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(54) **INDUSTRIAL AUTOMATION CONTROL PROGRAM UTILIZATION IN ANALYTICS MODEL ENGINE**

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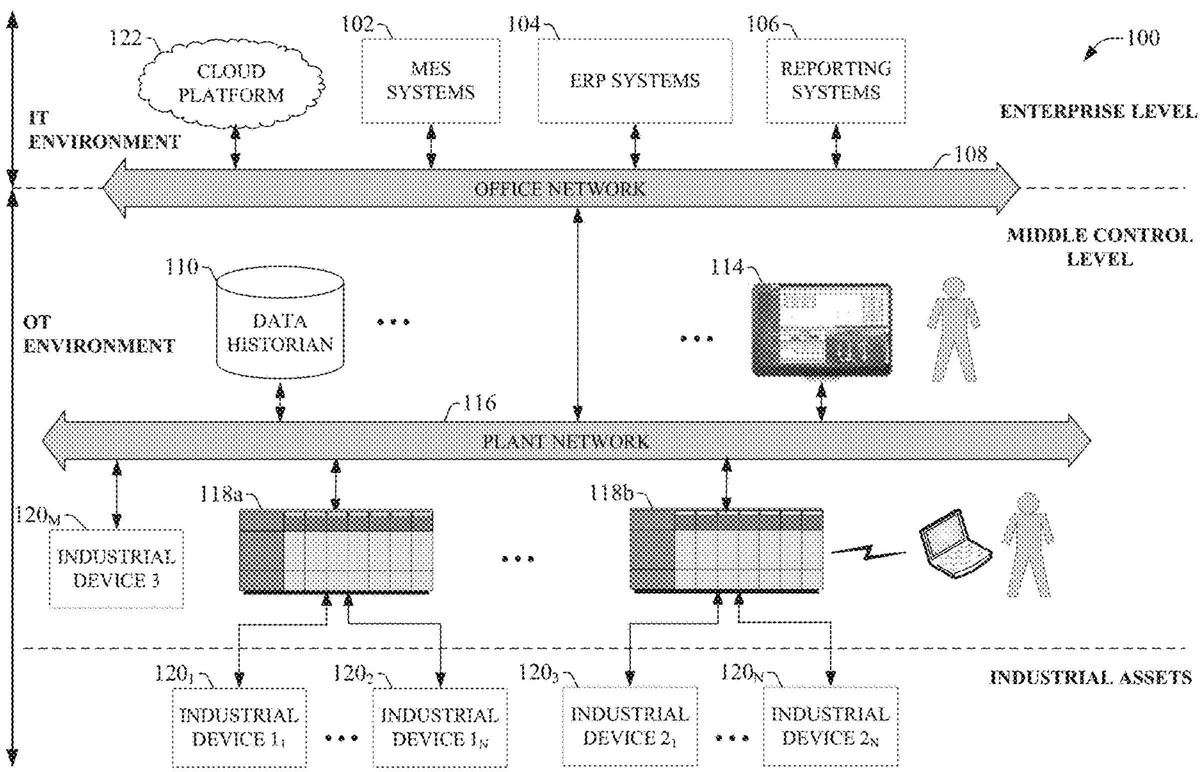
(52) **U.S. Cl.**
CPC ***G05B 19/41835*** (2013.01); *G05B 2219/33034* (2013.01); *G05B 2219/32043* (2013.01)

(57) **ABSTRACT**

An industrial device supports device-level data modeling that pre-models data stored in the device with known relationships, correlations, key variable identifiers, and other such metadata to assist higher-level analytic systems to more quickly and accurately converge to actionable insights relative to a defined business or analytic objective. Data at the device level can be modeled according to modeling templates stored on the device that define relationships between items of device data for respective analytic goals (e.g., improvement of product quality, maximizing product throughput, optimizing energy consumption, etc.). This device-level modeling data can be exposed to higher level systems for creation of analytic models that can be used to analyze data from the industrial device relative to desired business objectives.



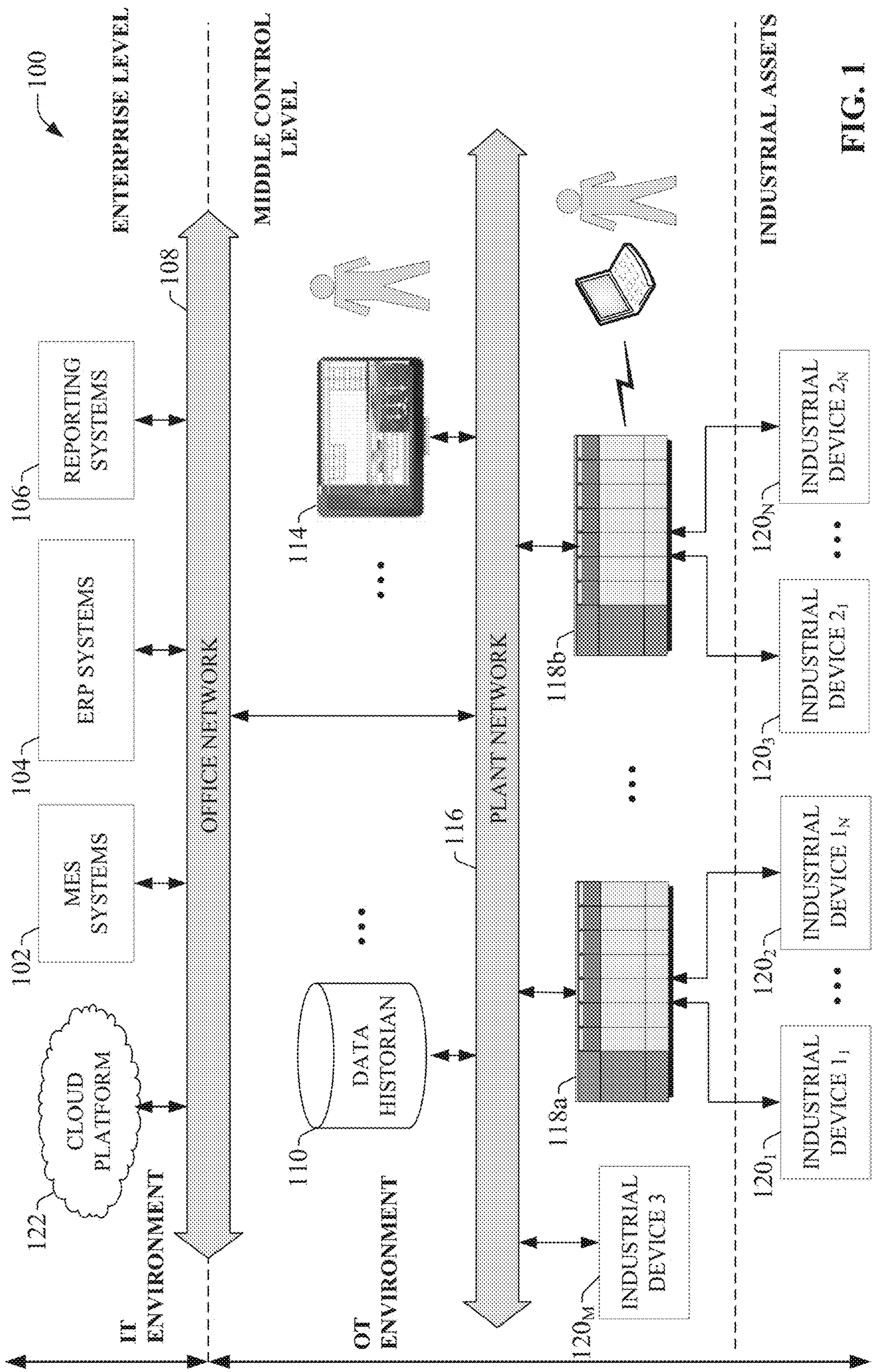

100
ENTERPRISE LEVEL
MIDDLE CONTROL LEVEL
INDUSTRIAL ASSETS
IT ENVIRONMENT
OT ENVIRONMENT
122
CLOUD PLATFORM
102
MES SYSTEMS
104
ERP SYSTEMS
106
REPORTING SYSTEMS
108
OFFICE NETWORK
110
DATA HISTORIAN
114
116
PLANT NETWORK
118a
118b
120_M
INDUSTRIAL DEVICE 3
120_1
INDUSTRIAL DEVICE 1_1
120_2
INDUSTRIAL DEVICE 1_N
120_3
INDUSTRIAL DEVICE 2_1
120_N
INDUSTRIAL DEVICE 2_N

FIG. 1

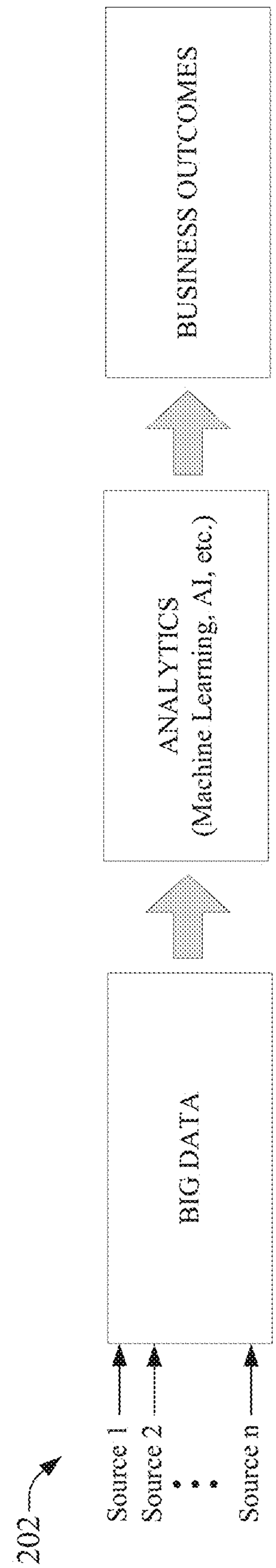

BUSINESS OUTCOMES
ANALYTICS
(Machine Learning, AI, etc.)
BIG DATA
Source 1
Source 2
Source n
202

FIG. 2a

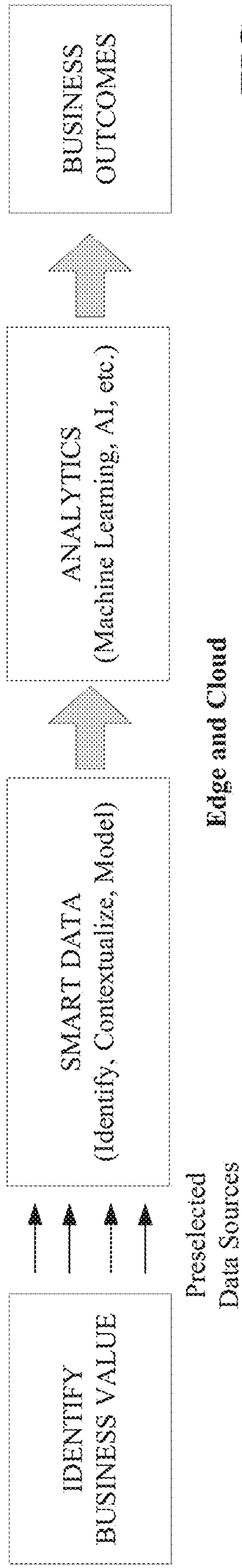

IDENTIFY
BUSINESS VALUE
Preselected
Data Sources
SMART DATA
(Identify, Contextualize, Model)
Edge and Cloud
ANALYTICS
(Machine Learning, AI, etc.)
BUSINESS
OUTCOMES

FIG. 2b

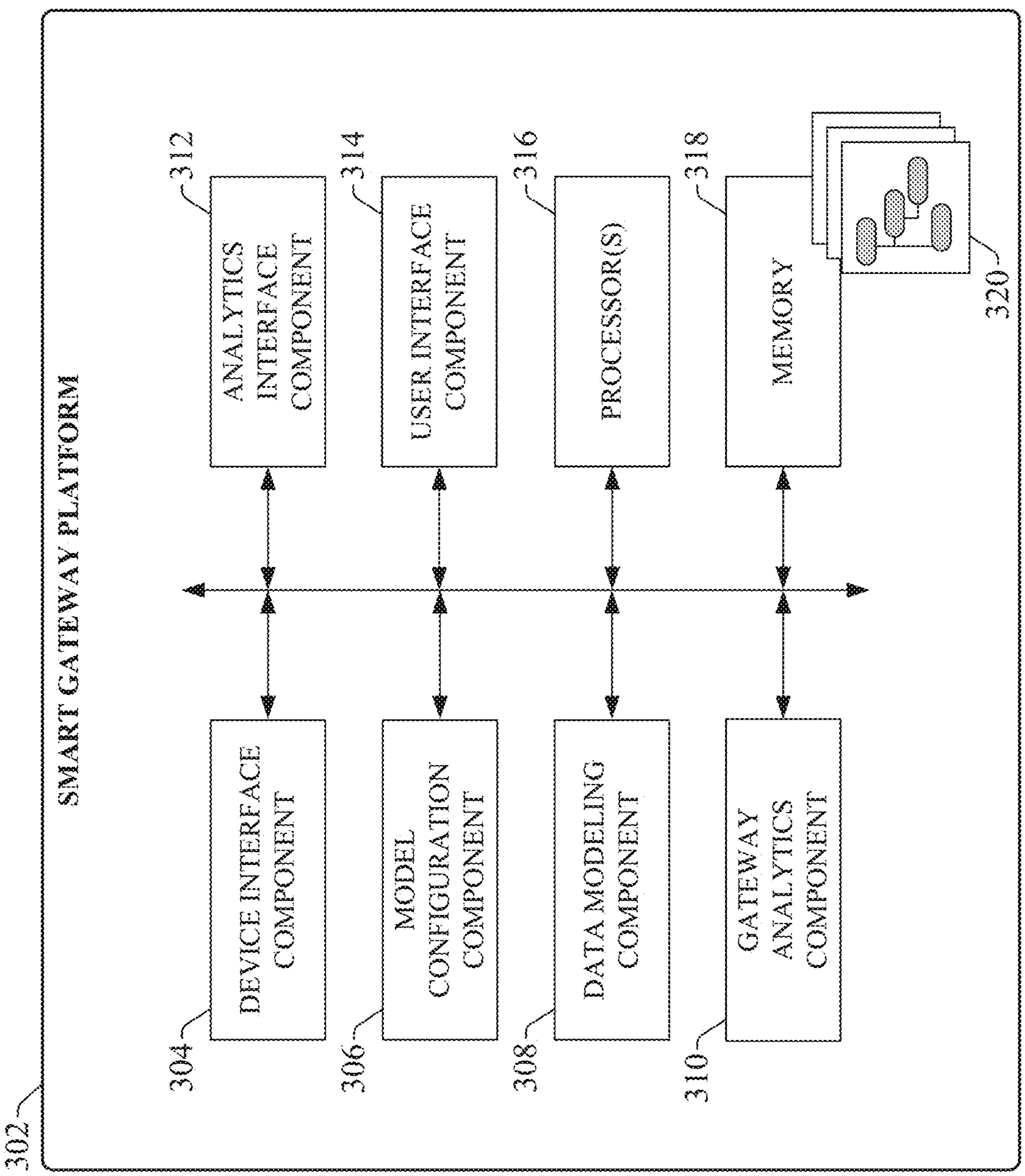

302
SMART GATEWAY PLATFORM
304
DEVICE INTERFACE COMPONENT
306
MODEL CONFIGURATION COMPONENT
308
DATA MODELING COMPONENT
310
GATEWAY ANALYTICS COMPONENT
312
ANALYTICS INTERFACE COMPONENT
314
USER INTERFACE COMPONENT
316
PROCESSOR(S)
318
MEMORY
320

FIG. 3

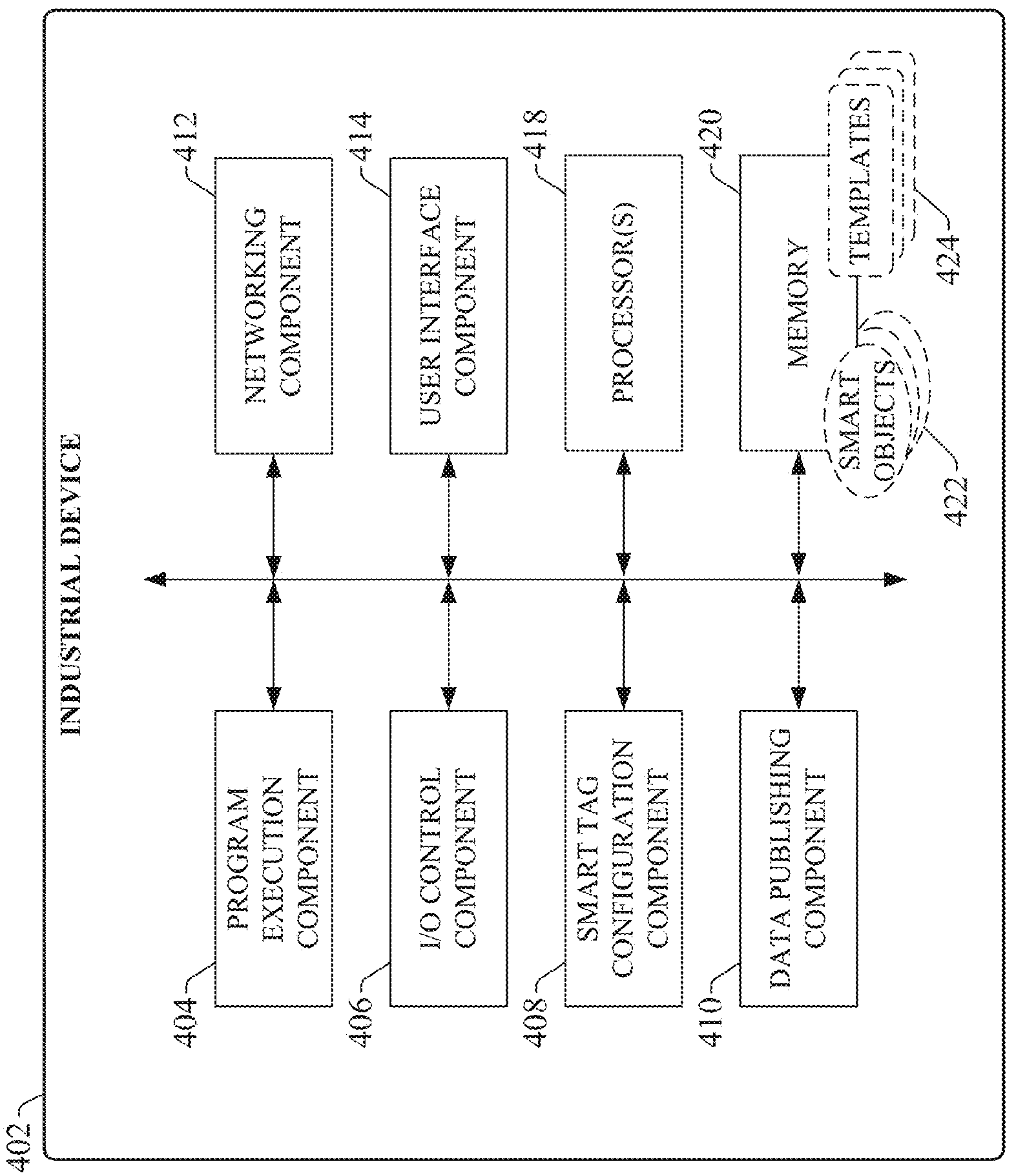
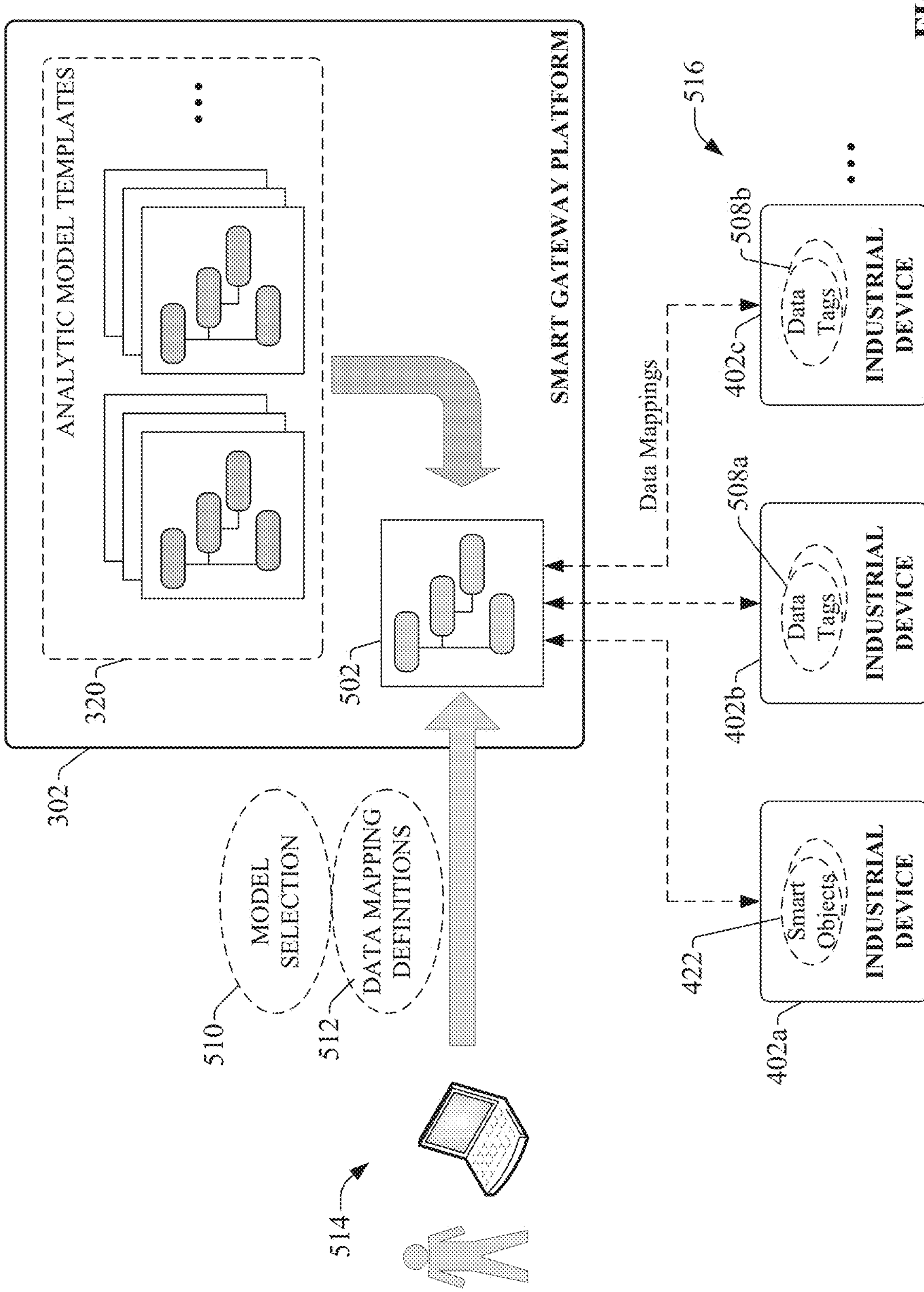

