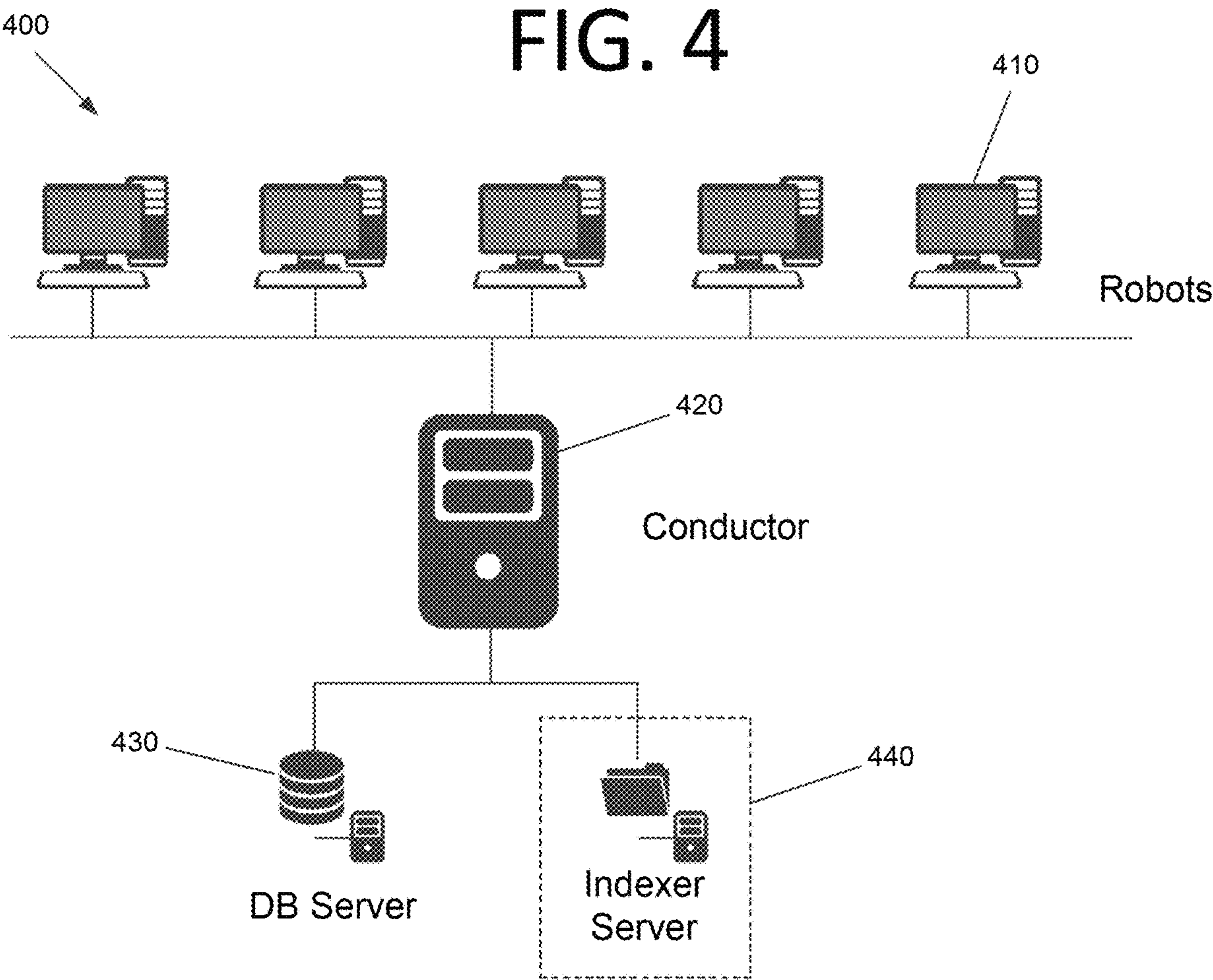


FIG. 3





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FIG. 5

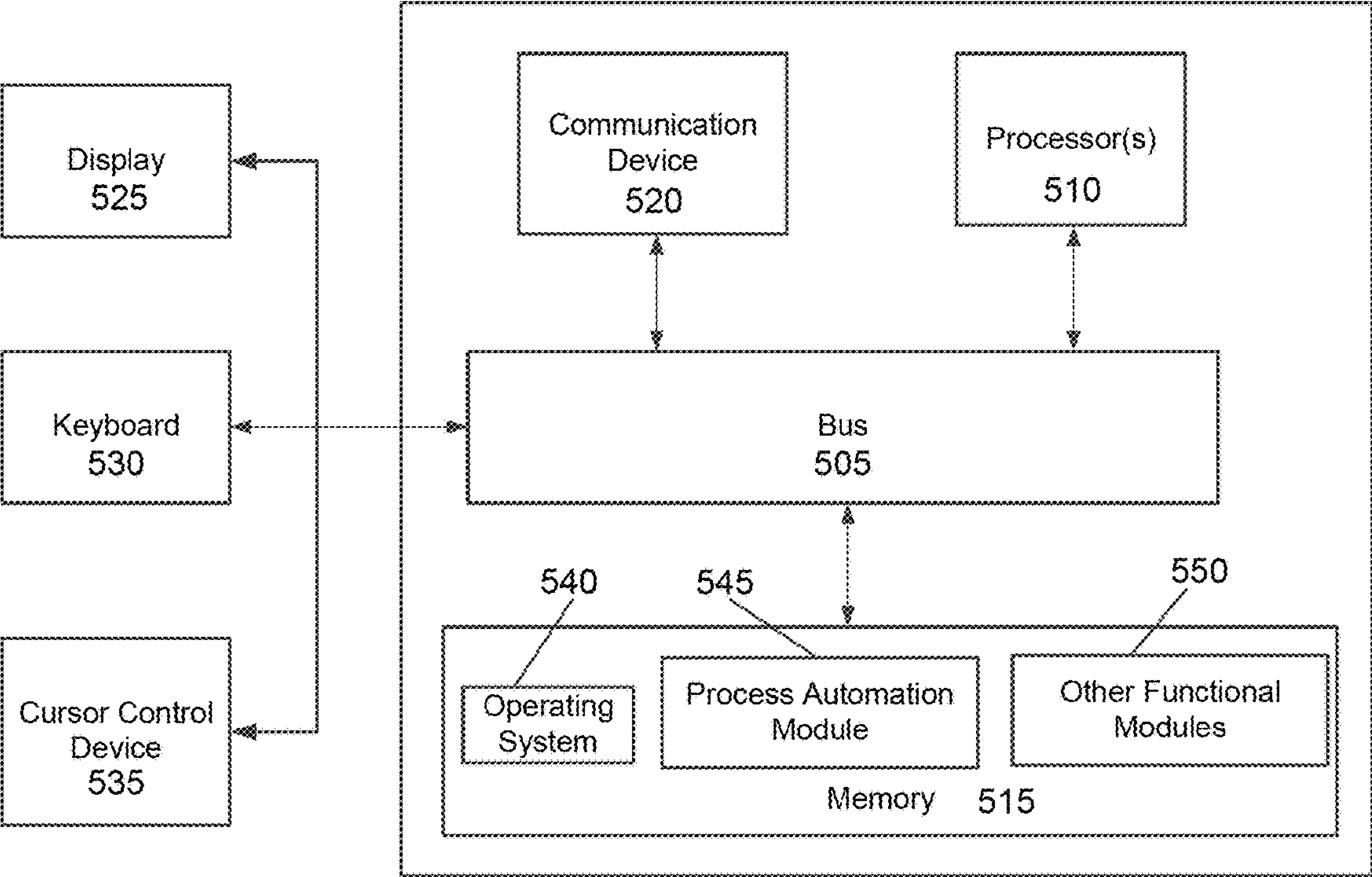
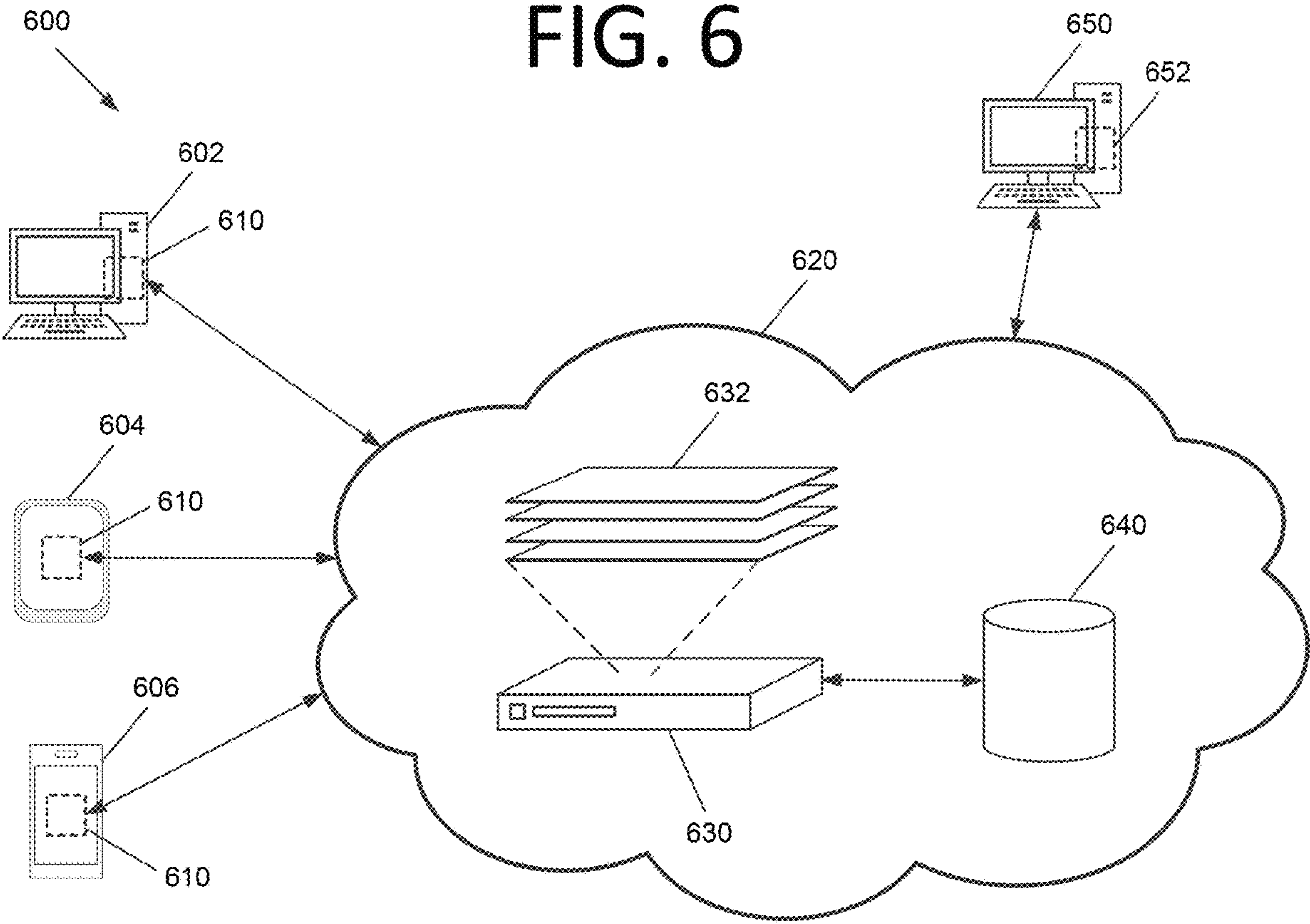