INDUSTRIAL DEVICE
402
PROGRAM EXECUTION COMPONENT
404
I/O CONTROL COMPONENT
406
SMART TAG CONFIGURATION COMPONENT
408
DATA PUBLISHING COMPONENT
410
NETWORKING COMPONENT
412
USER INTERFACE COMPONENT
414
PROCESSOR(S)
418
MEMORY
420
SMART OBJECTS
422
TEMPLATES
424

FIG. 4



SMART GATEWAY PLATFORM
ANALYTIC MODEL TEMPLATES
302
320
502
MODEL SELECTION
DATA MAPPING DEFINITIONS
510
512
514
Data Mappings
516
Data Tags
Data Tags
Smart Objects
508a
508b
422
INDUSTRIAL DEVICE
INDUSTRIAL DEVICE
INDUSTRIAL DEVICE
402a
402b
402c

FIG. 5

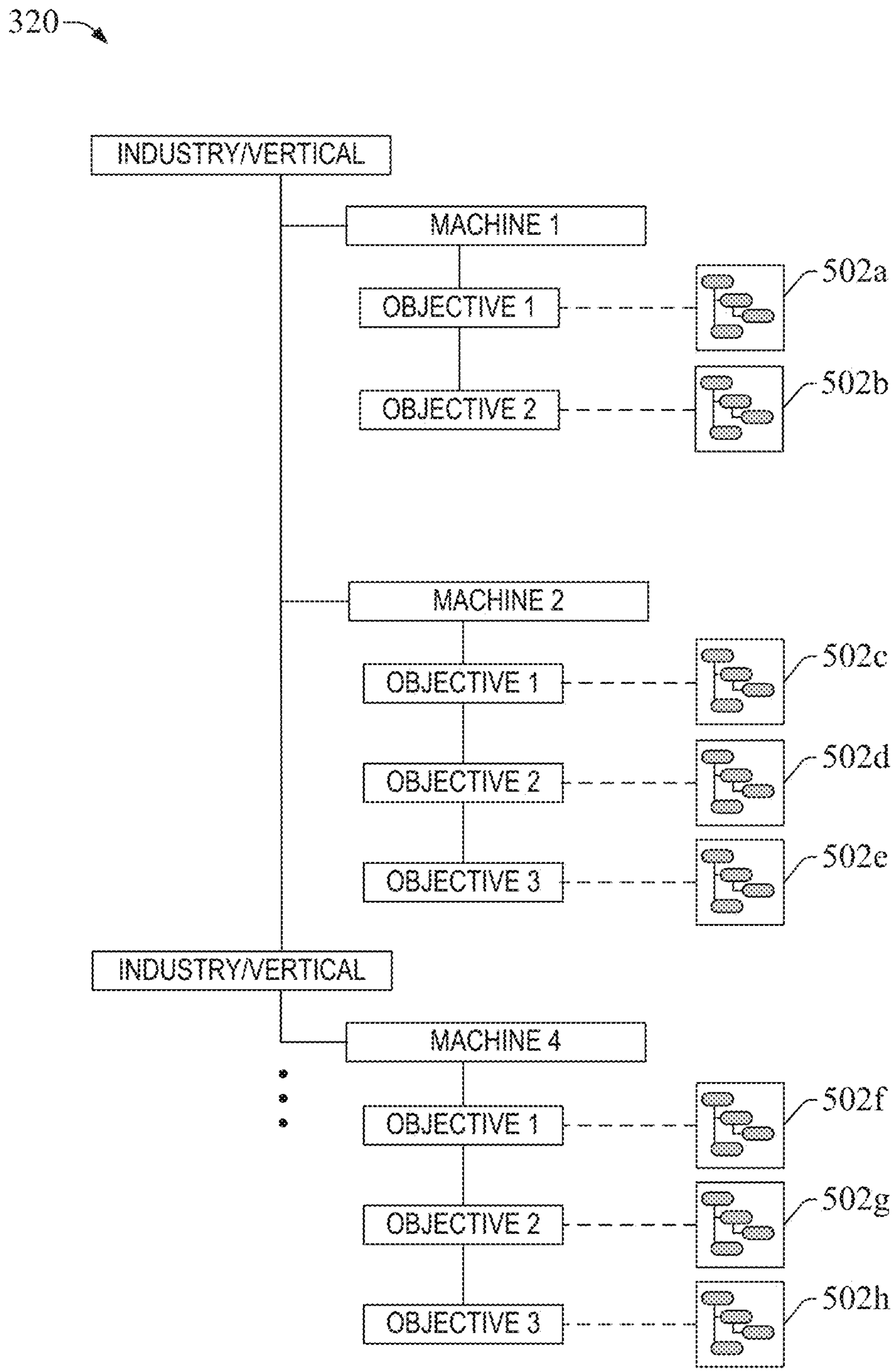

320
INDUSTRY/VERTICAL
MACHINE 1
OBJECTIVE 1
502a
OBJECTIVE 2
502b
MACHINE 2
OBJECTIVE 1
502c
OBJECTIVE 2
502d
OBJECTIVE 3
502e
INDUSTRY/VERTICAL
MACHINE 4
OBJECTIVE 1
502f
OBJECTIVE 2
502g
OBJECTIVE 3
502h

FIG. 6

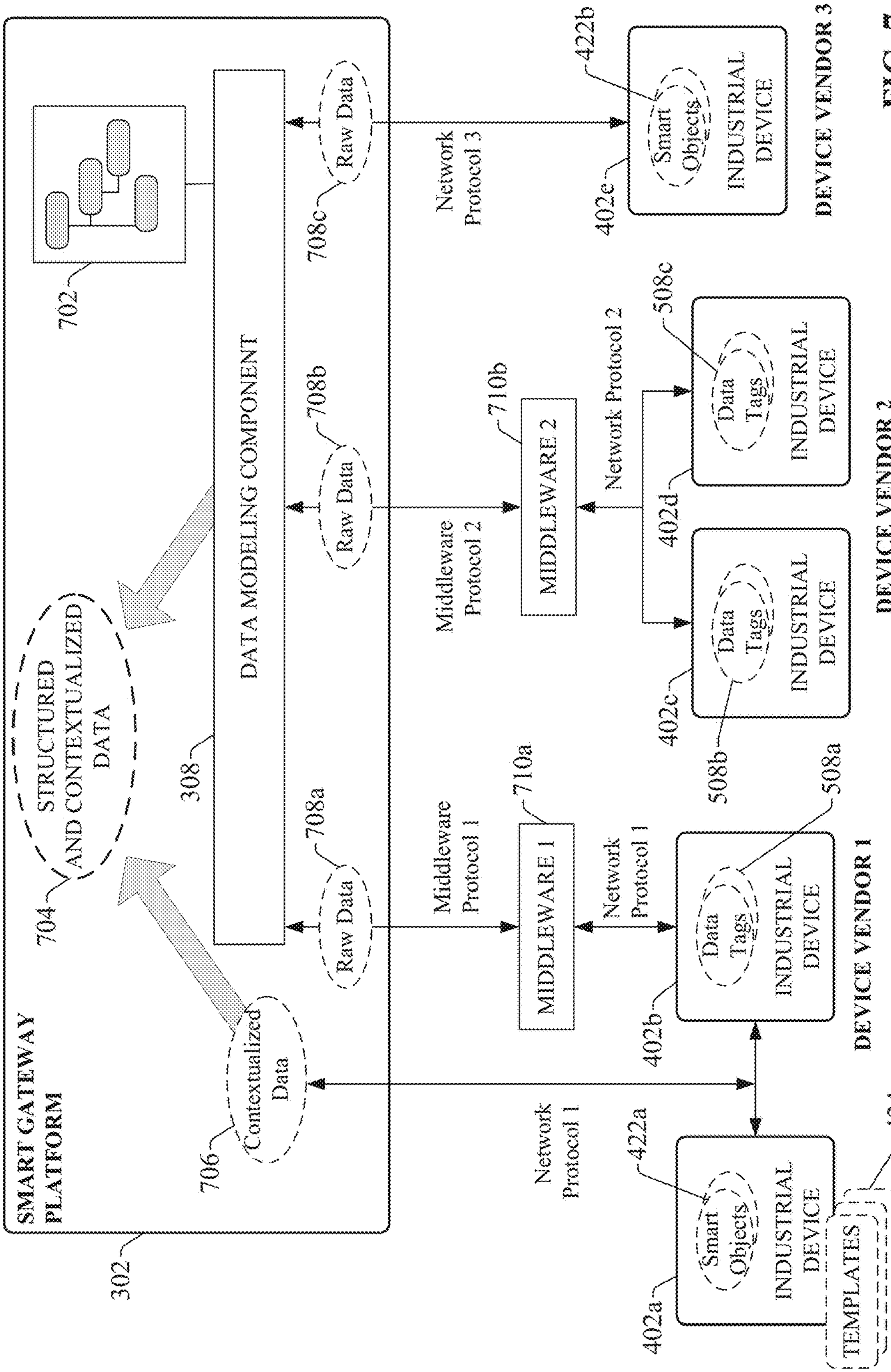

SMART GATEWAY PLATFORM
302
702
704
STRUCTURED AND CONTEXTUALIZED DATA
706
Contextualized Data
308
DATA MODELING COMPONENT
708a
Raw Data
708b
Raw Data
708c
Raw Data
Middleware Protocol 1
710a
MIDDLEWARE 1
Middleware Protocol 2
710b
MIDDLEWARE 2
Network Protocol 1
Network Protocol 1
Network Protocol 2
Network Protocol 3
402a
422a
Smart Objects
INDUSTRIAL DEVICE
TEMPLATES
424
402b
508a
Data Tags
INDUSTRIAL DEVICE
DEVICE VENDOR 1
402c
508b
Data Tags
INDUSTRIAL DEVICE
402d
508c
Data Tags
INDUSTRIAL DEVICE
DEVICE VENDOR 2
402e
422b
Smart Objects
INDUSTRIAL DEVICE
DEVICE VENDOR 3

FIG. 7

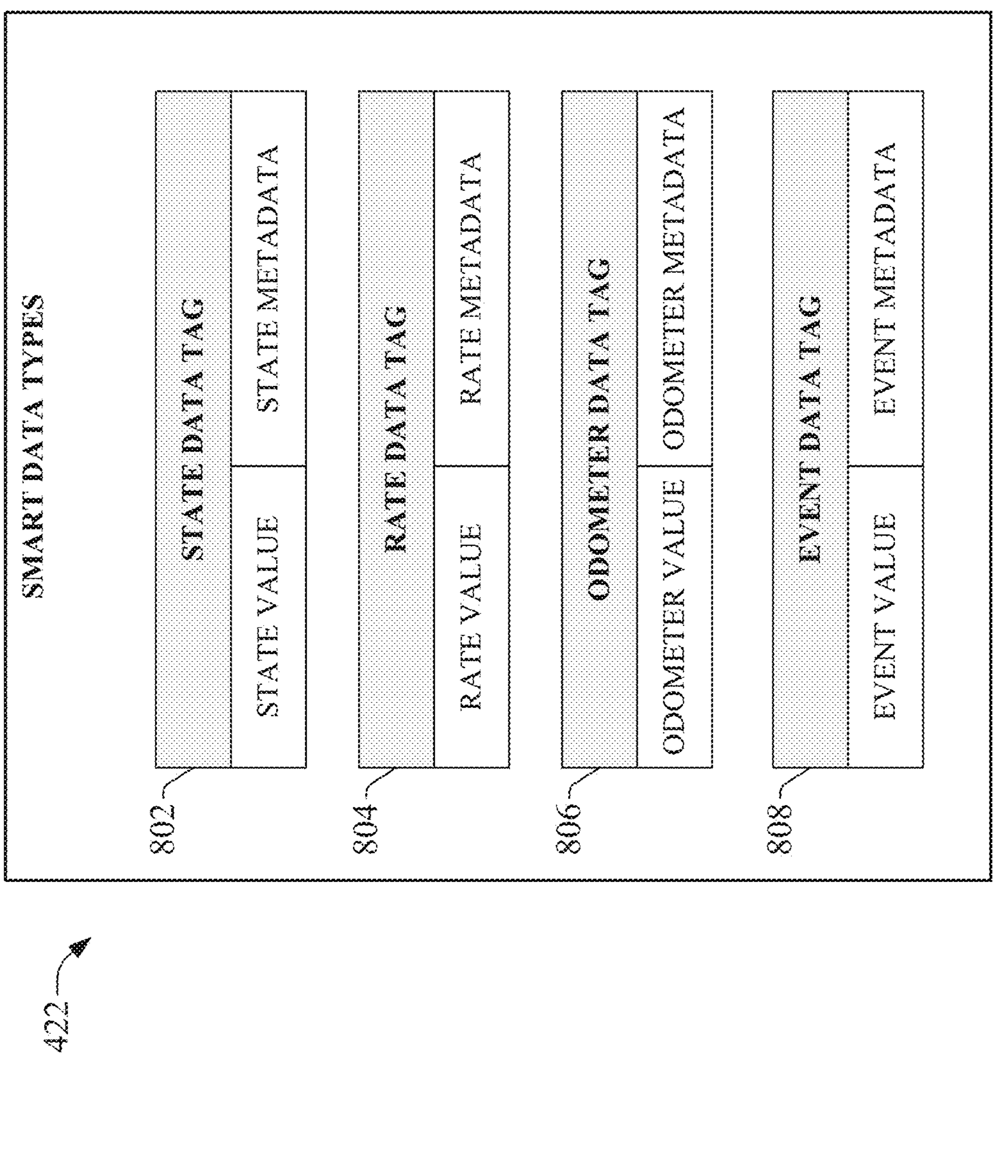

422
SMART DATA TYPES
802
STATE DATA TAG
STATE VALUE
STATE METADATA
804
RATE DATA TAG
RATE VALUE
RATE METADATA
806
ODOMETER DATA TAG
ODOMETER VALUE
ODOMETER METADATA
808
EVENT DATA TAG
EVENT VALUE
EVENT METADATA

FIG. 8

902

New AI Properties

<TAG 1>	STATE	VALUE	METADATA	AI FIELDS
<TAG 2>	STATE	VALUE	METADATA	AI FIELDS
<TAG 3>	RATE	VALUE	METADATA	AI FIELDS
<TAG 4>	EVENT	VALUE	METADATA	AI FIELDS
<TAG 5>	ODOMETER	VALUE	METADATA	AI FIELDS

...

904

FIG. 9

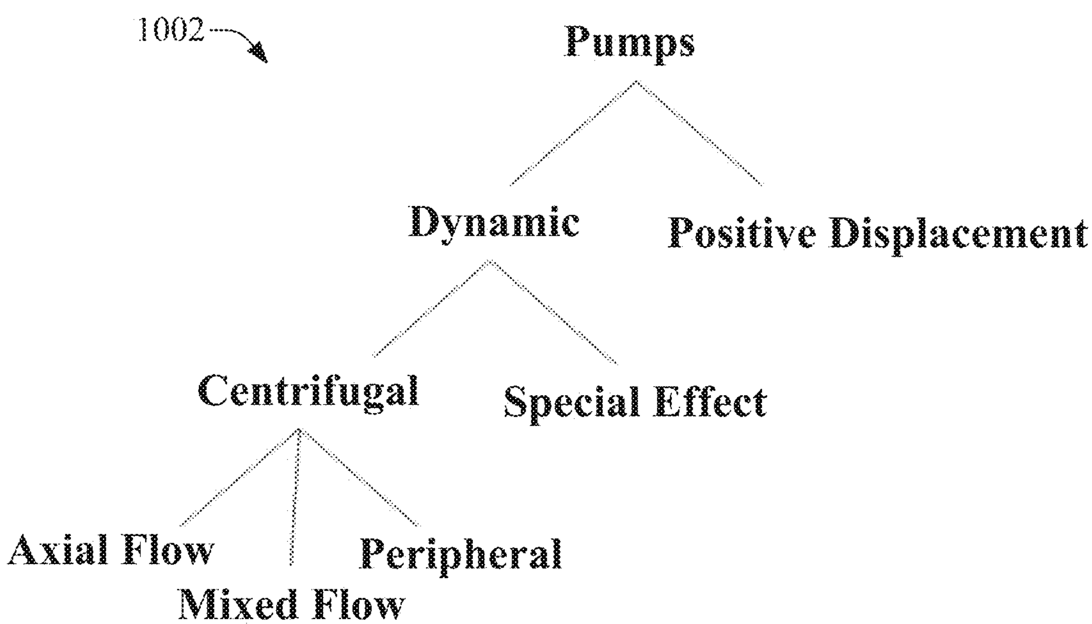

1002
Pumps
Dynamic
Positive Displacement
Centrifugal
Special Effect
Axial Flow
Mixed Flow
Peripheral

FIG. 10

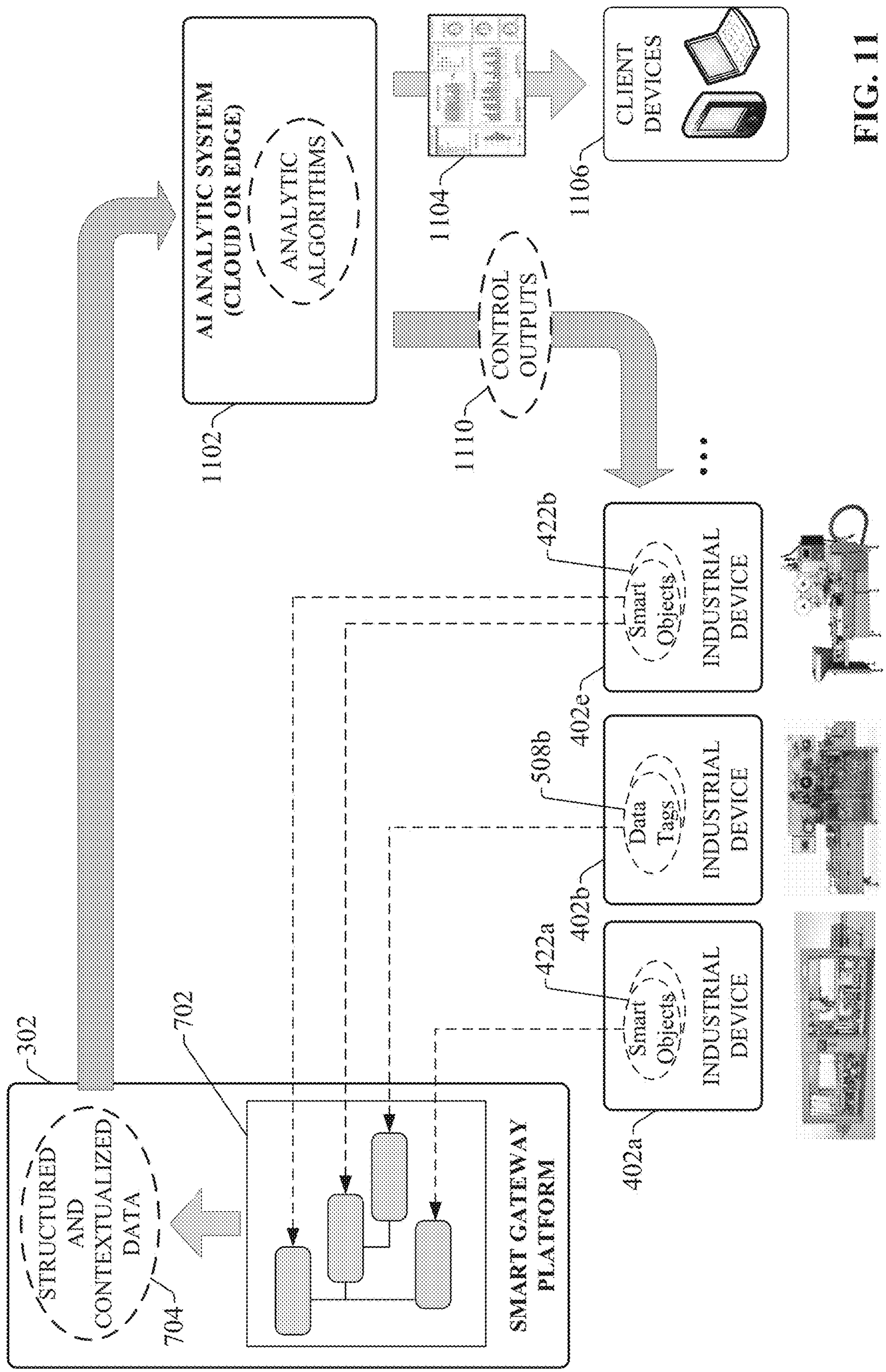
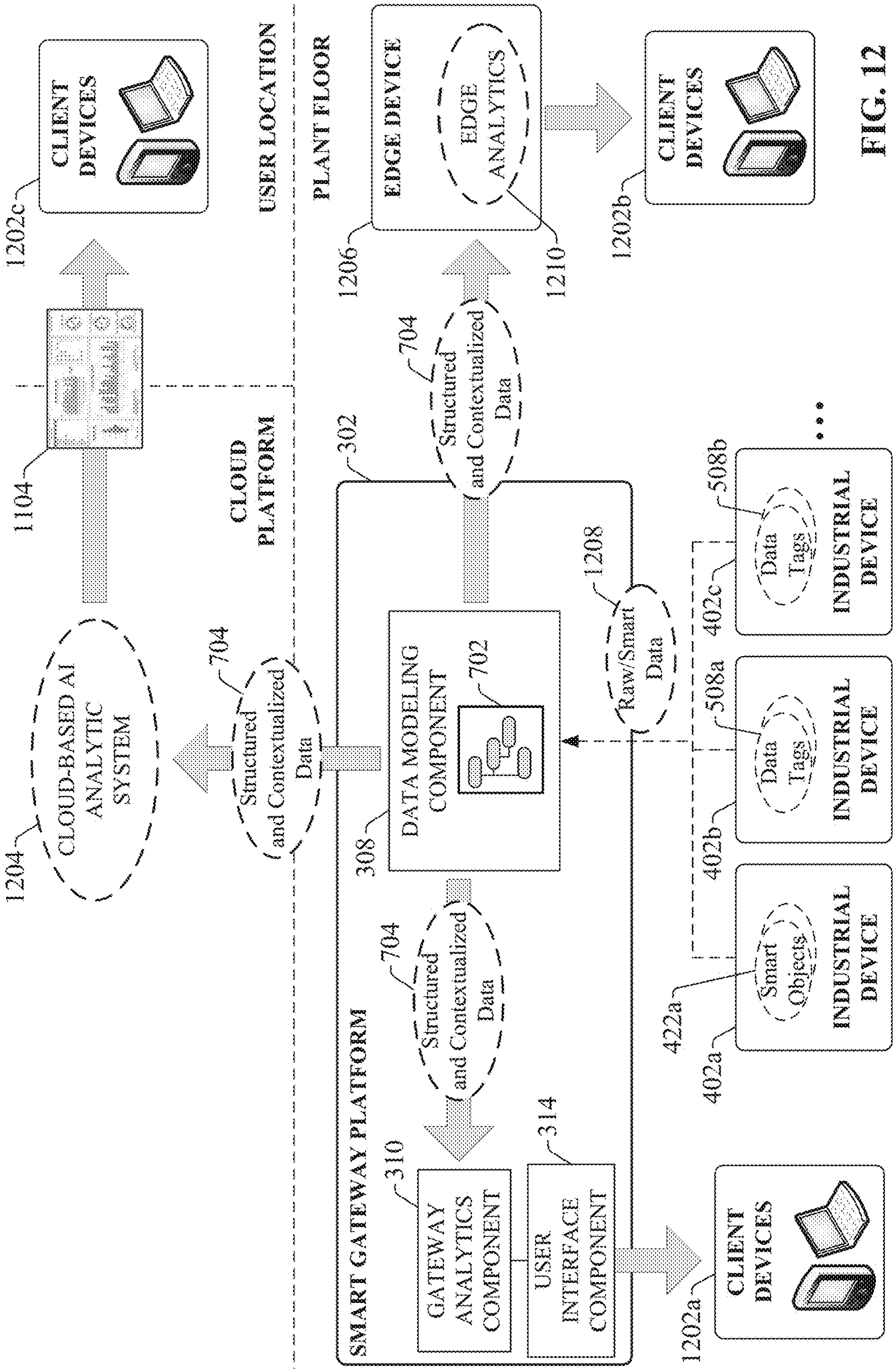

AI ANALYTIC SYSTEM
(CLOUD OR EDGE)
ANALYTIC
ALGORITHMS
1102
1104
CLIENT
DEVICES
1106
CONTROL
OUTPUTS
1110
302
702
STRUCTURED
AND
CONTEXTUALIZED
DATA
704
SMART GATEWAY
PLATFORM
Smart
Objects
422a
INDUSTRIAL
DEVICE
402a
Data
Tags
508b
INDUSTRIAL
DEVICE
402b
Smart
Objects
422b
INDUSTRIAL
DEVICE
402e

FIG. 11



CLIENT DEVICES
1202c
USER LOCATION
PLANT FLOOR
EDGE DEVICE
EDGE ANALYTICS
1206
1210
CLIENT DEVICES
1202b
1104
CLOUD PLATFORM
302
704
Structured and Contextualized Data
CLOUD-BASED AI ANALYTIC SYSTEM
1204
704
Structured and Contextualized Data
DATA MODELING COMPONENT
702
308
1208
Raw/Smart Data
Data Tags
508b
INDUSTRIAL DEVICE
402c
Data Tags
508a
INDUSTRIAL DEVICE
402b
Smart Objects
422a
INDUSTRIAL DEVICE
402a
704
Structured and Contextualized Data
SMART GATEWAY PLATFORM
310
GATEWAY ANALYTICS COMPONENT
314
USER INTERFACE COMPONENT
CLIENT DEVICES
1202a

FIG. 12

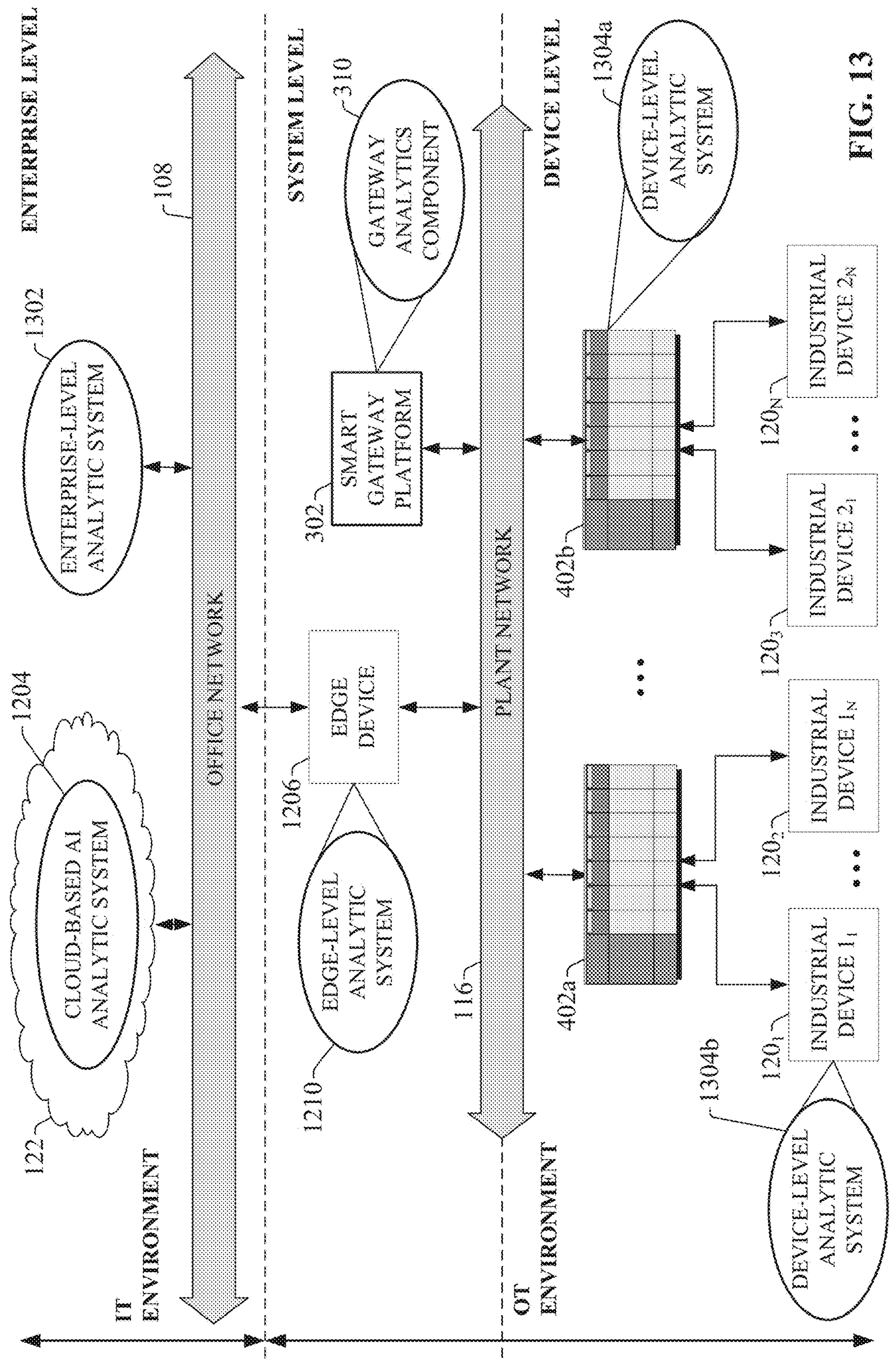
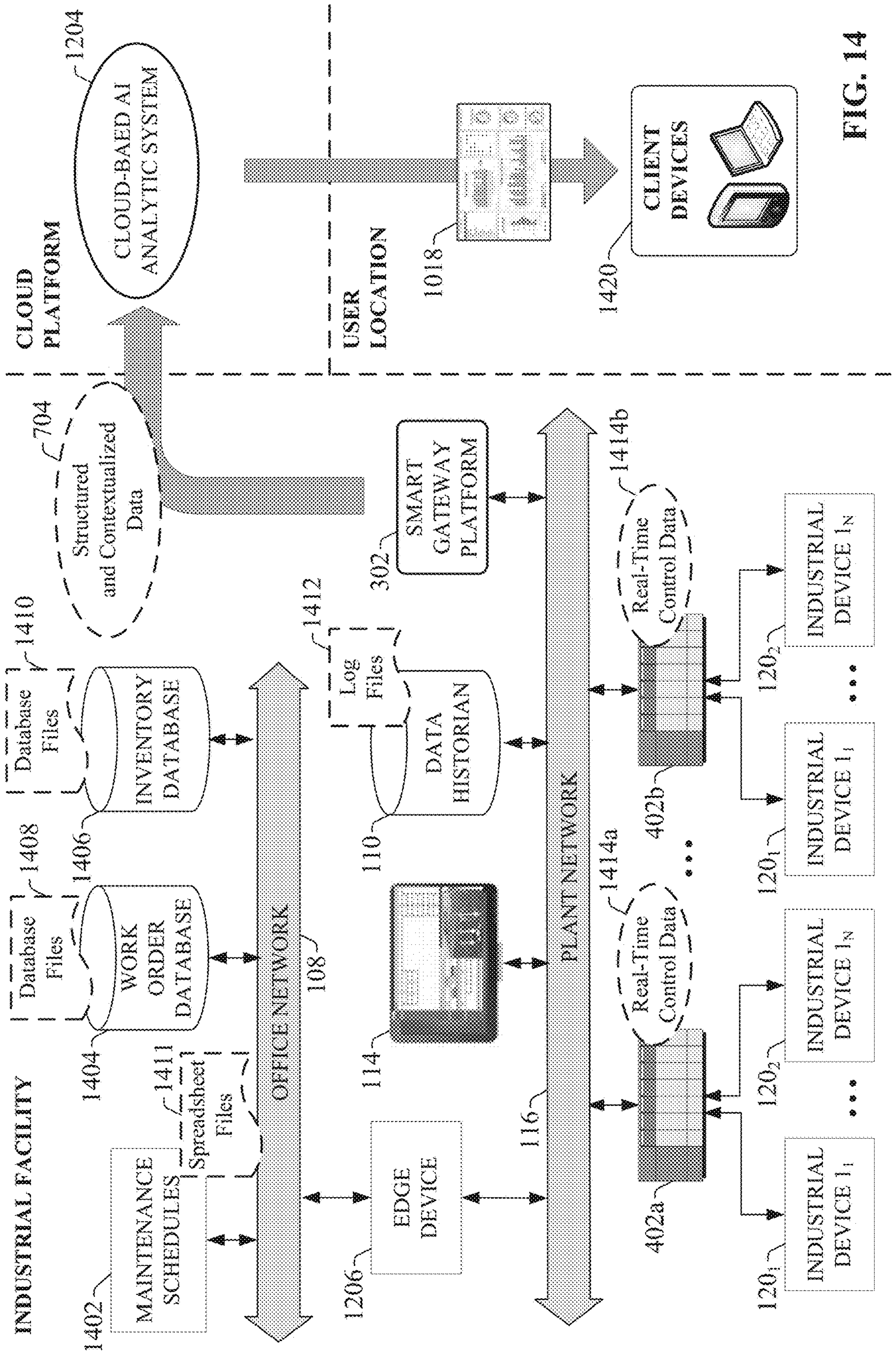

ENTERPRISE LEVEL
SYSTEM LEVEL
DEVICE LEVEL
IT ENVIRONMENT
OT ENVIRONMENT
122
1204
CLOUD-BASED AI ANALYTIC SYSTEM
1302
ENTERPRISE-LEVEL ANALYTIC SYSTEM
108
OFFICE NETWORK
1206
EDGE DEVICE
1210
EDGE-LEVEL ANALYTIC SYSTEM
302
SMART GATEWAY PLATFORM
310
GATEWAY ANALYTICS COMPONENT
116
PLANT NETWORK
402a
402b
1304a
DEVICE-LEVEL ANALYTIC SYSTEM
1304b
DEVICE-LEVEL ANALYTIC SYSTEM
120_1
INDUSTRIAL DEVICE 1_1
120_2
INDUSTRIAL DEVICE 1_N
120_3
INDUSTRIAL DEVICE 2_1
120_N
INDUSTRIAL DEVICE 2_N

FIG. 13



INDUSTRIAL FACILITY
CLOUD PLATFORM
USER LOCATION
1204
CLOUD-BAED AI ANALYTIC SYSTEM
704
Structured and Contextualized Data
1018
1420
CLIENT DEVICES
1402
MAINTENANCE SCHEDULES
1411
Spreadsheet Files
1404
WORK ORDER DATABASE
1408
Database Files
1406
INVENTORY DATABASE
1410
Database Files
OFFICE NETWORK
108
1206
EDGE DEVICE
114
110
DATA HISTORIAN
1412
Log Files
302
SMART GATEWAY PLATFORM
116
PLANT NETWORK
1414a
Real-Time Control Data
1414b
Real-Time Control Data
402a
402b
120_1
INDUSTRIAL DEVICE 1_1
120_2
INDUSTRIAL DEVICE 1_N
120_1
INDUSTRIAL DEVICE 1_1
120_2
INDUSTRIAL DEVICE 1_N

FIG. 14

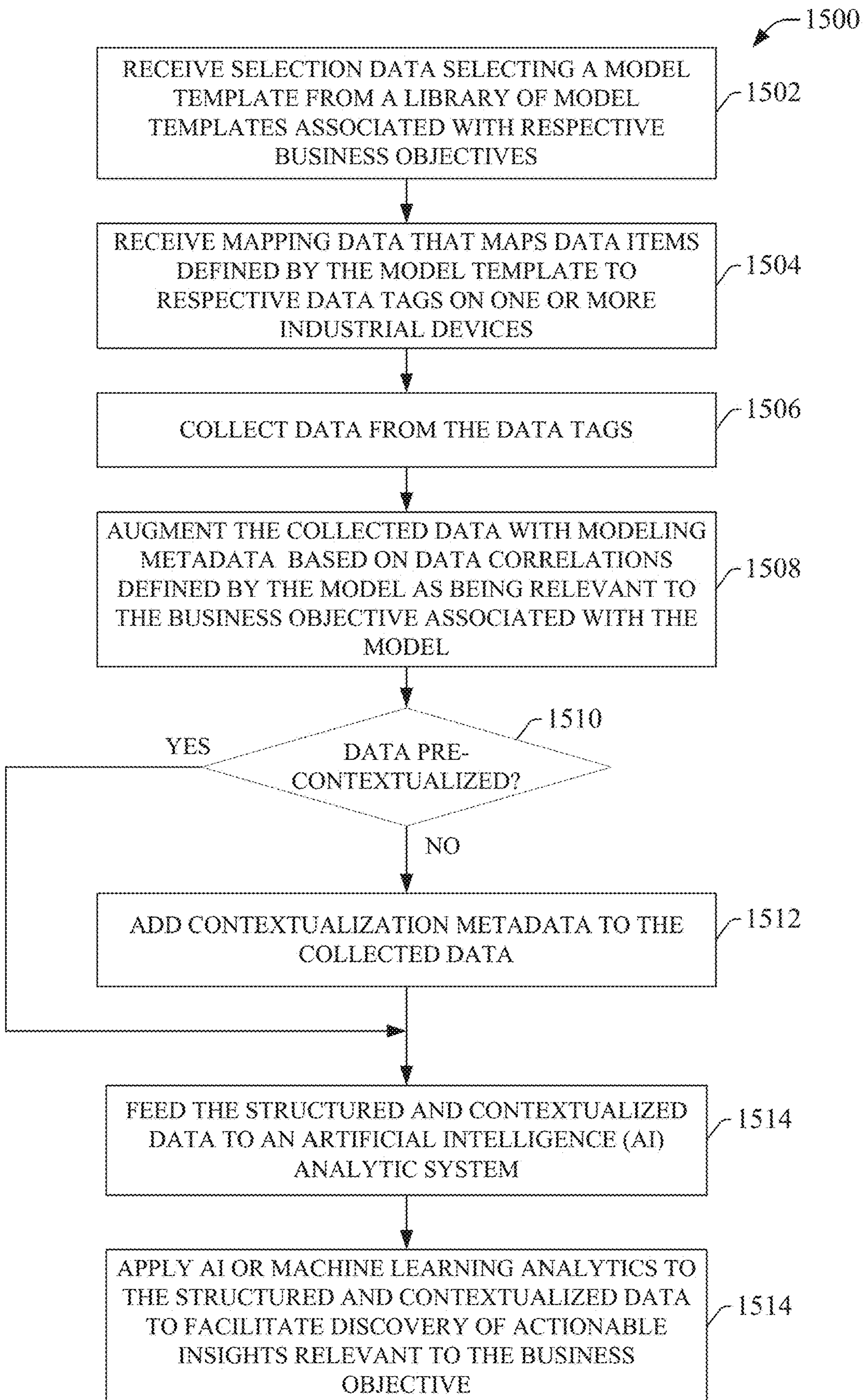

1500
RECEIVE SELECTION DATA SELECTING A MODEL TEMPLATE FROM A LIBRARY OF MODEL TEMPLATES ASSOCIATED WITH RESPECTIVE BUSINESS OBJECTIVES
1502
RECEIVE MAPPING DATA THAT MAPS DATA ITEMS DEFINED BY THE MODEL TEMPLATE TO RESPECTIVE DATA TAGS ON ONE OR MORE INDUSTRIAL DEVICES
1504
COLLECT DATA FROM THE DATA TAGS
1506
AUGMENT THE COLLECTED DATA WITH MODELING METADATA BASED ON DATA CORRELATIONS DEFINED BY THE MODEL AS BEING RELEVANT TO THE BUSINESS OBJECTIVE ASSOCIATED WITH THE MODEL
1508
DATA PRE-CONTEXTUALIZED?
1510
YES
NO
ADD CONTEXTUALIZATION METADATA TO THE COLLECTED DATA
1512
FEED THE STRUCTURED AND CONTEXTUALIZED DATA TO AN ARTIFICIAL INTELLIGENCE (AI) ANALYTIC SYSTEM
1514
APPLY AI OR MACHINE LEARNING ANALYTICS TO THE STRUCTURED AND CONTEXTUALIZED DATA TO FACILITATE DISCOVERY OF ACTIONABLE INSIGHTS RELEVANT TO THE BUSINESS OBJECTIVE
1514