FIG. 6





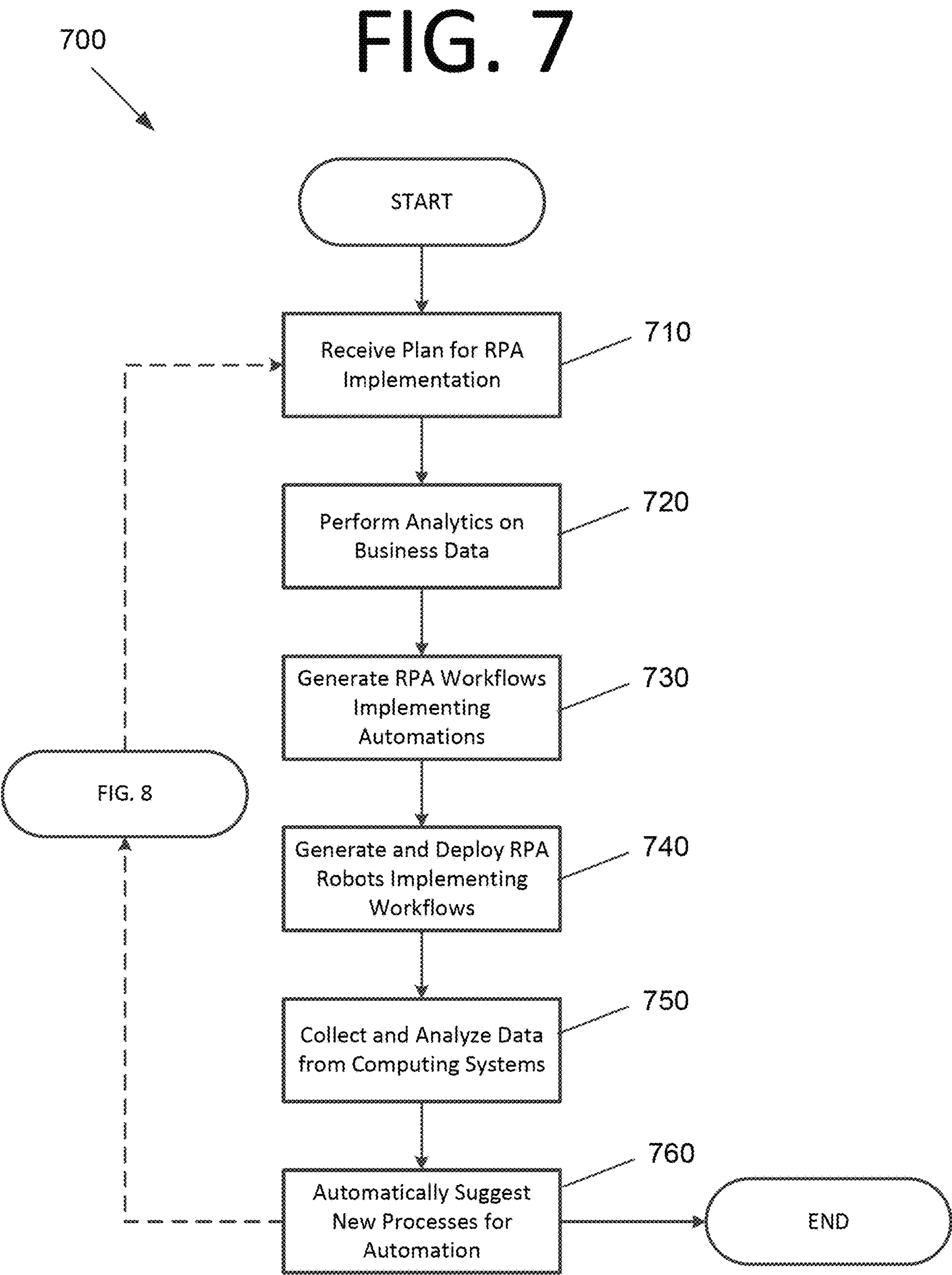
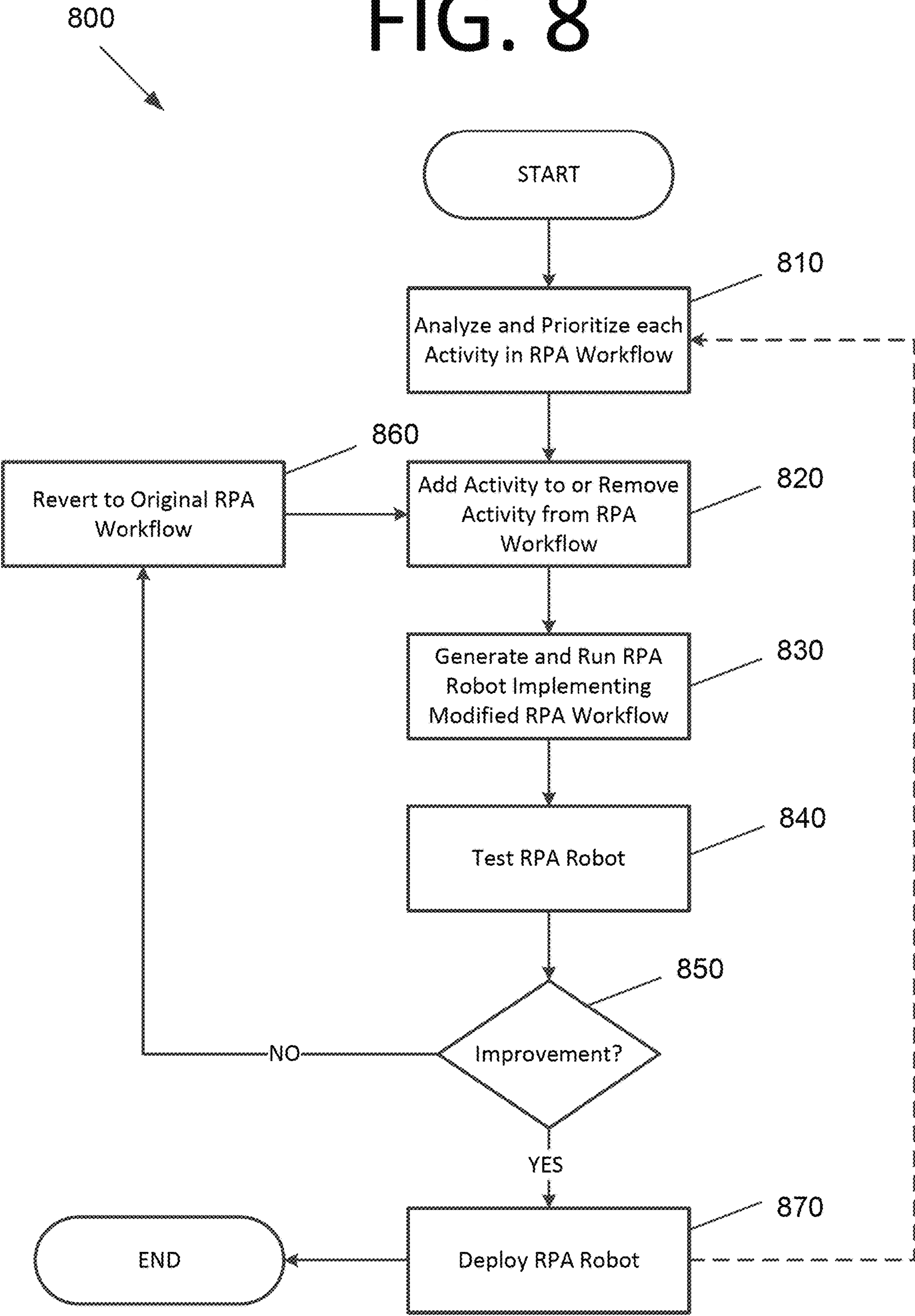


FIG. 8





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# PROCESS EVOLUTION FOR ROBOTIC PROCESS AUTOMATION AND WORKFLOW MICRO-OPTIMIZATION

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. Nonprovisional patent application Ser. No. 16/708,132 filed Dec. 9, 2019, which claims the benefit of U.S. Provisional Patent Application No. 62/915,442 filed Oct. 15, 2019. The subject matter of these earlier filed applications is hereby incorporated by reference in its entirety.

## FIELD

The present invention generally relates to robotic process automation (RPA), and more specifically, to process evolution for RPA and/or RPA workflow micro-optimization.

## BACKGROUND

Implementation of RPA automations is often done piecemeal, where a single implementation is planned and implemented. However, this disjointed process is not optimal. Also, robots may not always be optimal. Accordingly, an improved process may be beneficial.

## SUMMARY

Certain embodiments of the present invention may provide solutions to the problems and needs in the art that have not yet been fully identified, appreciated, or solved by current RPA technologies. For example, some embodiments of the present invention pertain to process evolution for RPA and/or RPA workflow micro-optimization.

In an embodiment, a computer-implemented method includes receiving, by a computing system, a plan for an RPA implementation. The plan includes business data. The computer-implemented method also includes performing analytics on the business data associated with the plan, by the computing system, to measure, report, and align RPA operations with strategic business outcomes. The computer-implemented method further includes generating one or more RPA workflows implementing automations based on the analytics, by the computing system, and generating and deploying the one or more RPA workflows via RPA robots, by the computing system.

In another embodiment, a computer-implemented method includes performing analytics on business data associated with a plan for an RPA implementation, by a computing system, to measure, report, and align RPA operations with strategic business outcomes. The computer-implemented method also includes generating one or more RPA workflows implementing automations based on the analytics, by the computing system, and generating and deploying the one or more RPA workflows via RPA robots, by the computing system.

In yet another embodiment, a computer-implemented method includes analyzing and prioritizing each activity in an RPA workflow, by a computing system, based on performance criteria. The computer-implemented method also includes adding an activity to the RPA workflow or deleting an activity from the RPA workflow to create a modified RPA workflow, by the computing system, and generating and running an RPA robot implementing the modified RPA workflow, by the computing system. The computer-implemented

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method further includes testing the generated RPA robot, by the computing system, to determine whether the RPA robot achieves a goal and realizes an improvement in the performance criteria.

## BRIEF DESCRIPTION OF THE DRAWINGS

In order that the advantages of certain embodiments of the invention will be readily understood, a more particular description of the invention briefly described above will be rendered by reference to specific embodiments that are illustrated in the appended drawings. While it should be understood that these drawings depict only typical embodiments of the invention and are not therefore to be considered to be limiting of its scope, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings, in which:

FIG. 1 is an architectural diagram illustrating an RPA system, according to an embodiment of the present invention.

FIG. 2 is an architectural diagram illustrating a deployed RPA system, according to an embodiment of the present invention.

FIG. 3 is an architectural diagram illustrating the relationship between a designer, activities, and drivers, according to an embodiment of the present invention.

FIG. 4 is an architectural diagram illustrating an RPA system, according to an embodiment of the present invention.

FIG. 5 is an architectural diagram illustrating a computing system configured to perform process evolution for RPA, according to an embodiment of the present invention.

FIG. 6 is an architectural diagram illustrating a system configured to implement process evolution for RPA and/or perform RPA workflow micro-optimization, according to an embodiment of the present invention.

FIG. 7 is a flowchart illustrating a process for implementing process evolution for RPA, according to an embodiment of the present invention.

FIG. 8 is a flowchart illustrating a process for performing RPA workflow micro-optimization, according to an embodiment of the present invention.