FIG. 15

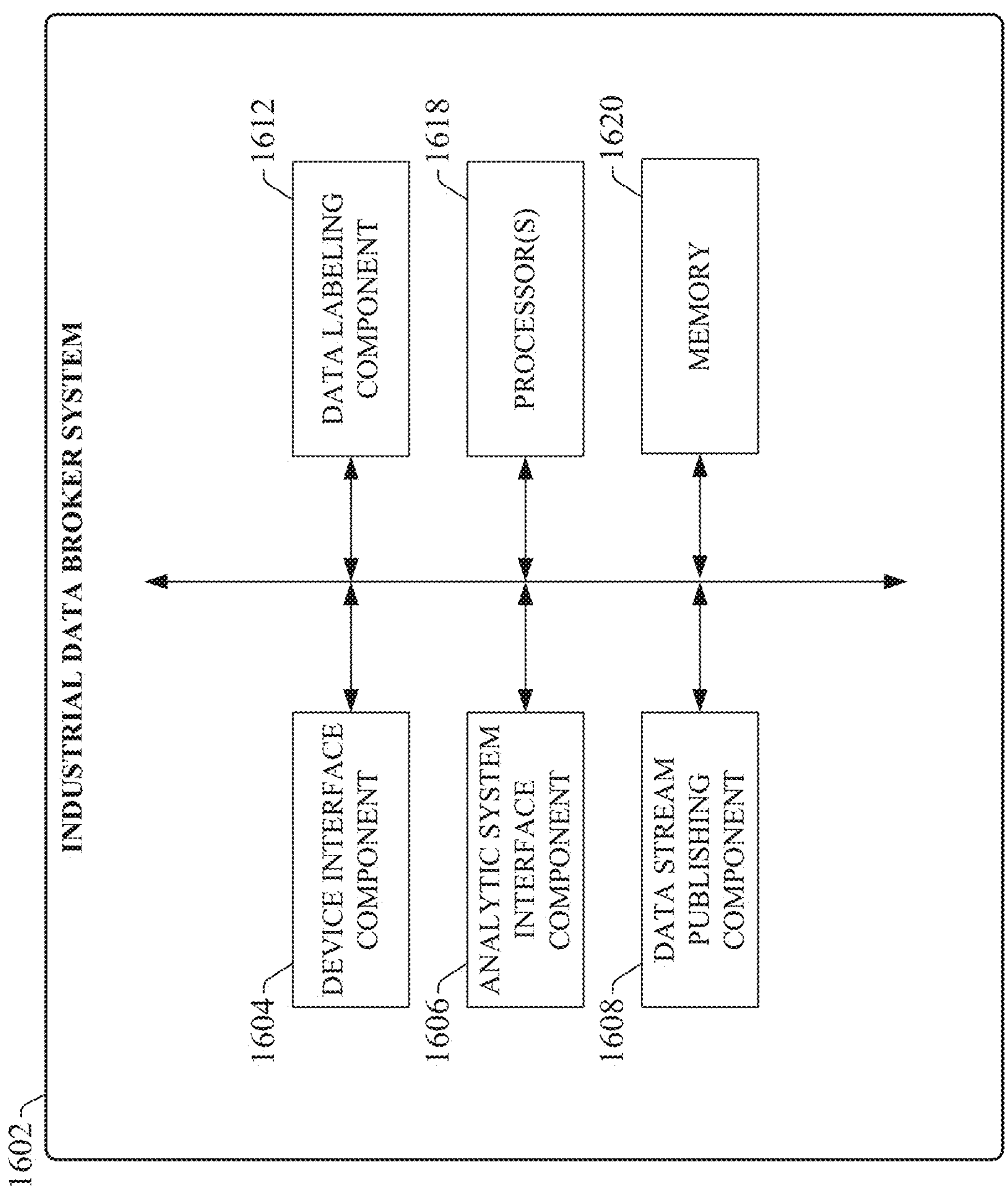

INDUSTRIAL DATA BROKER SYSTEM
1602
DEVICE INTERFACE COMPONENT
1604
ANALYTIC SYSTEM INTERFACE COMPONENT
1606
DATA STREAM PUBLISHING COMPONENT
1608
DATA LABELING COMPONENT
1612
PROCESSOR(S)
1618
MEMORY
1620

FIG. 16

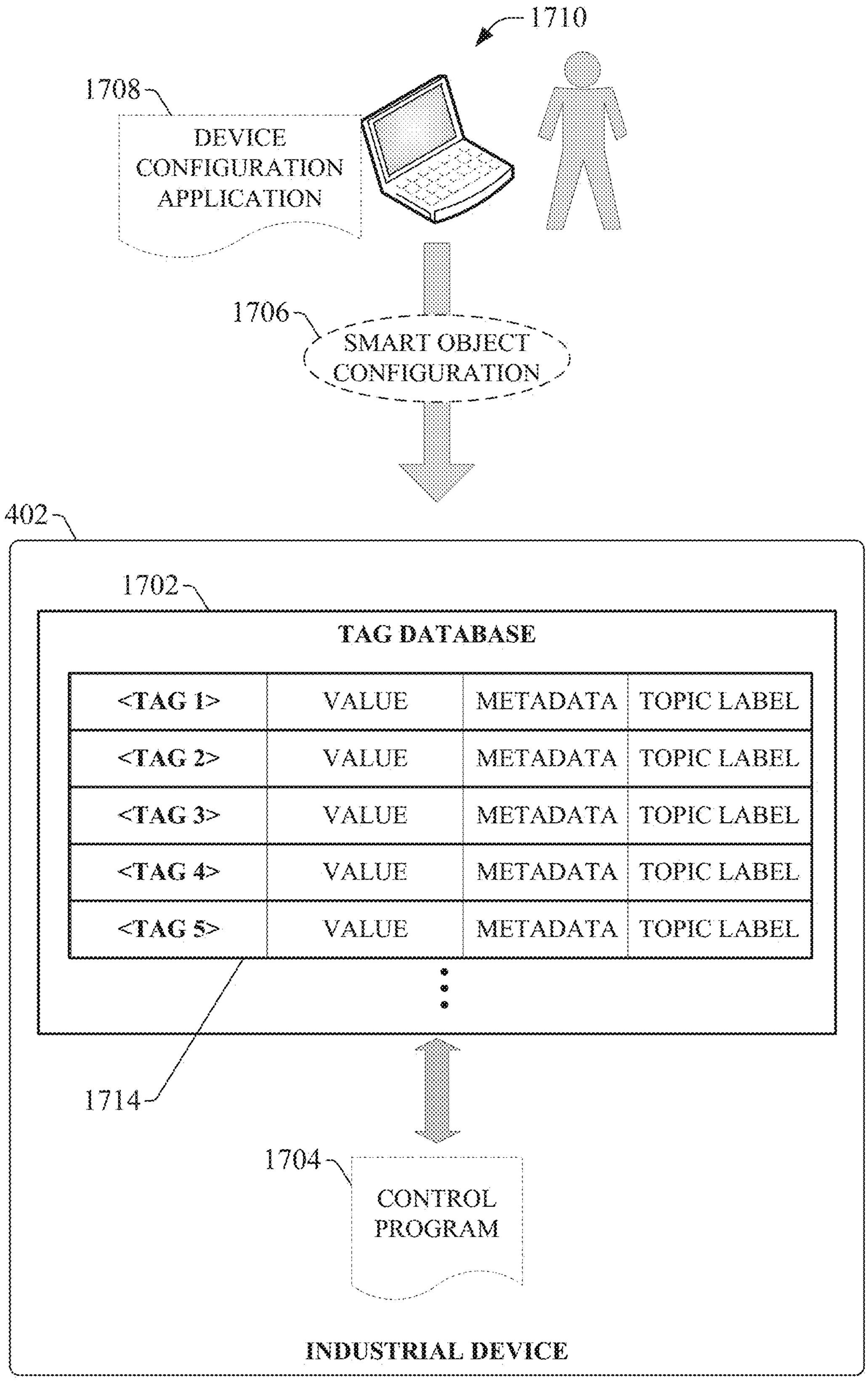

1710
1708
DEVICE CONFIGURATION APPLICATION
1706
SMART OBJECT CONFIGURATION
402
1702
TAG DATABASE
<TAG 1> VALUE METADATA TOPIC LABEL
<TAG 2> VALUE METADATA TOPIC LABEL
<TAG 3> VALUE METADATA TOPIC LABEL
<TAG 4> VALUE METADATA TOPIC LABEL
<TAG 5> VALUE METADATA TOPIC LABEL
1714
1704
CONTROL PROGRAM
INDUSTRIAL DEVICE

FIG. 17

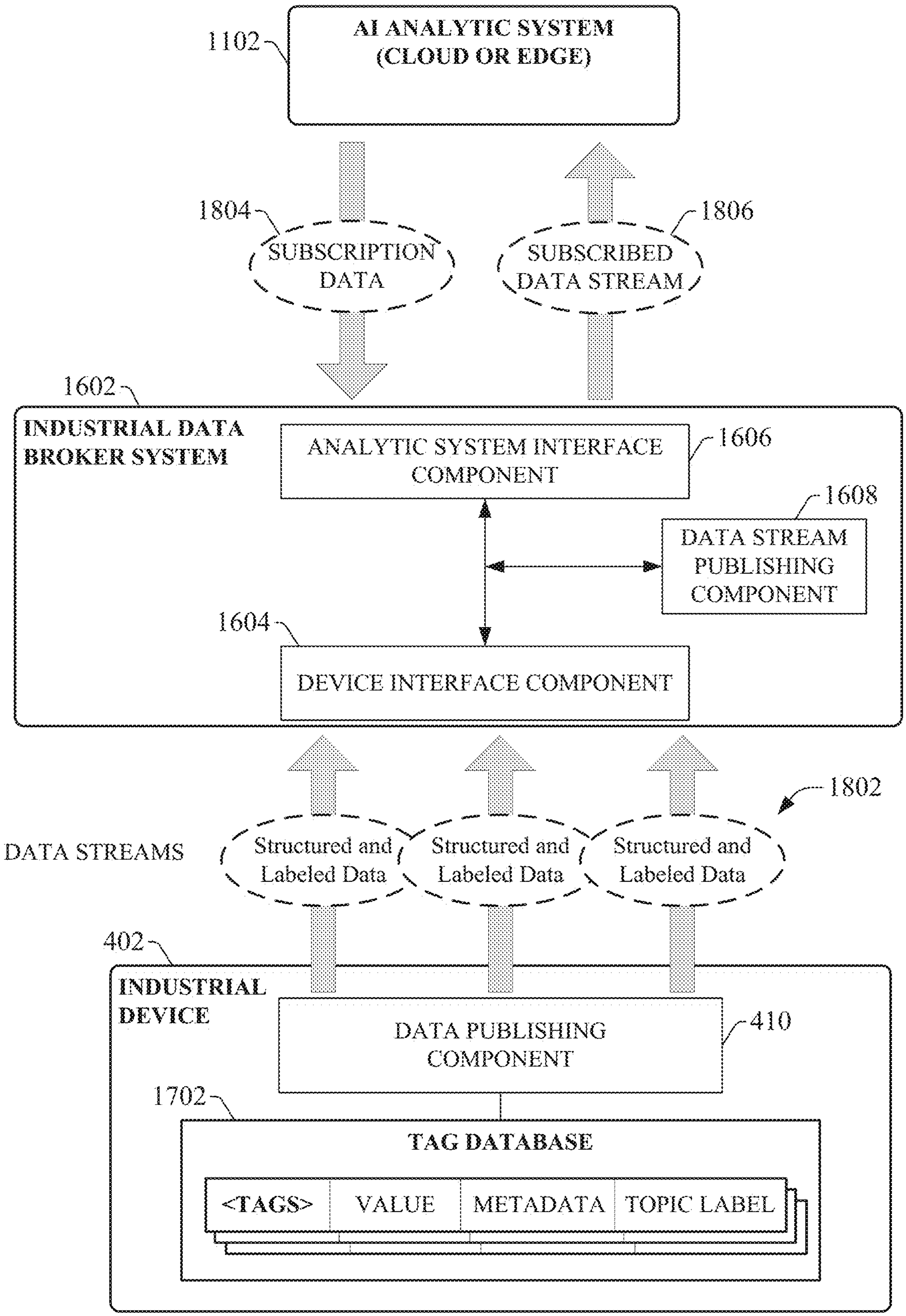

1102
AI ANALYTIC SYSTEM
(CLOUD OR EDGE)
1804
SUBSCRIPTION DATA
1806
SUBSCRIBED DATA STREAM
1602
INDUSTRIAL DATA BROKER SYSTEM
ANALYTIC SYSTEM INTERFACE COMPONENT
1606
1608
DATA STREAM PUBLISHING COMPONENT
1604
DEVICE INTERFACE COMPONENT
1802
DATA STREAMS
Structured and Labeled Data
Structured and Labeled Data
Structured and Labeled Data
402
INDUSTRIAL DEVICE
DATA PUBLISHING COMPONENT
410
1702
TAG DATABASE
<TAGS>
VALUE
METADATA
TOPIC LABEL

FIG. 18

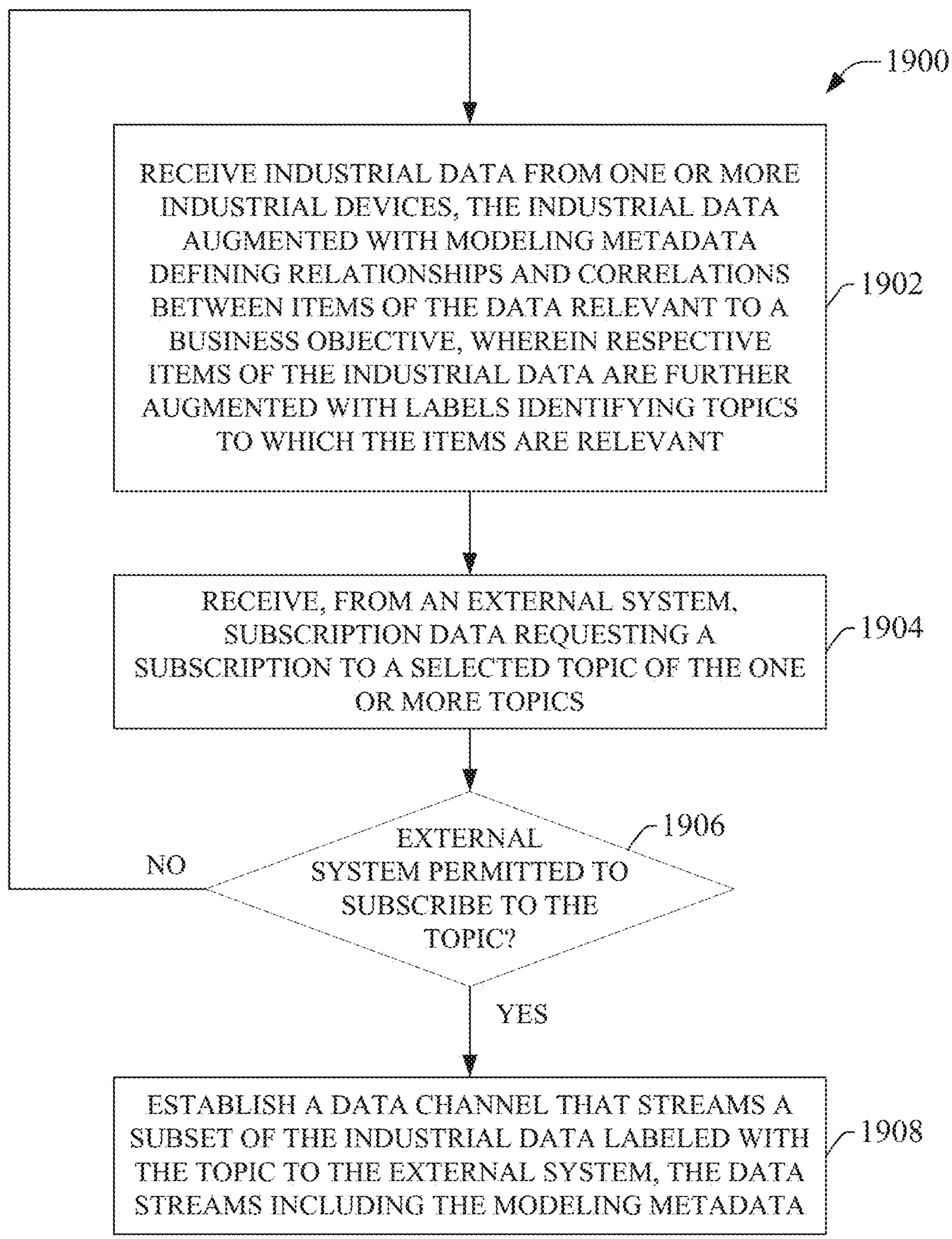

1900
RECEIVE INDUSTRIAL DATA FROM ONE OR MORE INDUSTRIAL DEVICES, THE INDUSTRIAL DATA AUGMENTED WITH MODELING METADATA DEFINING RELATIONSHIPS AND CORRELATIONS BETWEEN ITEMS OF THE DATA RELEVANT TO A BUSINESS OBJECTIVE, WHEREIN RESPECTIVE ITEMS OF THE INDUSTRIAL DATA ARE FURTHER AUGMENTED WITH LABELS IDENTIFYING TOPICS TO WHICH THE ITEMS ARE RELEVANT
1902
RECEIVE, FROM AN EXTERNAL SYSTEM, SUBSCRIPTION DATA REQUESTING A SUBSCRIPTION TO A SELECTED TOPIC OF THE ONE OR MORE TOPICS
1904
EXTERNAL SYSTEM PERMITTED TO SUBSCRIBE TO THE TOPIC?
1906
NO
YES
ESTABLISH A DATA CHANNEL THAT STREAMS A SUBSET OF THE INDUSTRIAL DATA LABELED WITH THE TOPIC TO THE EXTERNAL SYSTEM, THE DATA STREAMS INCLUDING THE MODELING METADATA
1908