## DETAILED DESCRIPTION OF THE EMBODIMENTS

Some embodiments pertain to process evolution for RPA and/or RPA workflow micro-optimization. Generally, when thinking of automation, an integrated system should be considered. This integrated system may bring several components together, such as a planning component, a measuring component, and an implementing component.

Initially, an RPA implementation may be scientifically planned, potentially using artificial intelligence (AI). Embedded analytics may be used to measure, report, and align RPA operations with strategic business outcomes. RPA may then be implemented by deploying AI skills (e.g., in the form of machine learning (ML) models) through an AI fabric that seamlessly applies, scales, manages AI for RPA workflows of robots. This cycle of planning, measuring, and reporting may be repeated, potentially guided by more and more AI, to iteratively improve the effectiveness of RPA for a business. RPA implementations may also be identified and implemented based on their estimated return on investment (ROI).

In some embodiments, a subject matter expert (SME) may display and record how certain processes are executed. The



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SME may then generate a robot based on these processes. In certain embodiments, listeners (e.g., robots that mine data with respect to user operations) may be deployed on user computing systems to determine what paths the users of the computing systems are taking, which applications the users are using, how users are using the applications, etc.

In some embodiments, there are different ways to discover and document processes. For example, a user of the computing system may submit ideas for automations. In another example, users could collaboratively build upon the idea for automation or collaboratively build a library of automations for the enterprise. The developed robots may be added to a portfolio that can be accessed and used by other users. In some embodiments, robots may access portfolios of other robots.

In certain embodiments, if a user knows which process he or she wishes to automate, the user can record this process (e.g., by recording a video of the user using his or her computing system). The video can then be analyzed to determine whether automation is possible. In certain embodiments, the user may use a supervised documentation tool to define the use case, which the tool can then document.

Some embodiments provide micro-optimization of processes. For example, consider the case where a user builds a workflow for an RPA robot with 20 steps, but 2 of the steps are not actually needed. The system may delete one or more steps and generate a robot implementing the modified workflow to check whether the workflow breaks. If it does not break, the modified workflow may be used to generate a new version of the robot, which may then be deployed to replace the previous version.

In certain embodiments, certain steps may be targeted above others. For instance, the system may determine how long each step takes to execute and remove steps and test modified workflows in the order of longest completion time to shortest. The system may thus determine steps that can be removed and also have a significant impact on total workflow execution time.

In some embodiments, the system may add and/or remove steps to see whether the realized ROI improves based on a reward function (e.g., a reward function for reinforcement learning). This may be determined by an increase in the revenue that is generated, a decrease in processing time, improvements in employee productivity, etc. If adding and/or removing one or more steps leads to an improvement, robots implementing the modified workflow may be generated and deployed.

FIG. 1 is an architectural diagram illustrating an RPA system 100, according to an embodiment of the present invention. RPA system 100 includes a designer 110 that allows a developer to design and implement workflows. Designer 110 may provide a solution for application integration, as well as automating third-party applications, administrative Information Technology (IT) tasks, and business IT processes. Designer 110 may facilitate development of an automation project, which is a graphical representation of a business process. Simply put, designer 110 facilitates the development and deployment of workflows and robots.

The automation project enables automation of rule-based processes by giving the developer control of the execution order and the relationship between a custom set of steps developed in a workflow, defined herein as “activities.” One commercial example of an embodiment of designer 110 is UiPath Studio™. Each activity may include an action, such

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as clicking a button, reading a file, writing to a log panel, etc. In some embodiments, workflows may be nested or embedded.

Some types of workflows may include, but are not limited to, sequences, flowcharts, Finite State Machines (FSMs), and/or global exception handlers. Sequences may be particularly suitable for linear processes, enabling flow from one activity to another without cluttering a workflow. Flowcharts may be particularly suitable to more complex business logic, enabling integration of decisions and connection of activities in a more diverse manner through multiple branching logic operators. FSMs may be particularly suitable for large workflows. FSMs may use a finite number of states in their execution, which are triggered by a condition (i.e., transition) or an activity. Global exception handlers may be particularly suitable for determining workflow behavior when encountering an execution error and for debugging processes.

Once a workflow is developed in designer 110, execution of business processes is orchestrated by conductor 120, which orchestrates one or more robots 130 that execute the workflows developed in designer 110. One commercial example of an embodiment of conductor 120 is UiPath Orchestrator™. Conductor 120 facilitates management of the creation, monitoring, and deployment of resources in an environment. Conductor 120 may act as an integration point with third-party solutions and applications.

Conductor 120 may manage a fleet of robots 130, connecting and executing robots 130 from a centralized point. Types of robots 130 that may be managed include, but are not limited to, attended robots 132, unattended robots 134, development robots (similar to unattended robots 134, but used for development and testing purposes), and nonproduction robots (similar to attended robots 132, but used for development and testing purposes). Attended robots 132 are triggered by user events and operate alongside a human on the same computing system. Attended robots 132 may be used with conductor 120 for a centralized process deployment and logging medium. Attended robots 132 may help the human user accomplish various tasks, and may be triggered by user events. In some embodiments, processes cannot be started from conductor 120 on this type of robot and/or they cannot run under a locked screen. In certain embodiments, attended robots 132 can only be started from a robot tray or from a command prompt. Attended robots 132 should run under human supervision in some embodiments.

Unattended robots 134 run unattended in virtual environments and can automate many processes. Unattended robots 134 may be responsible for remote execution, monitoring, scheduling, and providing support for work queues. Debugging for all robot types may be run in designer 110 in some embodiments. Both attended and unattended robots may automate various systems and applications including, but not limited to, mainframes, web applications, VMs, enterprise applications (e.g., those produced by SAP®, Salesforce®, Oracle®, etc.), and computing system applications (e.g., desktop and laptop applications, mobile device applications, wearable computer applications, etc.).

Conductor 120 may have various capabilities including, but not limited to, provisioning, deployment, configuration, queueing, monitoring, logging, and/or providing interconnectivity. Provisioning may include creating and maintenance of connections between robots 130 and conductor 120 (e.g., a web application). Deployment may include assuring the correct delivery of package versions to assigned robots 130 for execution. Configuration may include maintenance



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and delivery of robot environments and process configurations. Queueing may include providing management of queues and queue items. Monitoring may include keeping track of robot identification data and maintaining user permissions. Logging may include storing and indexing logs to a database (e.g., an SQL database) and/or another storage mechanism (e.g., ElasticSearch®, which provides the ability to store and quickly query large datasets). Conductor **120** may provide interconnectivity by acting as the centralized point of communication for third-party solutions and/or applications.

Robots **130** are execution agents that run workflows built in designer **110**. One commercial example of some embodiments of robot(s) **130** is UiPath Robots™. In some embodiments, robots **130** install the Microsoft Windows® Service Control Manager (SCM)-managed service by default. As a result, such robots **130** can open interactive Windows® sessions under the local system account, and have the rights of a Windows® service.

In some embodiments, robots **130** can be installed in a user mode. For such robots **130**, this means they have the same rights as the user under which a given robot **130** has been installed. This feature may also be available for High Density (HD) robots, which ensure full utilization of each machine at its maximum potential. In some embodiments, any type of robot **130** may be configured in an HD environment.

Robots **130** in some embodiments are split into several components, each being dedicated to a particular automation task. The robot components in some embodiments include, but are not limited to, SCM-managed robot services, user mode robot services, executors, agents, and command line. SCM-managed robot services manage and monitor Windows® sessions and act as a proxy between conductor **120** and the execution hosts (i.e., the computing systems on which robots **130** are executed). These services are trusted with and manage the credentials for robots **130**. A console application is launched by the SCM under the local system.

User mode robot services in some embodiments manage and monitor Windows® sessions and act as a proxy between conductor **120** and the execution hosts. User mode robot services may be trusted with and manage the credentials for robots **130**. A Windows® application may automatically be launched if the SCM-managed robot service is not installed.

Executors may run given jobs under a Windows® session (i.e., they may execute workflows. Executors may be aware of per-monitor dots per inch (DPI) settings. Agents may be Windows® Presentation Foundation (WPF) applications that display the available jobs in the system tray window. Agents may be a client of the service. Agents may request to start or stop jobs and change settings. The command line is a client of the service. The command line is a console application that can request to start jobs and waits for their output.

Having components of robots **130** split as explained above helps developers, support users, and computing systems more easily run, identify, and track what each component is executing. Special behaviors may be configured per component this way, such as setting up different firewall rules for the executor and the service. The executor may always be aware of DPI settings per monitor in some embodiments. As a result, workflows may be executed at any DPI, regardless of the configuration of the computing system on which they were created. Projects from designer **110** may also be independent of browser zoom level in some

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embodiments. For applications that are DPI-unaware or intentionally marked as unaware, DPI may be disabled in some embodiments.

FIG. **2** is an architectural diagram illustrating a deployed RPA system **200**, according to an embodiment of the present invention. In some embodiments, RPA system **200** may be, or may be a part of, RPA system **100** of FIG. **1**. It should be noted that the client side, the server side, or both, may include any desired number of computing systems without deviating from the scope of the invention. On the client side, a robot application **210** includes executors **212**, an agent **214**, and a designer **216**. However, in some embodiments, designer **216** may not be running on computing system **210**. Executors **212** are running processes. Several business projects may run simultaneously, as shown in FIG. **2**. Agent **214** (e.g., a Windows® service) is the single point of contact for all executors **212** in this embodiment. All messages in this embodiment are logged into conductor **230**, which processes them further via database server **240**, indexer server **250**, or both. As discussed above with respect to FIG. **1**, executors **212** may be robot components.

In some embodiments, a robot represents an association between a machine name and a username. The robot may manage multiple executors at the same time. On computing systems that support multiple interactive sessions running simultaneously (e.g., Windows® Server 2012), multiple robots may be running at the same time, each in a separate Windows® session using a unique username. This is referred to as HD robots above.

Agent **214** is also responsible for sending the status of the robot (e.g., periodically sending a “heartbeat” message indicating that the robot is still functioning) and downloading the required version of the package to be executed. The communication between agent **214** and conductor **230** is always initiated by agent **214** in some embodiments. In the notification scenario, agent **214** may open a WebSocket channel that is later used by conductor **230** to send commands to the robot (e.g., start, stop, etc.).

On the server side, a presentation layer (web application **232**, Open Data Protocol (OData) Representative State Transfer (REST) Application Programming Interface (API) endpoints **234**, and notification and monitoring **236**), a service layer (API implementation/business logic **238**), and a persistence layer (database server **240** and indexer server **250**) are included. Conductor **230** includes web application **232**, OData REST API endpoints **234**, notification and monitoring **236**, and API implementation/business logic **238**. In some embodiments, most actions that a user performs in the interface of conductor **220** (e.g., via browser **220**) are performed by calling various APIs. Such actions may include, but are not limited to, starting jobs on robots, adding/removing data in queues, scheduling jobs to run unattended, etc. without deviating from the scope of the invention. Web application **232** is the visual layer of the server platform. In this embodiment, web application **232** uses Hypertext Markup Language (HTML) and JavaScript (JS). However, any desired markup languages, script languages, or any other formats may be used without deviating from the scope of the invention. The user interacts with web pages from web application **232** via browser **220** in this embodiment in order to perform various actions to control conductor **230**. For instance, the user may create robot groups, assign packages to the robots, analyze logs per robot and/or per process, start and stop robots, etc.

In addition to web application **232**, conductor **230** also includes service layer that exposes OData REST API endpoints **234**. However, other endpoints may be included



without deviating from the scope of the invention. The REST API is consumed by both web application **232** and agent **214**. Agent **214** is the supervisor of one or more robots on the client computer in this embodiment.

The REST API in this embodiment covers configuration, logging, monitoring, and queueing functionality. The configuration endpoints may be used to define and configure application users, permissions, robots, assets, releases, and environments in some embodiments. Logging REST endpoints may be used to log different information, such as errors, explicit messages sent by the robots, and other environment-specific information, for instance. Deployment REST endpoints may be used by the robots to query the package version that should be executed if the start job command is used in conductor **230**. Queueing REST endpoints may be responsible for queues and queue item management, such as adding data to a queue, obtaining a transaction from the queue, setting the status of a transaction, etc.

Monitoring REST endpoints may monitor web application **232** and agent **214**. Notification and monitoring API **236** may be REST endpoints that are used for registering agent **214**, delivering configuration settings to agent **214**, and for sending/receiving notifications from the server and agent **214**. Notification and monitoring API **236** may also use WebSocket communication in some embodiments.

The persistence layer includes a pair of servers in this embodiment—database server **240** (e.g., a SQL server) and indexer server **250**. Database server **240** in this embodiment stores the configurations of the robots, robot groups, associated processes, users, roles, schedules, etc. This information is managed through web application **232** in some embodiments. Database server **240** may manages queues and queue items. In some embodiments, database server **240** may store messages logged by the robots (in addition to or in lieu of indexer server **250**).

Indexer server **250**, which is optional in some embodiments, stores and indexes the information logged by the robots. In certain embodiments, indexer server **250** may be disabled through configuration settings. In some embodiments, indexer server **250** uses ElasticSearch®, which is an open source project full-text search engine. Messages logged by robots (e.g., using activities like log message or write line) may be sent through the logging REST endpoint(s) to indexer server **250**, where they are indexed for future utilization.

FIG. **3** is an architectural diagram illustrating the relationship **300** between a designer **310**, activities **320**, **330**, and drivers **340**, according to an embodiment of the present invention. Per the above, a developer uses designer **310** to develop workflows that are executed by robots. Workflows may include user-defined activities **320** and UI automation activities **330**. Some embodiments are able to identify non-textual visual components in an image, which is called computer vision (CV) herein. Some CV activities pertaining to such components may include, but are not limited to, click, type, get text, hover, element exists, refresh scope, highlight, etc. Click in some embodiments identifies an element using CV, optical character recognition (OCR), fuzzy text matching, and multi-anchor, for example, and clicks it. Type may identify an element using the above and types in the element. Get text may identify the location of specific text and scan it using OCR. Hover may identify an element and hover over it. Element exists may check whether an element exists on the screen using the techniques described above. In some embodiments, there may be hundreds or even thousands of activities that can be imple-

mented in designer **310**. However, any number and/or type of activities may be available without deviating from the scope of the invention.

UI automation activities **330** are a subset of special, lower level activities that are written in lower level code (e.g., CV activities) and facilitate interactions with the screen. UI automation activities **330** facilitate these interactions via drivers **340** that allow the robot to interact with the desired software. For instance, drivers **340** may include OS drivers **342**, browser drivers **344**, VM drivers **346**, enterprise application drivers **348**, etc.

Drivers **340** may interact with the OS at a low level looking for hooks, monitoring for keys, etc. They may facilitate integration with Chrome®, IE®, Citrix®, SAP®, etc. For instance, the “click” activity performs the same role in these different applications via drivers **340**.

FIG. **4** is an architectural diagram illustrating an RPA system **400**, according to an embodiment of the present invention. In some embodiments, RPA system **400** may be or include RPA systems **100** and/or **200** of FIGS. **1** and/or **2**. RPA system **400** includes multiple client computing systems **410** running robots. Computing systems **410** are able to communicate with a conductor computing system **420** via a web application running thereon. Conductor computing system **420**, in turn, is able to communicate with a database server **430** and an optional indexer server **440**.