FIG. 19

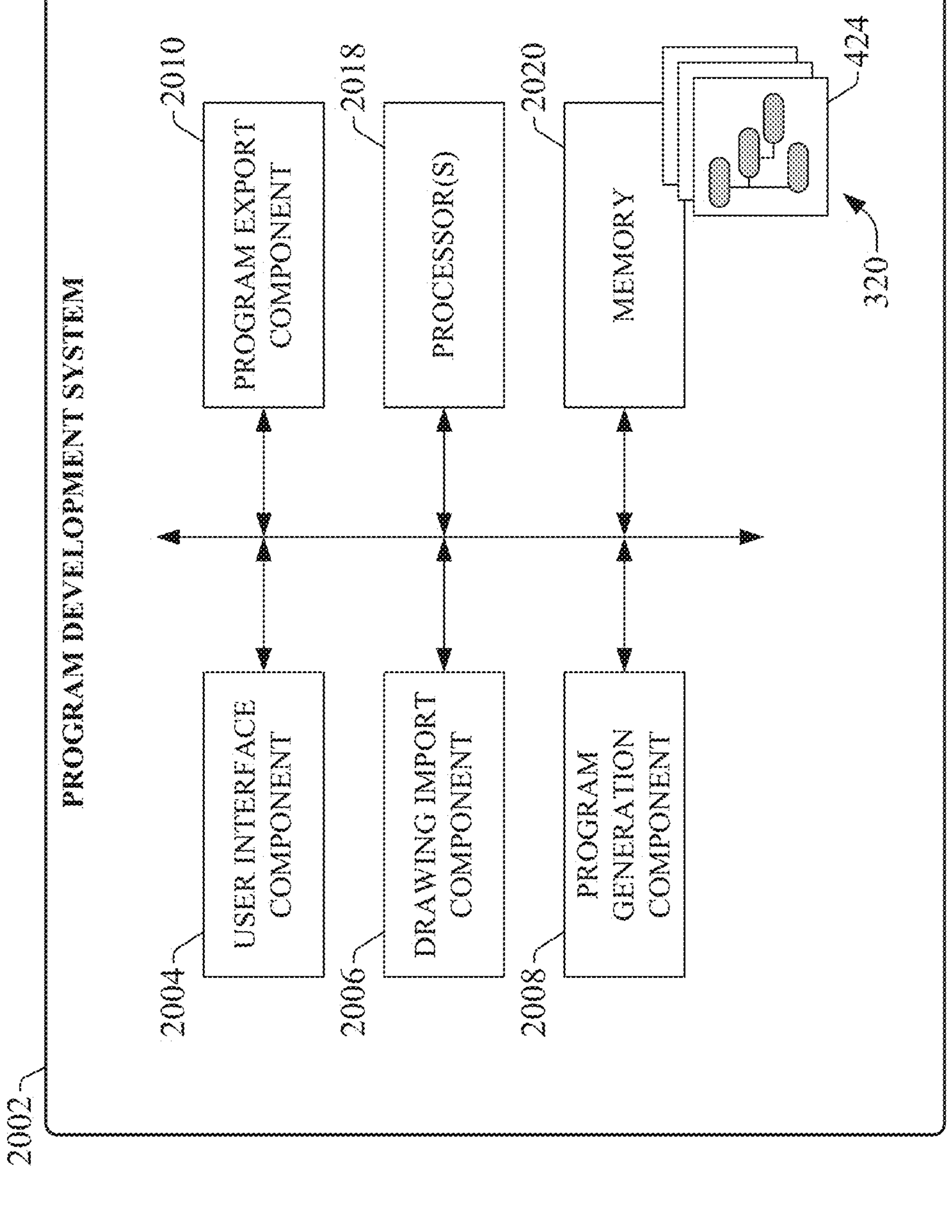
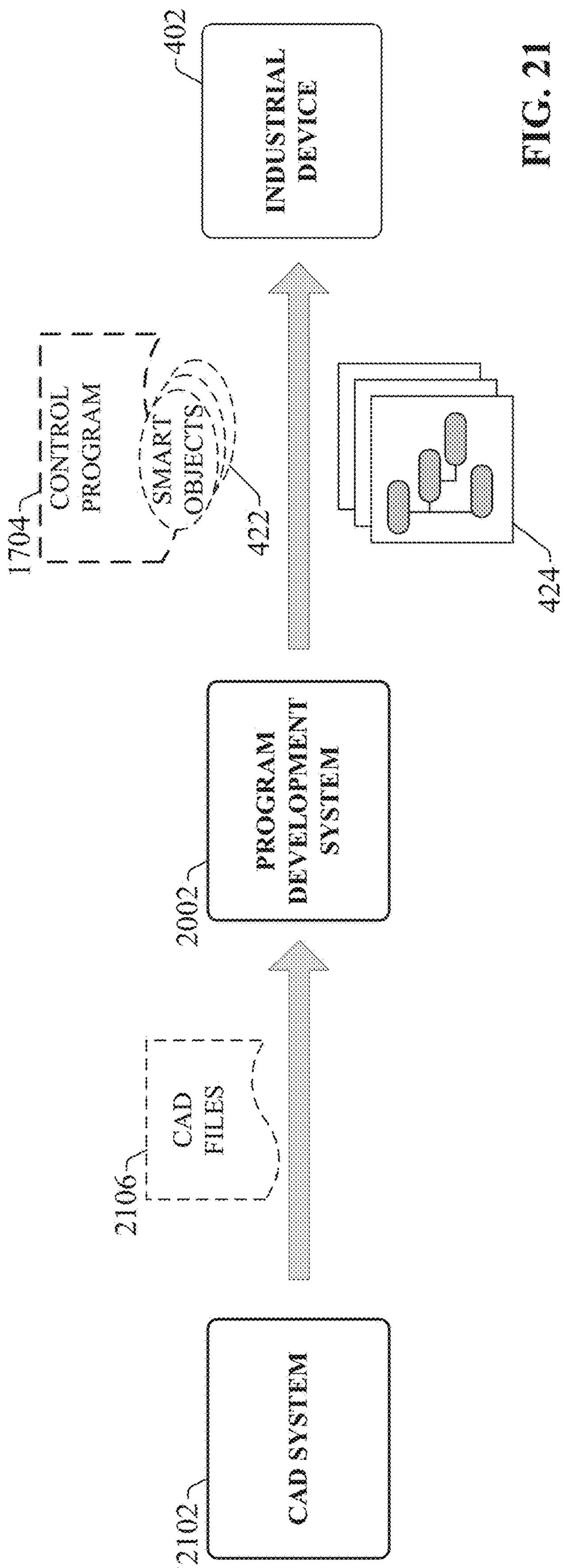

PROGRAM DEVELOPMENT SYSTEM
2002
USER INTERFACE COMPONENT
2004
DRAWING IMPORT COMPONENT
2006
PROGRAM GENERATION COMPONENT
2008
PROGRAM EXPORT COMPONENT
2010
PROCESSOR(S)
2018
MEMORY
2020
424
320

FIG. 20



402
INDUSTRIAL DEVICE
1704
CONTROL PROGRAM
SMART OBJECTS
422
424
2002
PROGRAM DEVELOPMENT SYSTEM
2106
CAD FILES
2102
CAD SYSTEM

FIG. 21

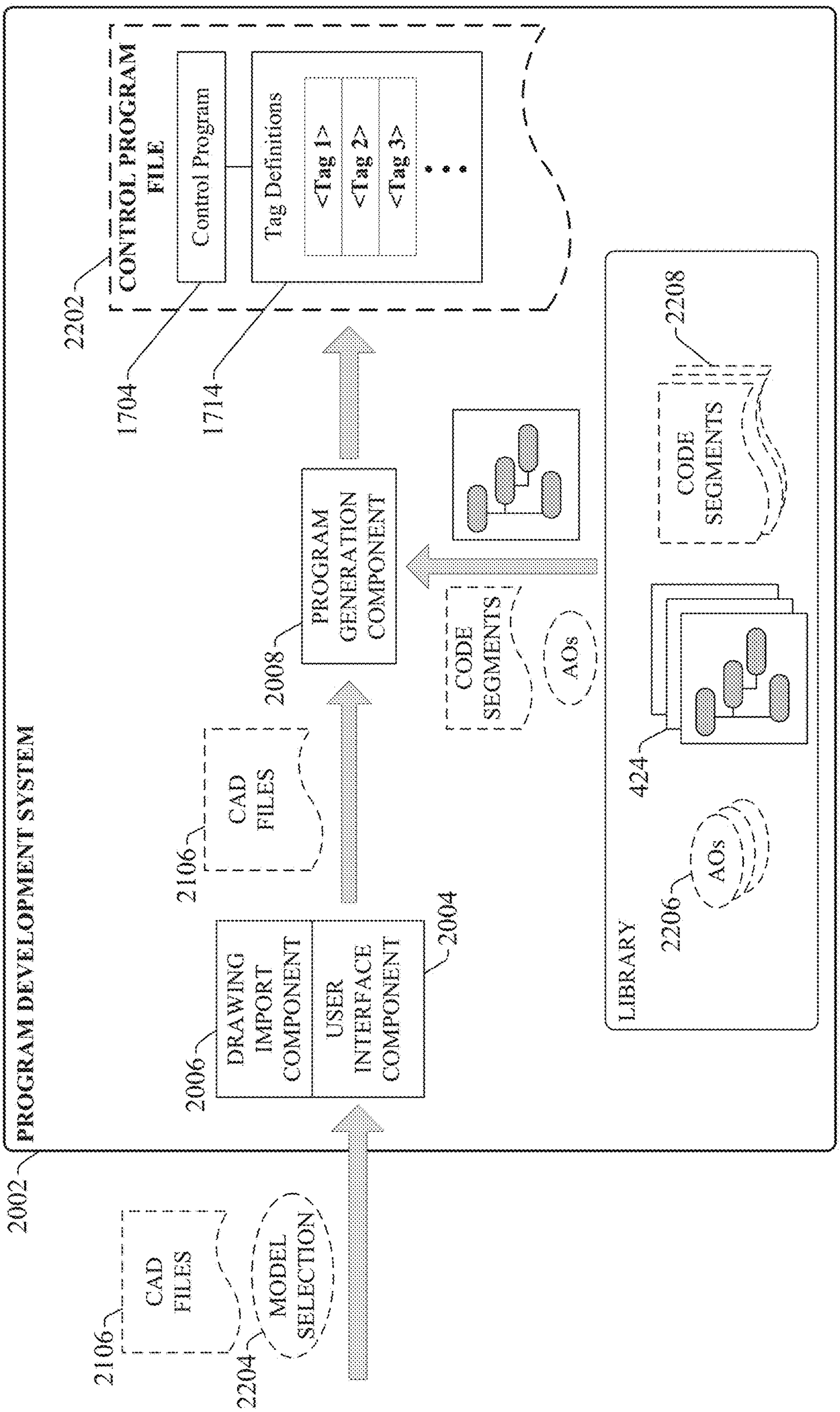

PROGRAM DEVELOPMENT SYSTEM
2002
CAD FILES
2106
MODEL SELECTION
2204
DRAWING IMPORT COMPONENT
2006
USER INTERFACE COMPONENT
2004
CAD FILES
2106
PROGRAM GENERATION COMPONENT
2008
CODE SEGMENTS
AOs
CONTROL PROGRAM FILE
2202
Control Program
1704
Tag Definitions
1714
<Tag 1>
<Tag 2>
<Tag 3>
LIBRARY
AOs
2206
424
CODE SEGMENTS
2208

FIG. 22

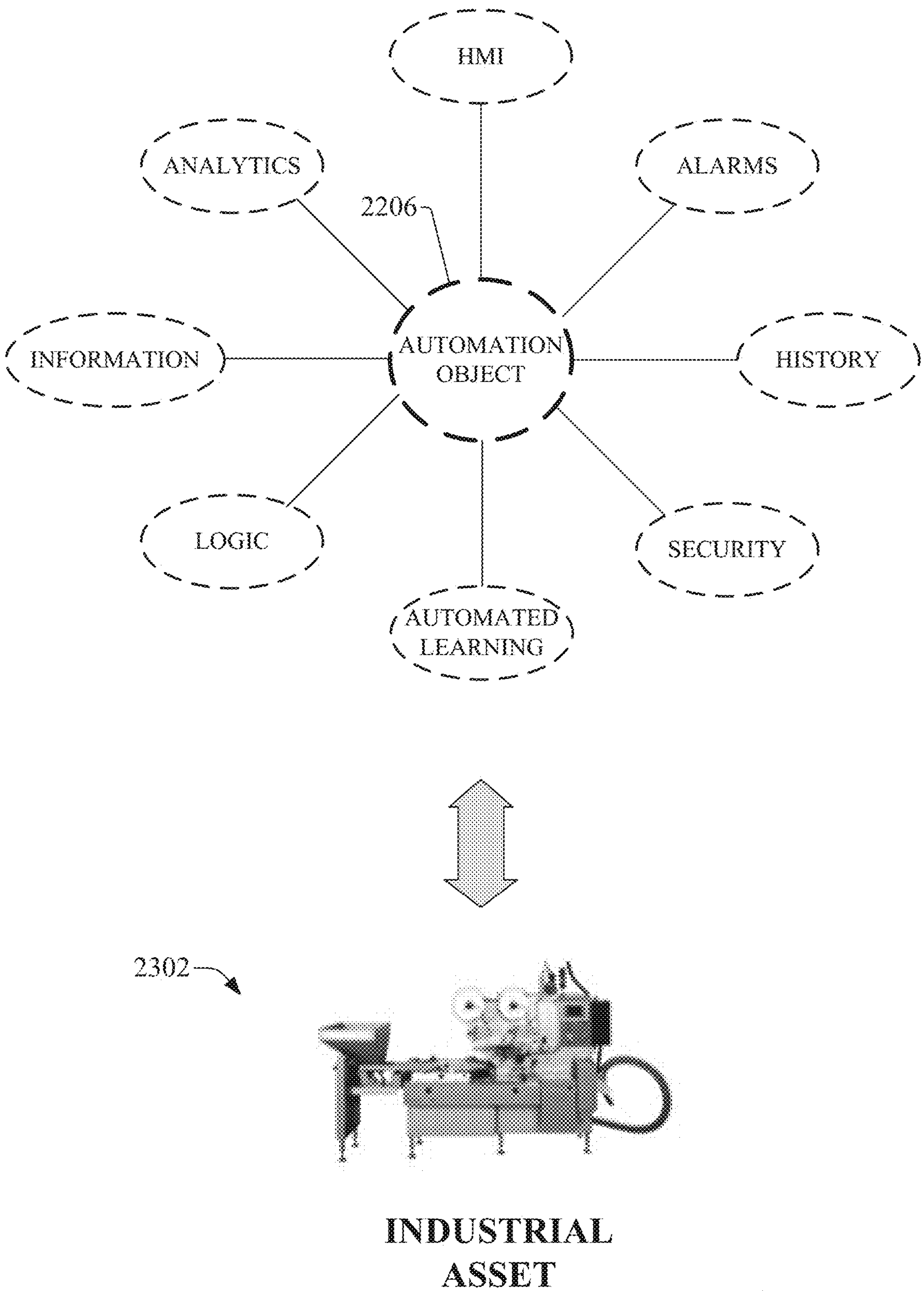
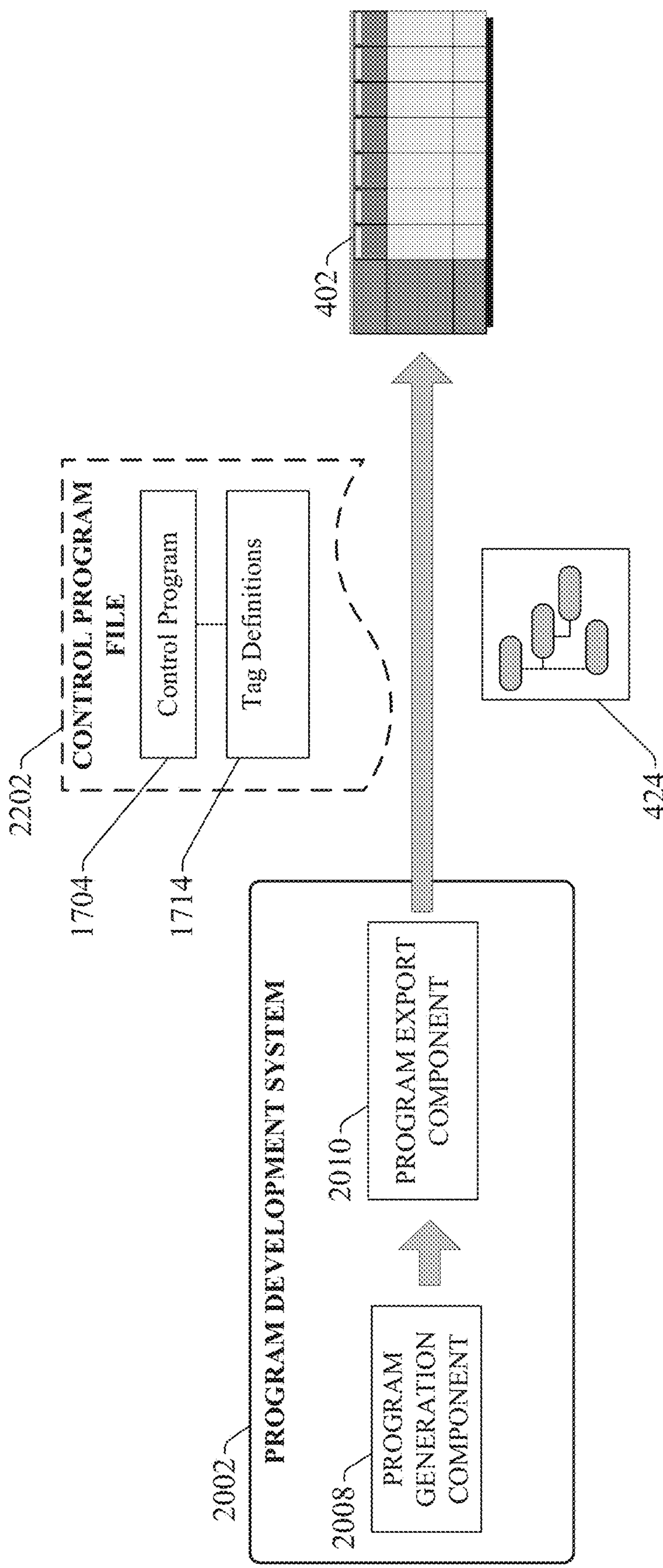

HMI
ANALYTICS
ALARMS
2206
AUTOMATION OBJECT
INFORMATION
HISTORY
LOGIC
SECURITY
AUTOMATED LEARNING
2302
INDUSTRIAL ASSET

FIG. 23



402
CONTROL PROGRAM FILE
Control Program
Tag Definitions
2202
1704
1714
424
PROGRAM DEVELOPMENT SYSTEM
PROGRAM EXPORT COMPONENT
PROGRAM GENERATION COMPONENT
2002
2008
2010

FIG. 24

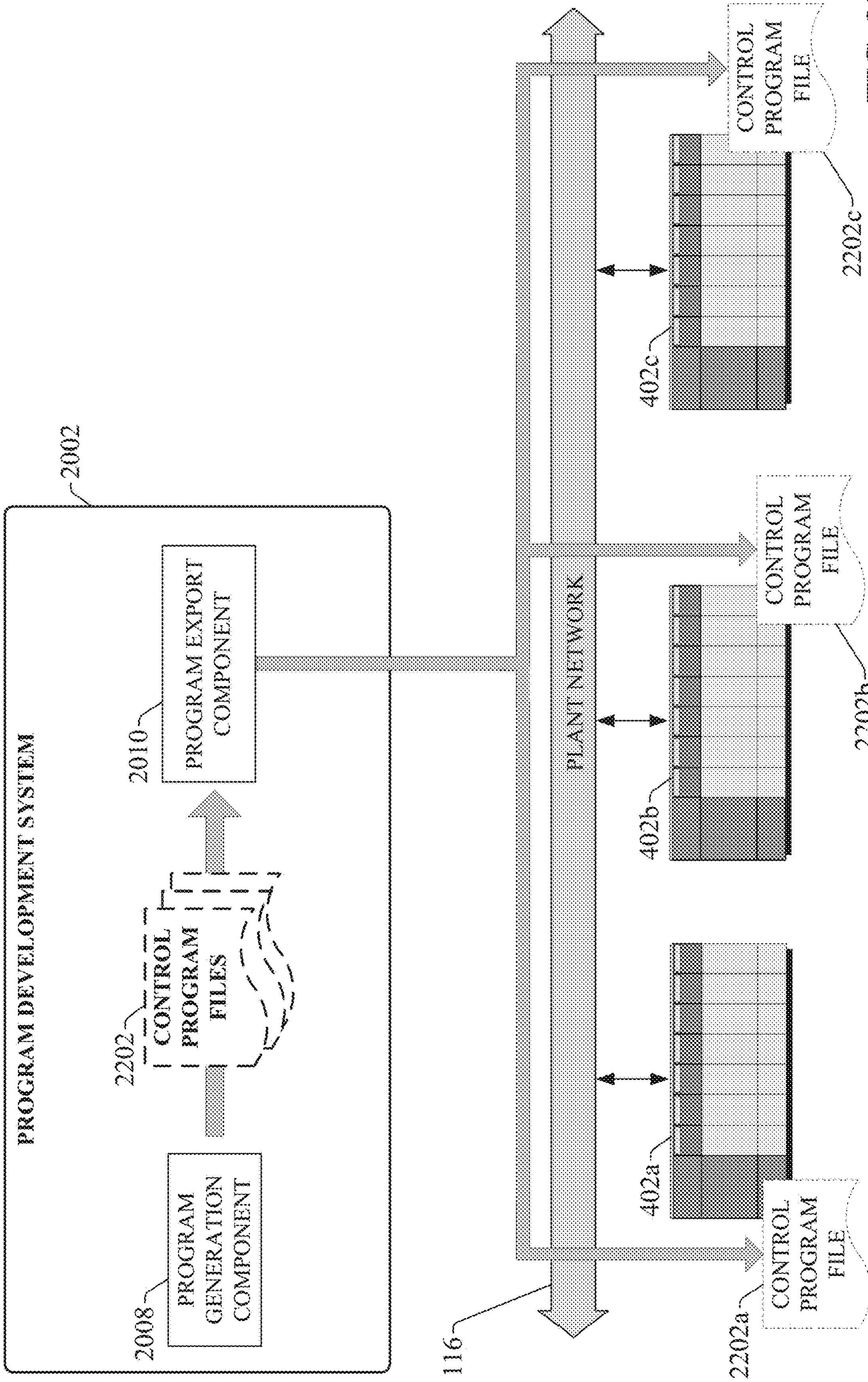

2002
PROGRAM DEVELOPMENT SYSTEM
2008
PROGRAM GENERATION COMPONENT
2202
CONTROL PROGRAM FILES
2010
PROGRAM EXPORT COMPONENT
PLANT NETWORK
116
402a
402b
402c
CONTROL PROGRAM FILE
2202a
CONTROL PROGRAM FILE
2202b
CONTROL PROGRAM FILE
2202c