With respect to FIGS. **1** and **3**, it should be noted that while a web application is used in these embodiments, any suitable client/server software may be used without deviating from the scope of the invention. For instance, the conductor may run a server-side application that communicates with non-web-based client software applications on the client computing systems.

FIG. **5** is an architectural diagram illustrating a computing system **500** configured to perform process evolution for RPA, according to an embodiment of the present invention. In some embodiments, computing system **500** may be one or more of the computing systems depicted and/or described herein. Computing system **500** includes a bus **505** or other communication mechanism for communicating information, and processor(s) **510** coupled to bus **505** for processing information. Processor(s) **510** may be any type of general or specific purpose processor, including a Central Processing Unit (CPU), an Application Specific Integrated Circuit (ASIC), a Field Programmable Gate Array (FPGA), a Graphics Processing Unit (GPU), multiple instances thereof, and/or any combination thereof. Processor(s) **510** may also have multiple processing cores, and at least some of the cores may be configured to perform specific functions. Multi-parallel processing may be used in some embodiments. In certain embodiments, at least one of processor(s) **510** may be a neuromorphic circuit that includes processing elements that mimic biological neurons. In some embodiments, neuromorphic circuits may not require the typical components of a Von Neumann computing architecture.

Computing system **500** further includes a memory **515** for storing information and instructions to be executed by processor(s) **510**. Memory **515** can be comprised of any combination of Random Access Memory (RAM), Read Only Memory (ROM), flash memory, cache, static storage such as a magnetic or optical disk, or any other types of non-transitory computer-readable media or combinations thereof. Non-transitory computer-readable media may be any available media that can be accessed by processor(s) **510** and may include volatile media, non-volatile media, or both. The media may also be removable, non-removable, or both.



Additionally, computing system **500** includes a communication device **520**, such as a transceiver, to provide access to a communications network via a wireless and/or wired connection. In some embodiments, communication device **520** may be configured to use Frequency Division Multiple Access (FDMA), Single Carrier FDMA (SC-FDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), Orthogonal Frequency Division Multiplexing (OFDM), Orthogonal Frequency Division Multiple Access (OFDMA), Global System for Mobile (GSM) communications, General Packet Radio Service (GPRS), Universal Mobile Telecommunications System (UMTS), cdma2000, Wideband CDMA (W-CDMA), High-Speed Downlink Packet Access (HSDPA), High-Speed Uplink Packet Access (HSUPA), High-Speed Packet Access (HSPA), Long Term Evolution (LTE), LTE Advanced (LTE-A), 802.11x, Wi-Fi, Zigbee, Ultra-WideBand (UWB), 802.16x, 802.15, Home Node-B (HnB), Bluetooth, Radio Frequency Identification (RFID), Infrared Data Association (IrDA), Near-Field Communications (NFC), fifth generation (5G), New Radio (NR), any combination thereof, and/or any other currently existing or future-implemented communications standard and/or protocol without deviating from the scope of the invention. In some embodiments, communication device **520** may include one or more antennas that are singular, arrayed, phased, switched, beamforming, beam-steering, a combination thereof, and or any other antenna configuration without deviating from the scope of the invention.

Processor(s) **510** are further coupled via bus **505** to a display **525**, such as a plasma display, a Liquid Crystal Display (LCD), a Light Emitting Diode (LED) display, a Field Emission Display (FED), an Organic Light Emitting Diode (OLED) display, a flexible OLED display, a flexible substrate display, a projection display, a 4K display, a high definition display, a Retina® display, an In-Plane Switching (IPS) display, or any other suitable display for displaying information to a user. Display **525** may be configured as a touch (haptic) display, a three dimensional (3D) touch display, a multi-input touch display, a multi-touch display, etc. using resistive, capacitive, surface-acoustic wave (SAW) capacitive, infrared, optical imaging, dispersive signal technology, acoustic pulse recognition, frustrated total internal reflection, etc. Any suitable display device and haptic I/O may be used without deviating from the scope of the invention.

A keyboard **530** and a cursor control device **535**, such as a computer mouse, a touchpad, etc., are further coupled to bus **505** to enable a user to interface with computing system. However, in certain embodiments, a physical keyboard and mouse may not be present, and the user may interact with the device solely through display **525** and/or a touchpad (not shown). Any type and combination of input devices may be used as a matter of design choice. In certain embodiments, no physical input device and/or display is present. For instance, the user may interact with computing system **500** remotely via another computing system in communication therewith, or computing system **500** may operate autonomously.

Memory **515** stores software modules that provide functionality when executed by processor(s) **510**. The modules include an operating system **540** for computing system **500**. The modules further include a process evolution module **545** that is configured to perform all or part of the processes described herein or derivatives thereof. Computing system **500** may include one or more additional functional modules **550** that include additional functionality.

One skilled in the art will appreciate that a “system” could be embodied as a server, an embedded computing system, a personal computer, a console, a personal digital assistant (PDA), a cell phone, a tablet computing device, a quantum computing system, or any other suitable computing device, or combination of devices without deviating from the scope of the invention. Presenting the above-described functions as being performed by a “system” is not intended to limit the scope of the present invention in any way, but is intended to provide one example of the many embodiments of the present invention. Indeed, methods, systems, and apparatuses disclosed herein may be implemented in localized and distributed forms consistent with computing technology, including cloud computing systems.

It should be noted that some of the system features described in this specification have been presented as modules, in order to more particularly emphasize their implementation independence. For example, a module may be implemented as a hardware circuit comprising custom very large scale integration (VLSI) circuits or gate arrays, off-the-shelf semiconductors such as logic chips, transistors, or other discrete components. A module may also be implemented in programmable hardware devices such as field programmable gate arrays, programmable array logic, programmable logic devices, graphics processing units, or the like.

A module may also be at least partially implemented in software for execution by various types of processors. An identified unit of executable code may, for instance, include one or more physical or logical blocks of computer instructions that may, for instance, be organized as an object, procedure, or function. Nevertheless, the executables of an identified module need not be physically located together, but may include disparate instructions stored in different locations that, when joined logically together, comprise the module and achieve the stated purpose for the module. Further, modules may be stored on a computer-readable medium, which may be, for instance, a hard disk drive, flash device, RAM, tape, and/or any other such non-transitory computer-readable medium used to store data without deviating from the scope of the invention.

Indeed, a module of executable code could be a single instruction, or many instructions, and may even be distributed over several different code segments, among different programs, and across several memory devices. Similarly, operational data may be identified and illustrated herein within modules, and may be embodied in any suitable form and organized within any suitable type of data structure. The operational data may be collected as a single data set, or may be distributed over different locations including over different storage devices, and may exist, at least partially, merely as electronic signals on a system or network.

FIG. 6 is an architectural diagram illustrating a system **600** configured to implement process evolution for RPA and/or perform RPA workflow micro-optimization, according to an embodiment of the present invention. System **600** includes user computing systems, such as desktop computer **602**, tablet **604**, and smart phone **606**. However, any desired computing system may be used without deviating from the scope of invention including, but not limited to, smart watches, laptop computers, Internet-of-Things (IoT) devices, vehicle computing systems, etc.

Each computing system **602**, **604**, **606** has a listener **610** installed thereon. Listeners **610** may be robots generated via an RPA designer application, part of an operating system, a downloadable application for a personal computer (PC) or smart phone, or any other software and/or hardware without



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deviating from the scope of the invention. Indeed, in some embodiments, the logic of one or more of listeners **610** is implemented partially or completely via physical hardware.