FIG. 25

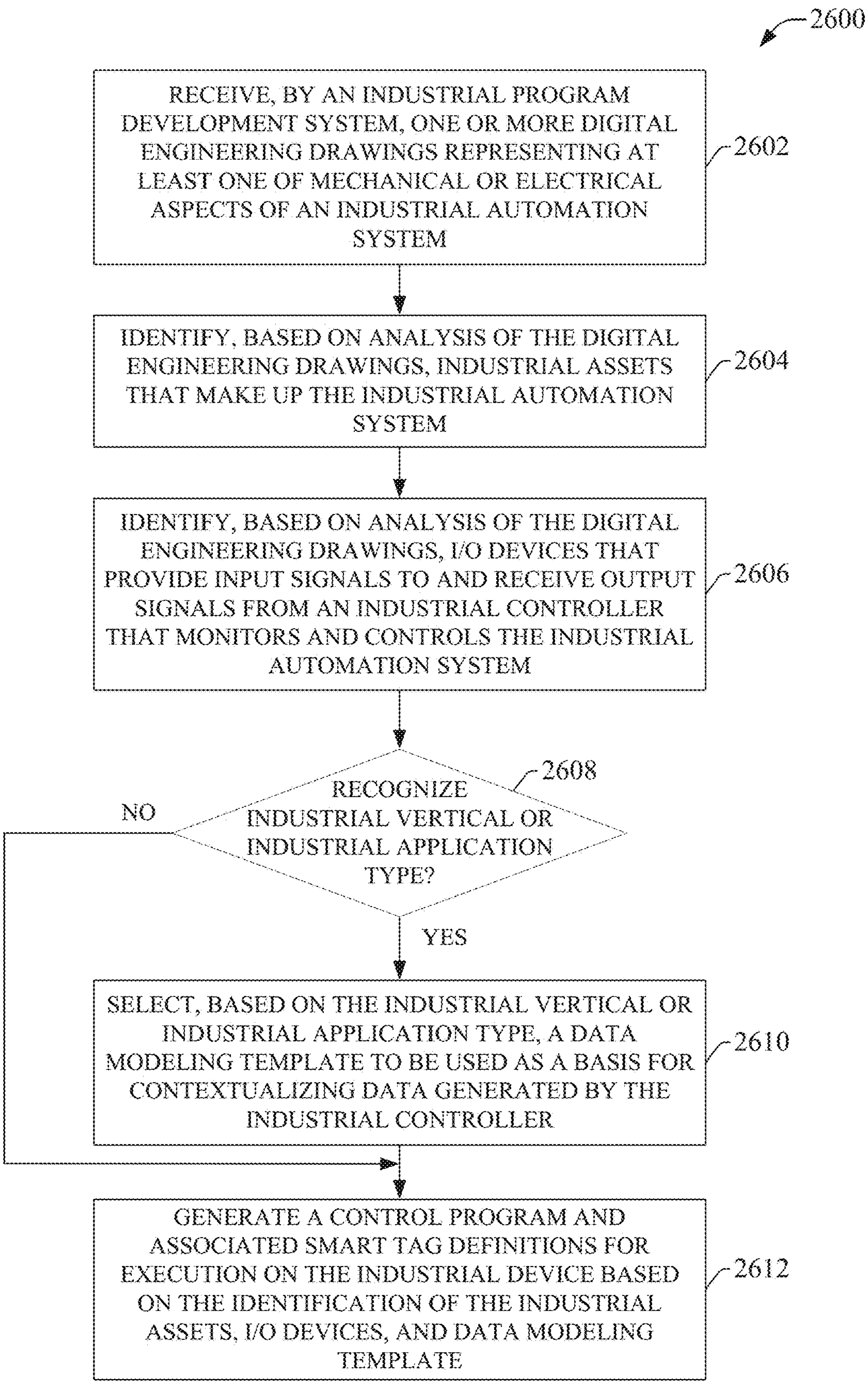

2600
RECEIVE, BY AN INDUSTRIAL PROGRAM DEVELOPMENT SYSTEM, ONE OR MORE DIGITAL ENGINEERING DRAWINGS REPRESENTING AT LEAST ONE OF MECHANICAL OR ELECTRICAL ASPECTS OF AN INDUSTRIAL AUTOMATION SYSTEM
2602
IDENTIFY, BASED ON ANALYSIS OF THE DIGITAL ENGINEERING DRAWINGS, INDUSTRIAL ASSETS THAT MAKE UP THE INDUSTRIAL AUTOMATION SYSTEM
2604
IDENTIFY, BASED ON ANALYSIS OF THE DIGITAL ENGINEERING DRAWINGS, I/O DEVICES THAT PROVIDE INPUT SIGNALS TO AND RECEIVE OUTPUT SIGNALS FROM AN INDUSTRIAL CONTROLLER THAT MONITORS AND CONTROLS THE INDUSTRIAL AUTOMATION SYSTEM
2606
RECOGNIZE INDUSTRIAL VERTICAL OR INDUSTRIAL APPLICATION TYPE?
2608
NO
YES
SELECT, BASED ON THE INDUSTRIAL VERTICAL OR INDUSTRIAL APPLICATION TYPE, A DATA MODELING TEMPLATE TO BE USED AS A BASIS FOR CONTEXTUALIZING DATA GENERATED BY THE INDUSTRIAL CONTROLLER
2610
GENERATE A CONTROL PROGRAM AND ASSOCIATED SMART TAG DEFINITIONS FOR EXECUTION ON THE INDUSTRIAL DEVICE BASED ON THE IDENTIFICATION OF THE INDUSTRIAL ASSETS, I/O DEVICES, AND DATA MODELING TEMPLATE
2612

FIG. 26

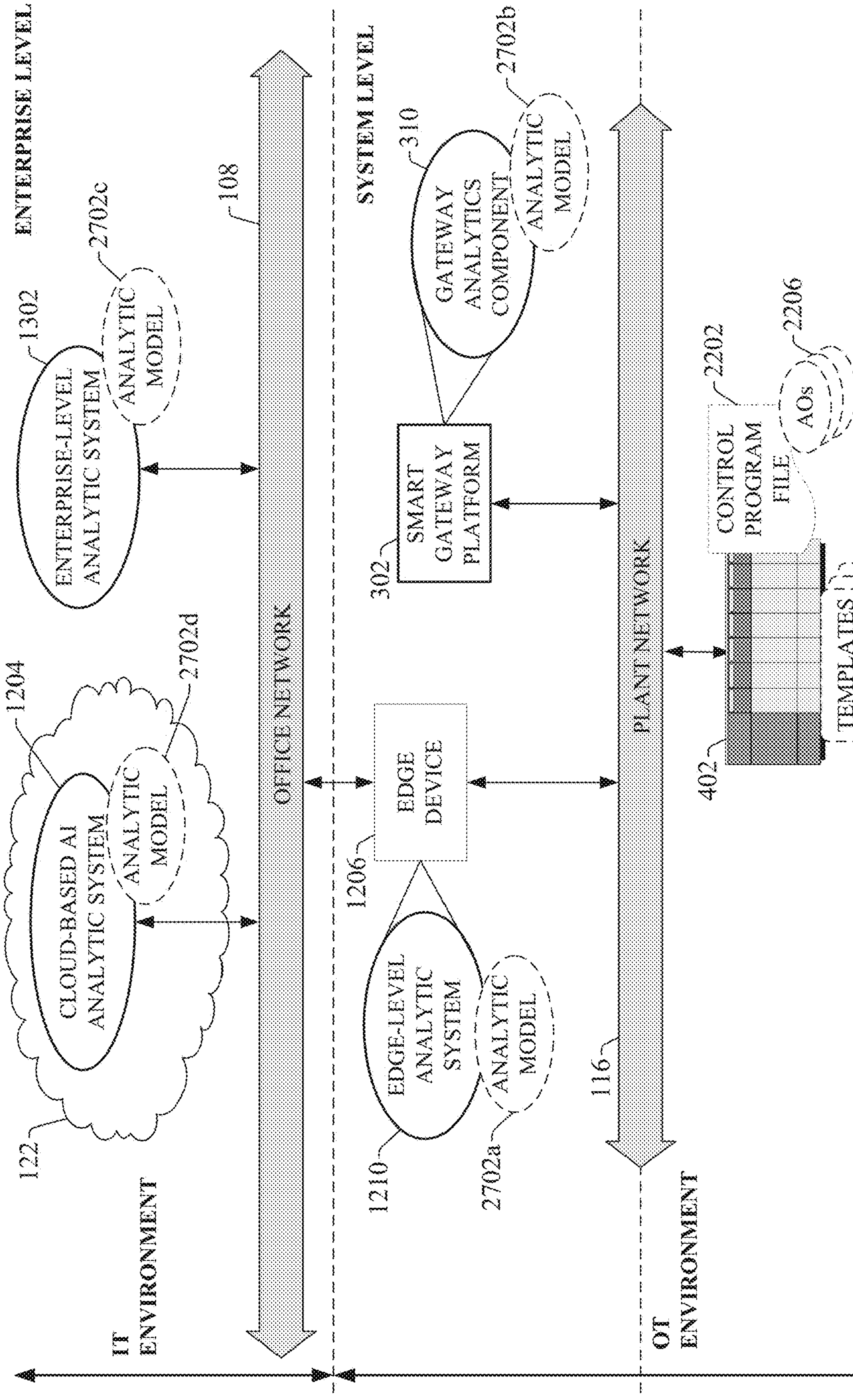

ENTERPRISE LEVEL
SYSTEM LEVEL
IT ENVIRONMENT
OT ENVIRONMENT
122
1204
CLOUD-BASED AI ANALYTIC SYSTEM
ANALYTIC MODEL
2702d
1302
ENTERPRISE-LEVEL ANALYTIC SYSTEM
ANALYTIC MODEL
2702c
108
OFFICE NETWORK
1210
EDGE-LEVEL ANALYTIC SYSTEM
ANALYTIC MODEL
2702a
1206
EDGE DEVICE
302
SMART GATEWAY PLATFORM
310
GATEWAY ANALYTICS COMPONENT
ANALYTIC MODEL
2702b
116
PLANT NETWORK
402
TEMPLATES
424
CONTROL PROGRAM FILE
2202
AOs
2206

FIG. 27

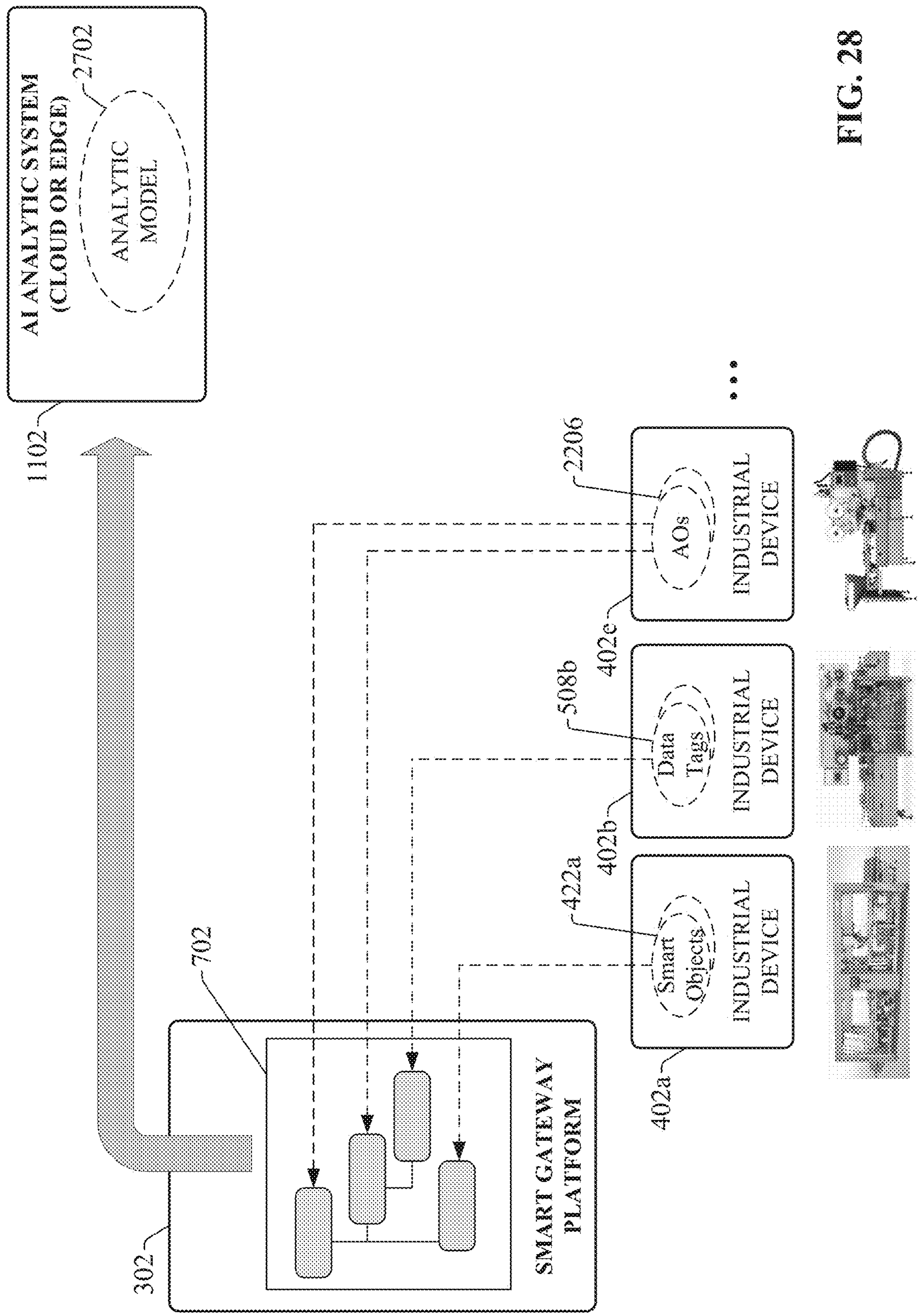

AI ANALYTIC SYSTEM
(CLOUD OR EDGE)
ANALYTIC MODEL
2702
1102
302
SMART GATEWAY PLATFORM
702
422a
Smart Objects
INDUSTRIAL DEVICE
402a
508b
Data Tags
INDUSTRIAL DEVICE
402b
2206
AOs
INDUSTRIAL DEVICE
402e

FIG. 28

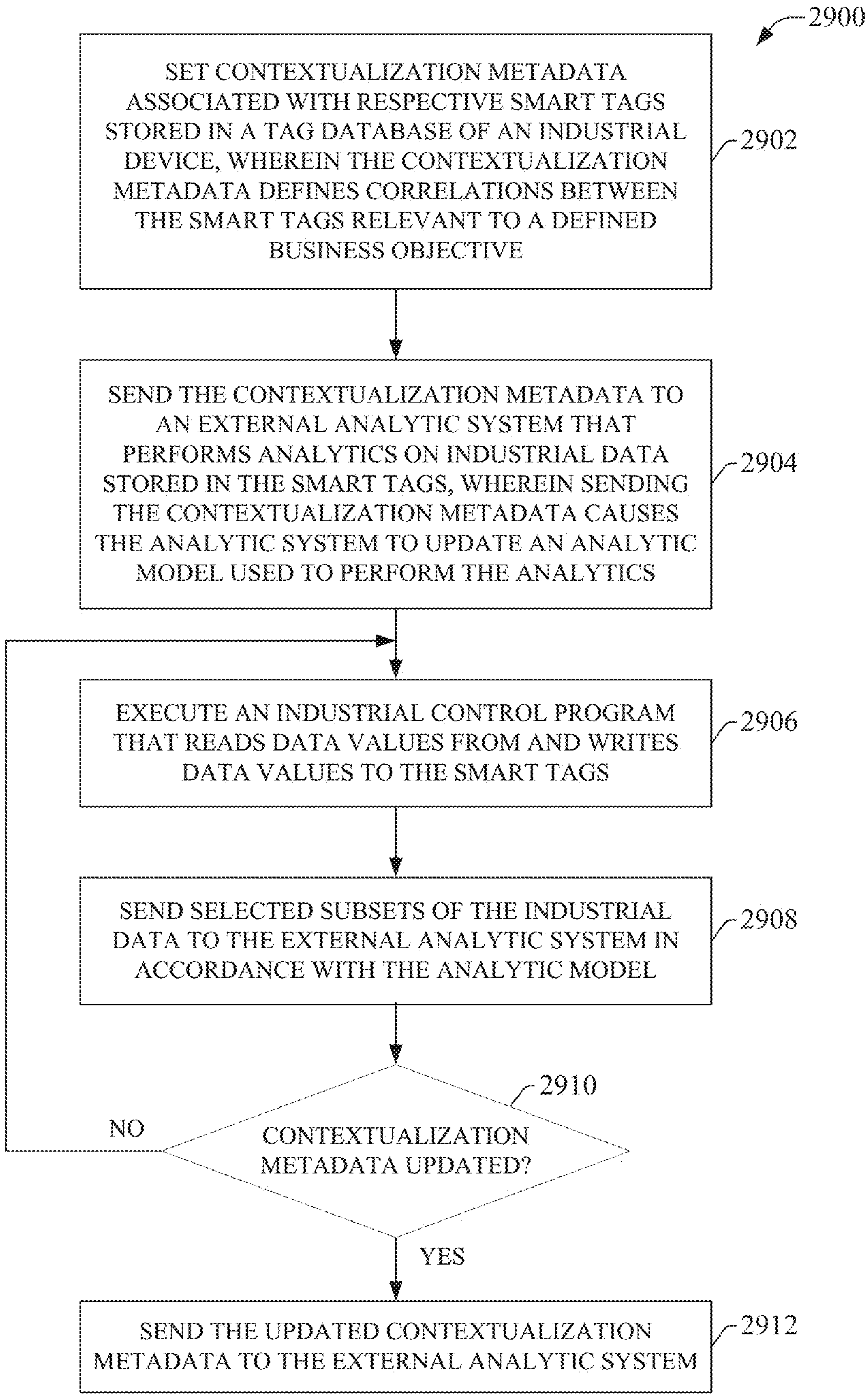

2900
SET CONTEXTUALIZATION METADATA ASSOCIATED WITH RESPECTIVE SMART TAGS STORED IN A TAG DATABASE OF AN INDUSTRIAL DEVICE, WHEREIN THE CONTEXTUALIZATION METADATA DEFINES CORRELATIONS BETWEEN THE SMART TAGS RELEVANT TO A DEFINED BUSINESS OBJECTIVE
2902
SEND THE CONTEXTUALIZATION METADATA TO AN EXTERNAL ANALYTIC SYSTEM THAT PERFORMS ANALYTICS ON INDUSTRIAL DATA STORED IN THE SMART TAGS, WHEREIN SENDING THE CONTEXTUALIZATION METADATA CAUSES THE ANALYTIC SYSTEM TO UPDATE AN ANALYTIC MODEL USED TO PERFORM THE ANALYTICS
2904
EXECUTE AN INDUSTRIAL CONTROL PROGRAM THAT READS DATA VALUES FROM AND WRITES DATA VALUES TO THE SMART TAGS
2906
SEND SELECTED SUBSETS OF THE INDUSTRIAL DATA TO THE EXTERNAL ANALYTIC SYSTEM IN ACCORDANCE WITH THE ANALYTIC MODEL
2908
2910
NO
CONTEXTUALIZATION METADATA UPDATED?
YES
SEND THE UPDATED CONTEXTUALIZATION METADATA TO THE EXTERNAL ANALYTIC SYSTEM
2912

FIG. 29

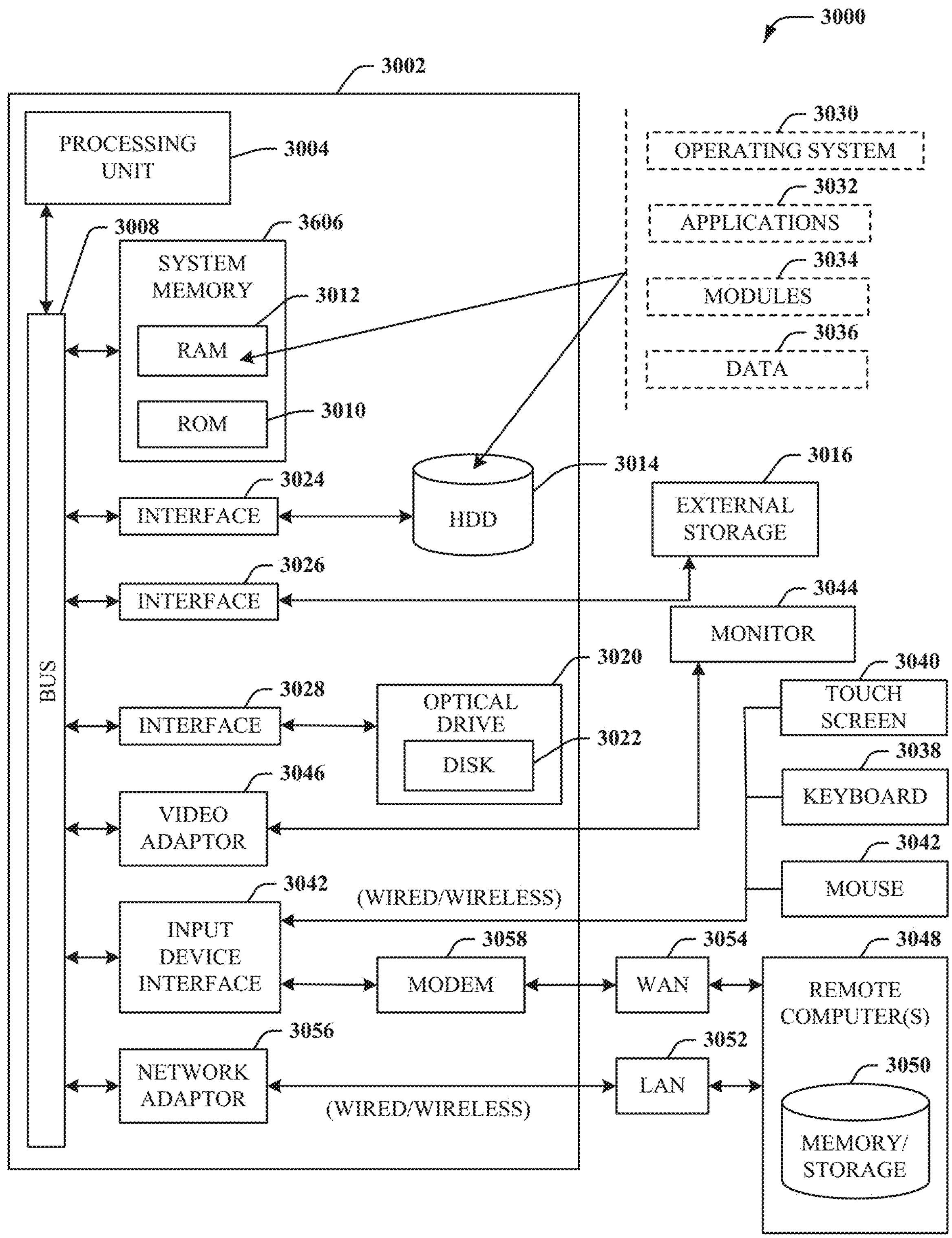

3000
3002
PROCESSING UNIT
3004
3008
SYSTEM MEMORY
3606
RAM
3012
ROM
3010
BUS
3030
OPERATING SYSTEM
3032
APPLICATIONS
3034
MODULES
3036
DATA
HDD
3014
3024
INTERFACE
3016
EXTERNAL STORAGE
3026
INTERFACE
3044
MONITOR
3020
OPTICAL DRIVE
DISK
3022
3028
INTERFACE
3040
TOUCH SCREEN
3038
KEYBOARD
3046
VIDEO ADAPTOR
3042
MOUSE
3042
(WIRED/WIRELESS)
INPUT DEVICE INTERFACE
3058
MODEM
3054
WAN
3048
REMOTE COMPUTER(S)
3056
NETWORK ADAPTOR
3052
LAN
3050
MEMORY/ STORAGE
(WIRED/WIRELESS)

FIG. 30

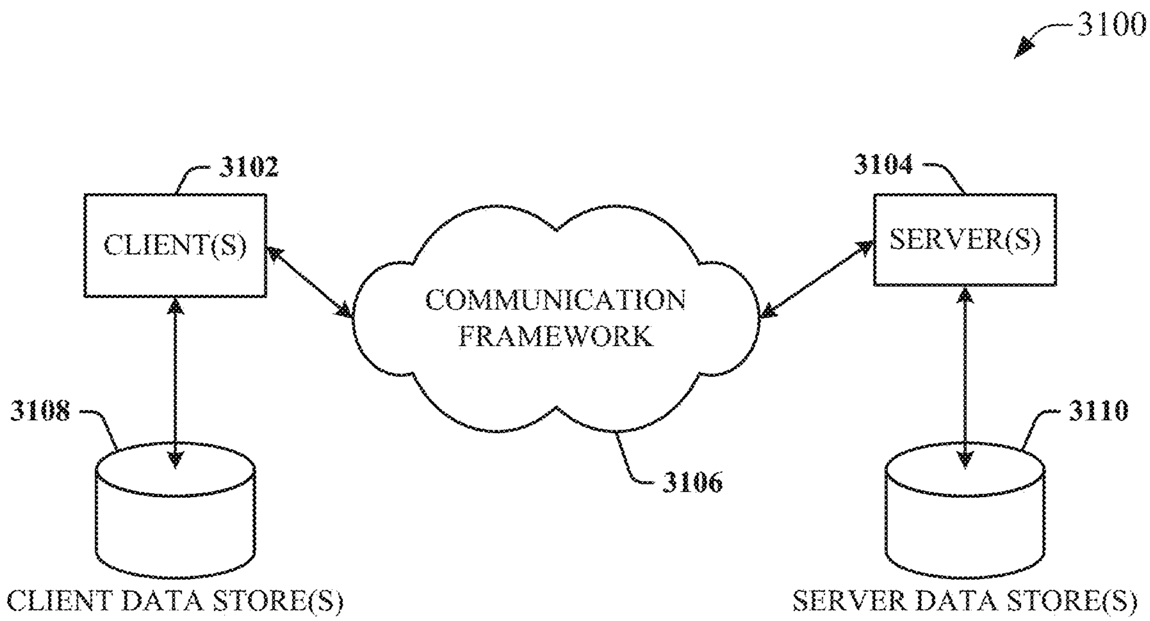

3100
3102
CLIENT(S)
3104
SERVER(S)
COMMUNICATION
FRAMEWORK
3108
3110
3106
CLIENT DATA STORE(S)
SERVER DATA STORE(S)

FIG. 31

INDUSTRIAL AUTOMATION CONTROL PROGRAM UTILIZATION IN ANALYTICS MODEL ENGINE

BACKGROUND

[0001] The subject matter disclosed herein relates generally to industrial automation systems, and, for example, to application of analytics to extract business value from industrial data.

BRIEF DESCRIPTION

[0002] The following presents a simplified summary in order to provide a basic understanding of some aspects described herein. This summary is not an extensive overview nor is it intended to identify key/critical elements or to delineate the scope of the various aspects described herein. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is presented later.

[0003] In one or more embodiments, an industrial device is provided, comprising a program execution component configured to execute an industrial control program, wherein the industrial control program reads data values from and writes data values to data tags stored on the memory, and at least a subset of the data tags comprise smart objects having associated contextualization metadata; a smart object configuration component configured to set the contextualization metadata associated with the smart objects, wherein the contextualization metadata defines correlations between the smart objects relevant to a defined business objective to yield a device-level data model; and a data publishing component configured to expose the contextualization metadata corresponding to the smart objects to an analytic system, wherein exposure of the contextualization metadata facilitates creation or updating, in accordance with the contextualization metadata, of an analytic model employed by the analytic system to perform analytic processing on subsets of data stored in the data tags.

[0004] Also, one or more embodiments provide a method, comprising executing, by an industrial device comprising a processor, an industrial control program, wherein the industrial control program reads data values from and writes data values to data tags stored in a memory, and wherein at least a subset of the data tags comprise smart objects having associated contextualization metadata; setting, by the industrial device, the contextualization metadata associated with the smart objects, wherein the contextualization metadata defines correlations between the smart objects relevant to a defined business objective to yield a device-level data model; and exposing, by the industrial device, the contextualization metadata corresponding to the smart objects to an analytic system, wherein the exposing facilitates creation or modification, based on the contextualization metadata, of an analytic model used by the analytic system to perform analytic processing on subsets of data stored in the data tags.

[0005] Also, according to one or more embodiments, a non-transitory computer-readable medium is provided having stored thereon instructions that, in response to execution, cause an industrial device comprising a processor to perform operations, the operations comprising executing an industrial control program, wherein the industrial control program reads data values from and writes data values to data tags stored in a memory, and wherein at least a subset of the data tags comprise smart objects having associated contextualization metadata; setting the contextualization metadata associated with the smart objects, wherein the contextualization metadata defines correlations between the smart objects relevant to a defined business objective to yield a device-level data model; and sending the contextualization metadata associated with the smart objects to an analytic system, wherein the exposing facilitates creation or modification, based on the contextualization metadata, of an analytic model used by the analytic system to perform analytic processing on subsets of data stored in the data tags.

[0006] To the accomplishment of the foregoing and related ends, certain illustrative aspects are described herein in connection with the following description and the annexed drawings. These aspects are indicative of various ways which can be practiced, all of which are intended to be covered herein. Other advantages and novel features may become apparent from the following detailed description when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a block diagram of an example industrial control environment.

[0008] FIG. **2***a* is a flow diagram illustrating a typical big data analysis approach.

[0009] FIG. **2***b* is a flow diagram illustrating an analytic approach in which a business value is initially identified and data is selected for streaming based on the business value.

[0010] FIG. **3** is a block diagram of an example smart gateway platform.

[0011] FIG. **4** is a block diagram of an example industrial device that supports smart object configuration.

[0012] FIG. **5** is a diagram illustrating selection and configuration of a model template designed to model industrial data for subsequent AI analysis.

[0013] FIG. **6** is a diagram illustrating an example model classification schema for storage of model templates in the smart gateway platform's library.

[0014] FIG. **7** is a diagram illustrating collection and structuring of industrial data by a smart gateway platform.

[0015] FIG. **8** is an illustration of four example smart data types that can be supported by some industrial device.

[0016] FIG. **9** is an example data schema depicting items of smart data that have been augmented by a data modeling component to include AI fields defining various AI properties.

[0017] FIG. **10** is an example asset type hierarchy for industrial pumps.

[0018] FIG. **11** is a diagram illustrating an example architecture in which a smart gateway platform collects, contextualizes, and structures data from industrial assets and provides the resulting structured and contextualized data to an AI analytic system.

[0019] FIG. **12** is a diagram illustrating an example architecture in which a smart gateway platform provides structured and contextualized data to analytic systems at various levels of an industrial enterprise.

[0020] FIG. **13** is a diagram of an example scalable industrial analytics architecture.

[0021] FIG. **14** is a diagram of an example industrial architecture in which a smart gateway platform feeds structured and contextualized data from disparate data sources throughout an industrial enterprise to a cloud-based analytic system executing on a cloud platform.

[0022] FIG. **15** is a flowchart of an example methodology for structuring industrial data and performing data analytics on the structured data to yield actionable insights relative to a desired business objective.

[0023] FIG. **16** is a block diagram of an example industrial data broker system.

[0024] FIG. **17** is a diagram illustrating configuration of smart objects in a tag database of an industrial device that supports smart objects.

[0025] FIG. **18** is a diagram illustrating example high-level data flows of an industrial publish-and-subscribe architecture facilitated by an industrial data broker system in conjunction with smart objects.

[0026] FIG. **19** is a flowchart of an example methodology for establishing contextualized data streams from industrial devices to external systems, including but not limited to AI or machine learning analytic systems.

[0027] FIG. **20** is a block diagram of an example program development system capable of translating engineering drawings into executable control programming and associated data tag definitions.

[0028] FIG. **21** is a diagram illustrating translation of digital engineering drawings into industrial control programming and data tag definitions by a program development system.

[0029] FIG. **22** is a diagram illustrating generation of a control program file by a program development system based on analysis of one or more digital engineering drawings as well as one or more selected data modeling templates.

[0030] FIG. **23** is a diagram illustrating several example automation object properties that can be leveraged by a program development system in connection with generating portions of a control program.

[0031] FIG. **24** illustrates export of a control program file generated based on analysis of digital design drawings to an industrial device

[0032] FIG. **25** is a diagram illustrating deployment of multiple control program files to respective industrial controllers by a program export component of a program development system.

[0033] FIG. **26** is a flowchart of an example methodology for generating industrial controller programming and associated smart object definitions based on analysis of digital engineering drawings.

[0034] FIG. **27** is a diagram illustrating an example architecture in which analytic systems on any level of an enterprise can leverage smart objects or automation objects defined by a control program file to create or refine analytic models.

[0035] FIG. **28** is a diagram illustrating another example architecture in which a data model on a smart gateway platform is used by an analytic system to generate an analytic model.

[0036] FIG. **29** is a flowchart of an example methodology for conveying device-level data models to external analytic systems for development of industrial analytic models.

[0037] FIG. **30** is an example computing environment.

[0038] FIG. **31** is an example networking environment.

DETAILED DESCRIPTION

[0039] The subject disclosure is now described with reference to the drawings, wherein like reference numerals are used to refer to like elements throughout. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding thereof. It may be evident, however, that the subject disclosure can be practiced without these specific details. In other instances, well-known structures and devices are shown in block diagram form in order to facilitate a description thereof.

[0040] As used in this application, the terms "component," "system," "platform," "layer," "controller," "terminal," "station," "node," "interface" are intended to refer to a computer-related entity or an entity related to, or that is part of, an operational apparatus with one or more specific functionalities, wherein such entities can be either hardware, a combination of hardware and software, software, or software in execution. For example, a component can be, but is not limited to being, a process running on a processor, a processor, a hard disk drive, multiple storage drives (of optical or magnetic storage medium) including affixed (e.g., screwed or bolted) or removable affixed solid-state storage drives; an object; an executable; a thread of execution; a computer-executable program, and/or a computer. By way of illustration, both an application running on a server and the server can be a component. One or more components can reside within a process and/or thread of execution, and a component can be localized on one computer and/or distributed between two or more computers, including cloud-based computing systems. Also, components as described herein can execute from various computer readable storage media having various data structures stored thereon. The components may communicate via local and/or remote processes such as in accordance with a signal having one or more data packets (e.g., data from one component interacting with another component in a local system, distributed system, and/or across a network such as the Internet with other systems via the signal). As another example, a component can be an apparatus with specific functionality provided by mechanical parts operated by electric or electronic circuitry which is operated by a software or a firmware application executed by a processor, wherein the processor can be internal or external to the apparatus and executes at least a part of the software or firmware application. As yet another example, a component can be an apparatus that provides specific functionality through electronic components without mechanical parts, the electronic components can include a processor therein to execute software or firmware that provides at least in part the functionality of the electronic components. As further yet another example, interface(s) can include input/output (I/O) components as well as associated processor, application, or Application Programming Interface (API) components. While the foregoing examples are directed to aspects of a component, the exemplified aspects or features also apply to a system, platform, interface, layer, controller, terminal, and the like.

[0041] As used herein, the terms "to infer" and "inference" refer generally to the process of reasoning about or inferring states of the system, environment, and/or user from a set of observations as captured via events and/or data. Inference can be employed to identify a specific context or action, or can generate a probability distribution over states, for example. The inference can be probabilistic—that is, the computation of a probability distribution over states of interest based on a consideration of data and events. Inference can also refer to techniques employed for composing higher-level events from a set of events and/or data. Such inference results in the construction of new events or actions from a set of observed events and/or stored event data, whether or not the events are correlated in close temporal proximity, and whether the events and data come from one or several event and data sources.

[0042] In addition, the term "or" is intended to mean an inclusive "or" rather than an exclusive "or." That is, unless specified otherwise, or clear from the context, the phrase "X employs A or B" is intended to mean any of the natural inclusive permutations. That is, the phrase "X employs A or B" is satisfied by any of the following instances: X employs A; X employs B; or X employs both A and B. In addition, the articles "a" and "an" as used in this application and the appended claims should generally be construed to mean "one or more" unless specified otherwise or clear from the context to be directed to a singular form.

[0043] Furthermore, the term "set" as employed herein excludes the empty set; e.g., the set with no elements therein. Thus, a "set" in the subject disclosure includes one or more elements or entities. As an illustration, a set of controllers includes one or more controllers; a set of data resources includes one or more data resources; etc. Likewise, the term "group" as utilized herein refers to a collection of one or more entities; e.g., a group of nodes refers to one or more nodes.

[0044] Various aspects or features will be presented in terms of systems that may include a number of devices, components, modules, and the like. It is to be understood and appreciated that the various systems may include additional devices, components, modules, etc. and/or may not include all of the devices, components, modules etc. discussed in connection with the figures. A combination of these approaches also can be used.

[0045] Industrial controllers, their associated I/O devices, motor drives, and other such industrial devices are central to the operation of modern automation systems. Industrial controllers interact with field devices on the plant floor to control automated processes relating to such objectives as product manufacture, material handling, batch processing, supervisory control, and other such applications. Industrial controllers store and execute user-defined control programs to effect decision-making in connection with the controlled process. Such programs can include, but are not limited to, ladder logic, sequential function charts, function block diagrams, structured text, C++, Python, Javascript, or other such platforms.

[0046] FIG. **1** is a block diagram of an example industrial environment **100**. In this example, a number of industrial controllers **118** are deployed throughout an industrial plant environment to monitor and control respective industrial systems or processes relating to product manufacture, machining, motion control, batch processing, material handling, or other such industrial functions. Industrial controllers **118** typically execute respective control programs to facilitate monitoring and control of industrial devices **120** making up the controlled industrial assets or systems (e.g., industrial machines). One or more industrial controllers **118** may also comprise a soft controller executed on a personal computer, on a server blade, or other hardware platform, or on a cloud platform. Some hybrid devices may also combine controller functionality with other functions (e.g., visualization). The control programs executed by industrial controllers **118** can comprise any conceivable type of code used to process input signals read from the industrial devices **120** and to control output signals generated by the industrial controllers, including but not limited to ladder logic, sequential function charts, function block diagrams, structured text, C++, Python, Javascript, etc.

[0047] Industrial devices **120** may include input devices that provide data relating to the controlled industrial systems to the industrial controllers **118**, output devices that respond to control signals generated by the industrial controllers **118** to control aspects of the industrial systems, or devices that act as both input and output devices. Example input devices can include telemetry devices (e.g., temperature sensors, flow meters, level sensors, pressure sensors, etc), manual operator control devices (e.g., push buttons, selector switches, etc.), safety monitoring devices (e.g., safety mats, safety pull cords, light curtains, etc.), and other such devices. Output devices may include motor drives, pneumatic actuators, signaling devices, robot control inputs, valves, and the like. Some industrial devices, such as industrial device **120**M, may operate autonomously on the plant network **116** without being controlled by an industrial controller **118**.

[0048] Industrial controllers **118** may communicatively interface with industrial devices **120** over hardwired connections or over wired or wireless networks. For example, industrial controllers **118** can be equipped with native hardwired inputs and outputs that communicate with the industrial devices **120** to effect control of the devices. The native controller I/O can include digital I/O that transmits and receives discrete voltage signals to and from the field devices, or analog I/O that transmits and receives analog voltage or current signals to and from the devices. The controller I/O can communicate with a controller's processor over a backplane such that the digital and analog signals can be read into and controlled by the control programs. Industrial controllers **118** can also communicate with industrial devices **120** over the plant network **116** using, for example, a communication module or an integrated networking port. Exemplary networks can include the Internet, intranets, Ethernet, EtherNet/IP, DeviceNet, ControlNet, Data Highway and Data Highway Plus (DH/DH+), Remote I/O, Fieldbus, Modbus, Profibus, wireless networks, serial protocols, and the like. The industrial controllers **118** can also store persisted data values that can be referenced by the control program and used for control decisions, including but not limited to measured or calculated values representing operational states of a controlled machine or process (e.g., tank levels, positions, alarms, etc.) or captured time series data that is collected during operation of the automation system (e.g., status information for multiple points in time, diagnostic occurrences, etc.). Similarly, some intelligent devices—including but not limited to motor drives, instruments, or condition monitoring modules—may store data values that are used for control and/or to visualize states of operation. Such devices may also capture time-series data or events on a log for later retrieval and viewing.

[0049] Industrial automation systems often include one or more human-machine interfaces (HMIs) **114** that allow plant personnel to view telemetry and status data associated with the automation systems, and to control some aspects of system operation. HMIs **114** may communicate with one or more of the industrial controllers **118** over a plant network **116**, and exchange data with the industrial controllers to facilitate visualization of information relating to the controlled industrial processes on one or more pre-developed operator interface screens. HMIs **114** can also be configured to allow operators to submit data to specified data tags or memory addresses of the industrial controllers **118**, thereby providing a means for operators to issue commands to the controlled systems (e.g., cycle start commands, device actuation commands, etc.), to modify setpoint values, etc. HMIs **114** can generate one or more display screens through which the operator interacts with the industrial controllers **118**, and thereby with the controlled processes and/or systems. Example display screens can visualize present states of industrial systems or their associated devices using graphical representations of the processes that display metered or calculated values, employ color or position animations based on state, render alarm notifications, or employ other such techniques for presenting relevant data to the operator. Data presented in this manner is read from industrial controllers **118** by HMIs **114** and presented on one or more of the display screens according to display formats chosen by the HMI developer. HMIs may comprise fixed location or mobile devices with either user-installed or pre-installed operating systems, and either user-installed or pre-installed graphical application software.

[0050] Some industrial environments may also include other systems or devices relating to specific aspects of the controlled industrial systems. These may include, for example, one or more data historians **110** that aggregate and store production information collected from the industrial controllers **118** and other industrial devices.

[0051] Industrial devices **120**, industrial controllers **118**, HMIs **114**, associated controlled industrial assets, and other plant-floor systems such as data historians **110**, vision systems, and other such systems operate on the operational technology (OT) level of the industrial environment. Higher level analytic and reporting systems may operate at the higher enterprise level of the industrial environment in the information technology (IT) domain; e.g., on an office network **108** or on a cloud platform **122**. Such higher level systems can include, for example, enterprise resource planning (ERP) systems **104** that integrate and collectively manage high-level business operations, such as finance, sales, order management, marketing, human resources, or other such business functions. Manufacturing Execution Systems (MES) **102** can monitor and manage control operations on the control level given higher-level business considerations. Reporting systems **106** can collect operational data from industrial devices on the plant floor and generate daily or shift reports that summarize operational statistics of the controlled industrial assets.