Listeners **610** generate logs of user interactions with the respective computing system **602**, **604**, **606** and/or log data pertaining to operations of robots running thereon. Listeners **610** then send the log data via a network **620** (e.g., a local area network (LAN), a mobile communications network, a satellite communications network, the Internet, any combination thereof, etc.) to a server **630**. The data that is logged may include, but is not limited to, which buttons were clicked, where a mouse was moved, the text that was entered in a field, that one window was minimized and another was opened, the application associated with a window, etc. In some embodiments, server **630** may run a conductor application and the data may be sent periodically as part of the heartbeat message. In certain embodiments, the log data may be sent to server **630** once a predetermined amount of log data has been collected, after a predetermined time period has elapsed, or both. Server **630** stores the received log data from listeners **610** in a database **640**.

When instructed by a human user (e.g., an RPA engineer or a data scientist), when a predetermined amount of log data has been collected, when a predetermined amount of time has passed since the last analysis, etc., server **630** accesses log data collected from various users by listeners **610** from database **640** and runs the log data through multiple AI layers **632**. AI layers **632** process the log data and identify one or more potential processes for ROI improvement therein, identify improvements to existing processes, or both. AI layers **632** may perform statistical modeling (e.g., hidden Markov models (HMMs)) and utilize deep learning techniques (e.g., long short term memory (LSTM) deep learning, encoding of previous hidden states, etc.) and perform case identification to identify an atomic instance of a process. For invoice processing, for example, completion of one invoice may be a case. The system thus determines where one case finishes and the next case begins. Opening an email may be the start of a case, for example, and the patterns of the cases may be analyzed to determine variations and commonalities.

If a similar process already exists, server **630** may identify this similarity and know that the identified process should replace an existing process for the same or a similar automation that works less optimally. For example, similarities between processes may be determined by a common beginning and end and some amount of statistical commonality in the steps taking in between. Commonality may be determined by entropy, minimization of a process detection objective function, etc. The objective function threshold may be set automatically in some embodiments, and this may be modified during training if processes that were identified as dissimilar by the system are indicated as being similar by a user. Server **630** may then automatically generate a workflow including the identified process, generate a robot implementing the workflow (or a replacement robot), and push the generated robot out to user computing systems **602**, **604**, **606** to be executed thereon.

Alternatively, in certain embodiments, suggested processes from AI layers **632** may be presented to an RPA engineer via a designer application **652** on a computing system **650**. The RPA engineer can then review the workflow, make any desired changes, and then deploy the workflow via a robot to computing systems **602**, **604**, **606**, or cause the robot to be deployed. For example, deployment may occur via a conductor application running on server **630** or another server, which may push a robot implementing the

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process out to user computing systems **602**, **604**, **606**. In some embodiments, this workflow deployment may be realized via automation manager functionality in the designer application, and the RPA engineer may merely click a button to implement the process in a robot.

## LISTENERS

In order to extract data pertaining to actions taken by users on computing systems **602**, **604**, **606**, listeners **610** may be employed on the client side at the driver level (e.g., drivers **340** of FIG. 3) to extract data from whitelisted applications. For example, listeners **610** may record where a user clicked on the screen and in what application, keystrokes, which button was clicked, instances of the user switching between applications, focus changes, that an email was sent and what the email pertains to, etc. Additionally or alternatively, listeners **610** may collect data pertaining to robots operating on computing systems **602**, **604**, **606**. In some embodiments, the robots that perform various tasks implementing workflows may function as listeners for their own operations. Such data can be used to generate high-fidelity logs of the user's interactions with computing systems **602**, **604**, **606** and/or the operation(s) of robots running thereon.

In addition to or alternatively to generating log data for process extraction, some embodiments may provide insights into what users are actually doing. For instance, listeners **610** may determine which applications the users are actually using, what percentage of the time users are using a given application, which features within the application the users are using and which they are not, etc. This information may be provided to a manager to make informed decisions regarding whether to renew a license for an application, whether to not renew a license for a feature or downgrade to a less expensive version that lacks the feature, whether a user is not using applications that tend to make other employees more productive so the user can be trained appropriately, whether a user spends a large amount of time performing non-work activities (e.g., checking personal email or surfing the web) or away from his or her desk (e.g., not interacting with the computing system), etc.

In some embodiments, detection updates can be pushed to the listeners to improve their driver-level user interaction and/or robot operation detection and capture processes. In certain embodiments, listeners **610** may employ AI in their detection. In certain embodiments, robots implementing processes from automation workflows may automatically be pushed to computing systems **602**, **604**, **606** via respective listeners **610**.

FIG. 7 is a flowchart **700** illustrating a process for implementing process evolution for RPA, according to an embodiment of the present invention. The process begins with receiving a plan for an RPA implementation at **710**. The plan includes business data, which may include, but is not limited to, employee interactions with computing systems, financial information, time taken to perform robot operations and/or workflow steps, etc. In some embodiments, the plan may be derived from processes automatically identified from data collected by robots using AI. Analytics are then performed on business data at **720** to measure, report, and align RPA operations with strategic business outcomes. For instance, analytics may be employed to determine revenue generated by an employee and/or robot, time taken to perform workflow operations by a robot, time it takes an employee to complete a business process, etc.

RPA workflows implementing the desired automations are then generated at **730**, which are deployed in the form of



RPA robots at 740. In some embodiments, the RPA robots may access AI skills through an AI fabric. After implementation, data is collected from business computing systems and analyzed at 750, and new processes for potential automations are automatically identified and suggested via ML models at 760. The process may then be iteratively repeated, increasing the effectiveness of RPA in the enterprise.

FIG. 8 is a flowchart illustrating a process 800 for performing RPA workflow micro-optimization, according to an embodiment of the present invention. The process begins (or proceeds from FIG. 7) with analyzing and prioritizing each activity in an RPA workflow based on performance criteria at 810. The performance criteria may include, but are not limited to, processing speed, generated revenue, employee productivity (e.g., speed), etc. An activity is added to the RPA workflow or deleted from the RPA workflow at 820 to create a modified RPA workflow. In some embodiments, activities to add may be selected from a pool of activities categorized by the type of goal that the workflow is intended to accomplish (e.g., invoice processing, assisting in generating leads, automating actions otherwise taken by employees, etc.). An RPA robot implementing the modified RPA workflow is then generated and run at 830.

The generated RPA robot is then tested at 840 to check whether the robot achieves a goal and realizes an improvement in the performance criteria. When the RPA robot does not achieve the goal, does not realize the improvement in the performance criteria, or both, at 850, the system reverts to the original RPA workflow prior to modification and returns to step 820, adding or removing another activity. However, when the RPA robot achieves the goal and realizes the improvement in the performance criteria at 850, the RPA robot is deployed at 870, potentially replacing an earlier version of the RPA robot.

The process steps performed in FIGS. 7 and 8 may be performed by a computer program, encoding instructions for the processor(s) to perform at least part of the process(es) described in FIGS. 7 and 8, in accordance with embodiments of the present invention. The computer program may be embodied on a non-transitory computer-readable medium. The computer-readable medium may be, but is not limited to, a hard disk drive, a flash device, RAM, a tape, and/or any other such medium or combination of media used to store data. The computer program may include encoded instructions for controlling processor(s) of a computing system (e.g., processor(s) 510 of computing system 500 of FIG. 5) to implement all or part of the process steps described in FIGS. 7 and 8, which may also be stored on the computer-readable medium.

The computer program can be implemented in hardware, software, or a hybrid implementation. The computer program can be composed of modules that are in operative communication with one another, and which are designed to pass information or instructions to display. The computer program can be configured to operate on a general purpose computer, an ASIC, or any other suitable device.

It will be readily understood that the components of various embodiments of the present invention, as generally described and illustrated in the figures herein, may be arranged and designed in a wide variety of different configurations. Thus, the detailed description of the embodiments of the present invention, as represented in the attached figures, is not intended to limit the scope of the invention as claimed, but is merely representative of selected embodiments of the invention.

The features, structures, or characteristics of the invention described throughout this specification may be combined in

any suitable manner in one or more embodiments. For example, reference throughout this specification to “certain embodiments,” “some embodiments,” or similar language means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases “in certain embodiments,” “in some embodiment,” “in other embodiments,” or similar language throughout this specification do not necessarily all refer to the same group of embodiments and the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

It should be noted that reference throughout this specification to features, advantages, or similar language does not imply that all of the features and advantages that may be realized with the present invention should be or are in any single embodiment of the invention. Rather, language referring to the features and advantages is understood to mean that a specific feature, advantage, or characteristic described in connection with an embodiment is included in at least one embodiment of the present invention. Thus, discussion of the features and advantages, and similar language, throughout this specification may, but do not necessarily, refer to the same embodiment.

Furthermore, the described features, advantages, and characteristics of the invention may be combined in any suitable manner in one or more embodiments. One skilled in the relevant art will recognize that the invention can be practiced without one or more of the specific features or advantages of a particular embodiment. In other instances, additional features and advantages may be recognized in certain embodiments that may not be present in all embodiments of the invention.

One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with steps in a different order, and/or with hardware elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention.

The invention claimed is:

1. One or more non-transitory computer-readable media storing one or more computer programs, the one or more computer programs configured to cause at least one processor to:

receive a plan for a robotic process automation (RPA) implementation;

perform analytics on data associated with the plan to measure, report, and align RPA operations with plan outcomes; and

generate one or more RPA workflows implementing automations based on the analytics, the one or more RPA workflows comprising a set of activities defining an execution order and a relationship of the set of activities to provide automation of one or more rule-based processes, wherein

the one or more RPA workflows configured to cause one or more RPA robots to use one or more drivers to control and interact with a respective computing system.

2. The one or more non-transitory computer-readable media of claim 1, wherein the data comprises employee interactions with computing systems, financial information,



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time taken to perform robot operations and/or workflow steps, or any combination thereof.

3. The one or more non-transitory computer-readable media of claim 1, wherein the plan is derived from processes automatically identified from data collected by robots using artificial intelligence (AI).

4. The one or more non-transitory computer-readable media of claim 1, wherein the analytics determine revenue generated by an employee and/or robot, time taken to perform workflow operations by a robot, time taken by an employee to complete a process, or any combination thereof.

5. The one or more non-transitory computer-readable media of claim 1, wherein the one or more computer programs are further configured to cause the at least one processor to:

collect and analyze data from computing systems; and automatically identify and suggest one or more new processes for potential automations via one or more machine learning (ML) models.

6. The one or more non-transitory computer-readable media of claim 5, wherein the one or more computer programs are further configured to cause the at least one processor to:

iteratively repeat the process of performing analytics on data associated with the plan, generating RPA workflows implementing automations based on the analytics, generating and deploying the generated workflows via RPA robots, collecting and analyzing data from the computing systems, and automatically identifying and suggesting one or more new processes for potential automations, thereby increasing effectiveness of RPA.

7. The one or more non-transitory computer-readable media of claim 1, wherein the one or more computer programs are further configured to cause the at least one processor to:

analyze and prioritize each activity in an RPA workflow of the one or more RPA workflows based on performance criteria.

8. The one or more non-transitory computer-readable media of claim 7, wherein the one or more computer programs are further configured to cause the at least one processor to:

add an activity to the RPA workflow or delete an activity from the RPA workflow to create a modified RPA workflow;

generate and run an RPA robot implementing the modified RPA workflow; and

test the generated RPA robot to confirm that the RPA robot achieves a goal and realizes an improvement in the performance criteria.

9. The one or more non-transitory computer-readable media of claim 8, wherein the confirmation that the RPA robot achieves the goal and realizes the improvement in the performance criteria is based on a reward function.

10. The one or more non-transitory computer-readable media of claim 7, wherein responsive to confirming that the RPA robot does not achieve the goal, does not realize the improvement in the performance criteria, or both, the one or more computer programs are further configured to cause the at least one processor to:

revert to the RPA workflow prior to modification; and add another activity to the RPA workflow or delete another activity from the RPA workflow, generate an RPA robot implementing the modified RPA workflow, and test the generated RPA robot.

11. The one or more non-transitory computer-readable media of claim 7, wherein responsive to confirming that the

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RPA robot achieves the goal and realizes the improvement in the performance criteria, the one or more computer programs are further configured to cause the at least one processor to:

deploy the RPA robot.

12. A computer-implemented method, comprising:

performing analytics on data associated with a plan for a robotic process automation (RPA) implementation, by one or more computing systems, to measure, report, and align RPA operations with outcomes; and

generating one or more RPA workflows implementing automations based on the analytics, by the one or more computing systems, the one or more RPA workflows comprising a set of activities defining an execution order and a relationship of the set of activities to provide automation of one or more rule-based processes, wherein

the one or more RPA workflows are configured to cause one or more RPA robots to use one or more drivers to control and interact with a respective computing system.

13. The computer-implemented method of claim 12, wherein the data comprises employee interactions with computing systems, financial information, time taken to perform robot operations and/or workflow steps, or any combination thereof.

14. The computer-implemented method of claim 12, wherein the plan is derived from processes automatically identified from data collected by robots using artificial intelligence (AI).

15. The computer-implemented method of claim 12, wherein the analytics determine revenue generated by an employee and/or robot, time taken to perform workflow operations by a robot, time taken by an employee to complete a process, or any combination thereof.

16. The computer-implemented method of claim 12, further comprising:

collecting and analyzing data from other computing systems, by the one or more computing systems; and automatically identifying and suggesting one or more new processes for potential automations via one or more machine learning (ML) models, by the one or more computing systems.

17. The computer-implemented method of claim 16, further comprising:

iteratively repeating the process of performing analytics on the data associated with the plan, generating RPA workflows implementing automations based on the analytics, generating and deploying the generated workflows via RPA robots, collecting and analyzing data from the other computing systems, and automatically identifying and suggesting one or more new processes for potential automations, thereby increasing effectiveness of RPA.

18. A computing system, comprising:

memory storing computer program instructions; and

at least one processor configured to execute the computer program instructions, wherein the computer program instructions are configured to cause at least one processor to:

analyze and prioritize each activity of a set of activities in a robotic process automation (RPA) workflow based on performance criteria; and

add an activity to the RPA workflow or delete an activity from the RPA workflow to create a modified RPA workflow, wherein

the set of activities define an execution order and a relationship of the set of activities to provide automation of one or more rule-based processes, and the RPA workflow and the modified RPA workflow are configured to cause an RPA robot to use one or more drivers to control and interact with the computing system.

**19.** The computing system method of claim **18**, wherein the computer program instructions are further configured to cause the at least one processor to:

generate and run the RPA robot implementing the modified RPA workflow as an automation run by the RPA robot; and

test the generated RPA robot to confirm that the RPA robot achieves a goal and realizes an improvement in the performance criteria.

**20.** The computing system of claim **19**, wherein responsive to confirming that the RPA robot does not achieve the goal, does not realize the improvement in the performance criteria, or both, the computer program instructions are further configured to cause the at least one processor to:

revert to the RPA workflow prior to modification; and add another activity to the RPA workflow or delete another activity from the RPA workflow, generate an RPA robot implementing the modified RPA workflow, and test the generated RPA robot.

**21.** The computing system of claim **19**, wherein responsive to confirming that the RPA robot achieves the goal and realizes the improvement in the performance criteria, the computer program instructions are further configured to cause the at least one processor to:

deploy the RPA robot.

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