[0052] A given industrial enterprise can comprise many of these industrial assets, which generate large amounts of information during plant operation. With the advent of big data storage and analytic approaches, it becomes possible to continually stream data from these disparate industrial data sources to big data storage (e.g., a data lake) and transform these large and disparate sets of data into actionable insights into controlled industrial processes and machines. Artificial intelligence (AI) and machine learning hold great promise for extracting insights from industrial big data. These analytic approaches can discover patterns in data that can be leveraged to predict machine failures and identify other useful correlations between industrial data. As a plant's equipment ages, discovery of new correlations between data can provide valuable new insights. For example, AI analytics applied to industrial big data can discover that wear of a pump's bearing is likely to change the vibration of the pump. The insights gleaned from such big data analysis can lead to increased productivity, optimized production, and new business value.

[0053] FIG. **2***a* is a flow diagram illustrating a typical big data analysis approach. According to this approach, data from multiple industrial data sources **202** is streamed to big data storage (e.g., a data lake or database). High-level analytics—such as AI, machine learning, statistical analysis, or another data science approach—are applied to these large and disparate sets of data until useful correlations and actionable insights are discovered. These actionable insights may be in the form of business outcomes, recommendations for minimizing or predicting machine downtime events, recommendations for minimizing energy utilization, recommendations for maximizing product throughput, or other such business goals. Big data analytics can yield insights into these desired business outcomes by discovering correlations between machines, devices, plant-floor events, sensor inputs, and other measurable factors represented by the aggregated sets of big data.

[0054] Although data streams from industrial data sources can be used to amass very large sets of data to which analytics (e.g., AI, machine learning, data science, etc.) can be applied, the time to derive value from these large data sets, and the costs associated with storing and processing industrial big data, can be significant. This is because the data generated by industrial devices and other industrial data sources is typically unstructured and initially uncorrelated. Consequently, intelligent analytics must spend a considerable amount of processing time learning correlations and causalities between these sets of unstructured industrial data. This approach also requires considerable data storage capacity given the large amounts of data generated by the industrial enterprise. For example, an oil and gas company is likely to generate large amounts of data from compressors alone, which can produce 500 gigabytes of data per day in some cases, yielding data volumes in excess of a petabyte in one year. Thus, although the approach illustrated in FIG. **2***a* can lead to discovery of new insights from learned correlations between large data sets, this approach can also produce relatively few insights relative to the large amount of data being stored and processed.

[0055] Also, although the analytic approach illustrated in FIG. **2***a* can identify valid and useful correlations between data sets, big data analytic systems may also identify spurious, misleading, or unhelpful correlations between data sets. Humans are therefore ultimately required to determine whether a correlation learned by the analytic system is valid, and why this relationship exists. Applying this human expertise to analytic results at the back end of the analytic process, by submitting results produced by the AI analytics to an industry expert for review or verification, can result in a considerable amount of analytic processing and data storage wasted on producing spurious results.

[0056] To address these and other issues, one or more embodiments described herein provide a smart gateway platform that leverages industrial expertise to identify limited subsets of available industrial data deemed relevant to a desired business objective. This approach can reduce the data space to which AI analytics are applied, and provides useful constraints on the AI analytics, in the form of predefined correlations and causalities between the data, that assist data analytic systems to more quickly derive valuable insights and business outcomes. In some embodiments, the smart gateway platform can operate within the context of a multi-level industrial analytic system, feeding pre-modeled data to one or more analytic systems (e.g., AI, machine learning, or statistical analysis systems) executing on one or more different levels of an industrial enterprise.

[0057] In a related aspect, one or more embodiments also provide tools at the device level, the gateway level, and/or the cloud level that allow users to subscribe to data subsets of interest using an industrial publish-subscribe approach. These tools can include smart object support at the industrial device level that allows selected data items (e.g., smart objects, automation objects representing industrial assets that serve as building blocks for control programming, etc.) to be labeled according to analytic or business topics to which the data items relate (e.g., Quality, Energy Consumption, Product Throughput, Machine Runtime, etc.). These labeled data sets can be streamed from the lower device levels to higher broker or analytic levels, and users or high-level analytics systems can subscribe to selected data streams of interest according to the label associated with the data streams. In the case of structured data, such as smart objects or automation objects, the associated data streams include any contextualization or metadata associated with those tags/objects. In this way, device-level data models provide a means to feed selected sets of structured industrial data to analytic systems (e.g., industrial AI systems).

[0058] Industrial processes such as pumping, packaging, sorting, filling, distillation, and brewing follow patterns of behavior that are, to a degree, predictable and understood by system designers and operators. People who have knowledge of specific sets of industrial machines and processes are known as domain experts. One or more embodiments of the industrial analytic system described herein leverage this domain expertise to aggregate and model selected sets of industrial data as a function of the business output desired from the analytics, then feed this modeled industrial data to higher-level analytic systems for storage and AI analysis. FIG. **2*b*** is a flow diagram illustrating this general analytic approach. Rather than collecting, storing, and analyzing all raw data available from an industrial enterprise (or unnecessarily large sets of this available data), as in the approach depicted in FIG. **2*a***, this approach begins with identification of the business value or outcome desired—e.g., minimize downtime of a certain type of industrial machine, maximize product output, optimize energy efficiency, improve product quality, reduce emissions, etc.—and leverages domain experts' knowledge of causality in industrial systems to select data sets relevant to the desired business outcome, and to contextualize and model the data in a manner that drives the desired business outcome. The system then matches and applies appropriate analytics and data processing solutions to the modeled data. This approach can dramatically reduce the time-to-value of industrial data analytics relative to sifting through large sets of uncorrelated and unstructured industrial data (as in conventional big data analytics approaches). Since the encoded domain expertise specifies the subset of available plant data known to be relevant to the desired business objective, the system can reference this expertise to select and stream only the data items known to be relevant to the problem or business objective to be solved, reducing the amount of data storage required for industrial data analysis.

[0059] According to the approach depicted in FIG. **2*b***, the starting point for application of industrial machine learning and AI is identification of the business problem to be solved. Relevant smart data (also referred to as contextualized data) or raw data from one or more industrial data sources is then selected to match desired business outcomes based on defined domain expertise, and the smart data is contextualized and modeled. In some embodiments, the data may be modeled according to object-oriented models. In the case of scalable analytic environments, analytics can be applied to the contextualized and modeled smart data at the level of the industrial enterprise to which the business outcome is most relevant. For example, analysis and actions that relate to real-time operation of industrial machines can be implemented on an edge device (e.g., a network infrastructure device that communicatively links the plant network to external networks or systems) and acted upon at the machine level, without the involvement of a higher-level system to determine the necessary control actions.

[0060] FIG. **3** is a block diagram of an example smart gateway platform **302** according to one or more embodiments of this disclosure. Aspects of the systems, apparatuses, or processes explained in this disclosure can constitute machine-executable components embodied within machine (s), e.g., embodied in one or more computer-readable mediums (or media) associated with one or more machines. Such components, when executed by one or more machines, e.g., computer(s), computing device(s), automation device(s), virtual machine(s), etc., can cause the machine(s) to perform the operations described.

[0061] Smart gateway platform **302** can include a device interface component **304**, a model configuration component **306**, a data modeling component **308**, a gateway analytics component **310**, an analytics interface component **312**, a user interface component **314**, one or more processors **316**, and memory **318**. In various embodiments, one or more of the device interface component **304**, model configuration component **306**, data modeling component **308**, gateway analytics component **310**, analytics interface component **312**, user interface component **314**, the one or more processors **316**, and memory **318** can be electrically and/or communicatively coupled to one another to perform one or more of the functions of the smart gateway platform **302**. In some embodiments, components **304**, **306**, **308**, **310**, **312**, and **314** can comprise software instructions stored on memory **318** and executed by processor(s) **316**. Smart gateway platform **302** may also interact with other hardware and/or software components not depicted in FIG. **3**. For example, processor (s) **316** may interact with one or more external user interface devices, such as a keyboard, a mouse, a display monitor, a touchscreen, a smart phone, a tablet computer, an AR/VR wearable appliance, or other such interface devices. In some embodiments, smart gateway platform **302** can serve as a logical entity that is embedded in another device, including but not limited to an edge device, an industrial controller, or an HMI terminal.

[0062] Device interface component **304** can be configured to exchange information between the smart gateway platform **302** and sources of industrial data at one or more plant facilities. Sources of industrial data that can be accessed by the device interface component **304** can include, but are not limited to, industrial controllers, telemetry devices, motor drives, quality check systems (e.g., vision systems or other quality verification systems), industrial safety systems, cameras or other types of optical sensors, data collection devices (e.g., industrial data historians), or other such information sources. These industrial data sources can comprise devices of different types and vendors, and include sources of both structured and unstructured data. In some embodiments, device interface component **304** can exchange data with these industrial devices via the plant networks on which the devices reside. Device interface component **304** can also receive at least some of the industrial data via a public network such as the Internet in some embodiments. The device interface component **304** can directly access the data generated by these industrial devices and systems via the one or more public and/or private networks in some embodiments. Alternatively, device interface component **304** can access the data on these data sources via a proxy or edge device that aggregates the data from multiple industrial devices for migration to the smart gateway platform **302** via the device interface component **304**.

[0063] Model configuration component **306** can be configured to generate an analytic model that can be leveraged by an AI or machine learning analytic system in connection with applying suitable analytics for achieving a desired business objective. The analytic model can be generated based on a model template—selected from a library **320** of model templates stored on memory **318**—that encodes domain expertise relevant to the business objective. The model template can define data items (e.g., sensor inputs, measured process variables, key performance indicators, machine operating modes, environmental factors, etc.) that are relevant to the business objective, as well as correlations between these data items. Model configuration component **306** can transform this model template to a customized model based on user input that maps the generic data items defined by the model template to actual sources of the data discovered by the device interface component **304**.

[0064] Data modeling component **308** can be configured to model and contextualize industrial data collected by the device interface component **304** based on relationships defined by the analytic model to yield modeled data that can be fed to a local or external AI analytics system. Data modeling component **308** can model both structured (e.g., smart objects, automation objects, etc.) and unstructured data from a heterogeneous collection of industrial data sources.

[0065] Gateway analytics component **310** can be configured to perform local analytics (e.g., AI, machine learning, statistical analysis, etc.) on the modeled industrial data. Analytics interface component **312** can be configured to interface and exchange data with external systems that consume this data to extract business value (e.g., AI systems, machine learning systems, data lakes etc.). This can include sending the modeled industrial data to these external analytic systems or sending results of local analytics performed by the gateway analytics component **310**.

[0066] User interface component **314** can be configured to exchange information between the smart gateway platform **302** and a client device having authorization to access the platform. In some embodiments, user interface component **314** can be configured to generate and deliver interface displays to the client device that allow the user to specify a business objective to be solved and to customize or edit a model template associated with the specified business objective to map the model template to industrial data sources. User interface component **314** can also deliver analytic results to the client device, including notifications of predicted asset performance issues, recommendations for achieving the specified business objective, or other such analytic outputs.

[0067] The one or more processors **316** can perform one or more of the functions described herein with reference to the systems and/or methods disclosed. Memory **318** can be a computer-readable storage medium storing computer-executable instructions and/or information for performing the functions described herein with reference to the systems and/or methods disclosed.

[0068] FIG. **4** is a block diagram of an example industrial device **402** that supports smart objects and data streaming channels according to one or more embodiments of this disclosure. Industrial device **402** can comprise substantially any type of data-generating industrial device, including but not limited to an industrial controller, a motor drive, an HMI terminal, a vision system, an industrial optical scanner, or other such device or system. Industrial device **402** can include a program execution component **404**, an I/O control component **406**, a smart object configuration component **408**, a data publishing component **410**, a networking component **412**, a user interface component **414**, one or more processors **418**, and memory **420**. In various embodiments, one or more of the program execution component **404**, I/O control component **406**, smart object configuration component **408**, data publishing component **410**, networking component **412**, user interface component **414**, the one or more processors **418**, and memory **420** can be electrically and/or communicatively coupled to one another to perform one or more of the functions of the industrial device **402**. In some embodiments, components **404**, **406**, **408**, **410**, **412**, and **414** can comprise software instructions stored on memory **420** and executed by processor(s) **418**. Industrial device **402** may also interact with other hardware and/or software components not depicted in FIG. **4**. For example, processor(s) **418** may interact with one or more external user interface devices, such as a keyboard, a mouse, a display monitor, a touchscreen, a smart phone, a tablet computer, an AR/VR wearable appliance, or other such interface devices.

[0069] Program execution component **404** can be configured to compile and execute a user-defined control program or executable interpreted code. In various embodiments, the control program can be written in any suitable programming format (e.g., ladder logic, sequential function charts, structured text, C++, Python, Javascript, etc.) and downloaded to the industrial device **402**. Typically, the control program uses data values read by the industrial device's analog and digital inputs as input variables, and sets values of the industrial device's analog and digital outputs in accordance with the control program instructions based in part on the input values. I/O control component **406** can be configured to control the electrical output signals of the industrial device's digital and analog electrical outputs in accordance with the control program outputs, and to convert electrical signals on the industrial device's analog and digital inputs to data values that can be processed by the program execution component **404**.

[0070] Smart object configuration component **408** can be configured to set metadata values or labels associated with smart objects defined for the industrial device **402** based on metadata configuration input data. As will be described in more detail below, in addition to standard general data types (e.g., real, analog, digital, etc.), industrial device **402** is configured to support smart objects **422** corresponding to industrial-specific data types. Smart objects **422** have associated metadata that can be configured by the user via smart object configuration component **408** in order to customize the data tags for a given industrial application. Smart object **422** can also have associated metadata that contextualizes data associated with the tag **422** based on industrial or user expertise in ways that facilitate business-driven analytics, as will be described in more detail herein, effectively pre-modeling the data at the device level. In some embodiments, this data modeling can be defined by vertical-specific or application-specific data modeling templates **424** stored on the device **402**, which define key variables as well as relationships and correlations between data items for various business objectives. Templates **424** and smart objects **422** are stored in memory **420** (e.g., in the industrial device's tag database together other defined data tags of other data types).

[0071] Data publishing component **410** is configured to expose defined data tags (including smart objects **422**) to external systems, allowing the data associated with these tags to be discovered by such systems over a local and/or remote network. In some embodiments, data publishing component **410** can also support data streaming to higher level broker or analytic systems as part of an industrial publish-subscribe architecture, where the resulting data streams serve as data channels to which analytic systems or users can selectively subscribe. For data streams sourced by smart objects, the data streams include any contextualization or data labels associated with the tag.

[0072] Networking component **412** can be configured to exchange data with one or more external devices over a wired or wireless network using any suitable network protocol. User interface component **414** can be configured to receive user input and to render output to the user in any suitable format (e.g., visual, audio, tactile, etc.). In some embodiments, user interface component **414** can be configured to communicatively interface with a development application that executes on a client device (e.g., a laptop computer, tablet computer, smart phone, etc.) that is communicatively connected to the industrial device **402** (e.g., via a hardwired or wireless connection). The user interface component **414** can then receive user input data and render output data via the development application. In other embodiments, user interface component **414** can be configured to generate and serve suitable graphical interface screens to a client device, and exchange data via these graphical interface screens. Input data that can be received via user interface component **414** can include, but is not limited to, user-defined control programs or routines, data tag definitions, smart object metadata configurations, or other such data.

[0073] The one or more processors **418** can perform one or more of the functions described herein with reference to the systems and/or methods disclosed. Memory **420** can be a computer-readable storage medium storing computer-executable instructions and/or information for performing the functions described herein with reference to the systems and/or methods disclosed.

[0074] As noted above, that industrial analytic approach implemented by embodiments of the smart gateway platform **302** leverages industry domain expertise to reduce the data space over which AI analytics are to be applied by explicitly defining the data items known to be relevant to a given business objective (e.g., reduction of machine downtime, reduction of specified machine failures such as paper web breaks, optimization of energy utilization by a specified type of industrial machine, improvement of quality of a particular type of product, etc.). Known correlations and/or causalities between these relevant data items—also drawn from domain expertise—are also predefined and modeled into the data, thereby applying useful analytic constraints that lead to a desired insight more quickly and with less processing overhead relative to applying unconstrained big data analysis over unnecessarily large data sets. This domain expertise is encoded in the form of model templates stored on the smart gateway platform **302**.

[0075] FIG. **5** is a diagram illustrating selection and configuration of a model template **502** designed to model industrial data for subsequent AI analysis. In one or more embodiments, smart gateway platform **302** can store a library **320** of model templates **502** that are each associated with a corresponding business objective or outcome. Example business objectives can include, but are not limited to, reduction in total machine downtime or number of machine failures; minimization of machine power consumption; optimization of operational efficiency (e.g., amount of machine output relative to an amount of energy consumed by the machine); minimization of emissions; improvement of product quality; identification of factors that yield maximum product output, minimal machine downtime, or maximum product quality; or other such objectives.

[0076] In some embodiments, these objectives can be grouped according to industry or vertical (e.g., automotive, oil and gas, food and drug, mining, textiles, etc.), machine type, or other such categorizations. FIG. **6** is a diagram illustrating an example model classification schema for storage of model templates **502** in the smart gateway platform's library. User interface component **314** can generate and deliver model template selection screens to a client device that allow the user to navigate the model classification schema in order to select a model template associated with a desired industry-specific and application-specific business objective. According to this example schema, model templates **502** are classified within a hierarchical classification schema according to industry or vertical (e.g., automotive, oil and gas, mining, food and drug, power generation, textiles, etc.). Although only one industry/vertical layer is depicted in FIG. **6**, some industries/verticals may include child classifications representing sub-industries classified under the parent industry. For example, selection of an "Automotive" industry classification may prompt the user to select from among several automotive sub-industries, such as Tire and Rubber, Painting, Engine Manufacture, etc.

[0077] Under each industry or vertical classification (or sub-industry) is one or more machine selections relevant to that industry or vertical. For example, a Tire and Rubber sub-industry may be associated with several different machines that are typically associated with tire manufacture (e.g., Calendering, Extrusion, Curing Press, Tire Building Machine, Tire Picking Station, etc.). Each machine is associated with one or more predefined business objectives related to the selected machine. Some business objectives may be relatively high level and global objectives, such as minimization of machine downtime or failures, maximization of throughput, minimization of energy consumption, optimization of machine efficiency, etc. Other objectives may be specific or unique to the selected machine and vertical. For example, business objectives associated with a paper cone wrapping machine may include minimization of paper tears or web breaks as the paper is fed from a roller into the machine, or minimization of paper jams as the paper is fed into the machine. In another example, a business objective associated with a washing machine may be to minimize instances of imbalanced spinning.

[0078] Selection of a business objective associated with a selected machine invokes the model template **502** associated with that objective. Returning now to FIG. **5**, a user selects the desired model template **502** by submitting model selection input **510** (via user interface component **314**) that navigates the model template selection hierarchy to the desired business objective. In general, each model template **502** encodes domain expertise applicable to the selected industry- and machine-specific business objective, in terms of which data items are relevant to the problem to be solved and the correlations and causalities between these data items. Each model template **502** specifies which data inputs from the plant-floor industrial devices (e.g., industrial controllers, telemetry devices, sensors, etc.) should be examined by AI or traditional analytics in order to learn causes and possible solutions for the problem represented by the selected business objective, and also defines, where appropriate, correlations and causations between these data inputs that are relevant to the business objective.

[0079] These definitions of relevant data items and the relationships therebetween are based on collective domain expertise gleaned from industry experts experienced in designing, maintaining, and troubleshooting the selected machine. For a given operational problem relating to a certain machine that carries out a common industrial application, domain experts may have knowledge of which sensory inputs should be examined in order to determine a root cause of non-optimal machine performance, as well as what machine events, modes, or measured operating parameters correlate to certain outcomes. This collective knowledge can be encoded by the model templates **502** and used to apply useful constraints on subsequent AI analysis (or traditional analytics) in connection with evaluating the desired business objective. Some model templates **502** may also specify a type of analytics to run on the specified data items, which is a function of the business problem to be solved.

[0080] Model template **502** defines the relevant data items generically since the sources of these data items may vary across different industrial enterprises. For example, a model template **502** associated with the business objective of maximizing product output for a certain machine may specify that conveyor speed is one of the data inputs relevant to evaluating machine performance and learning possible operational modifications that can increase product output. However, the source of this conveyor speed data depends on the equipment in use at the customer facility. This conveyor speed value may be obtainable from a data tag on a motor drive that controls the conveyor motor at one facility, while at another facility the conveyor speed may be measured by a speed sensor and output as an analog signal. Moreover, the conveyor speed may be available in different data formats at different facilities; e.g., as unstructured raw data or as a structured value having associated metadata identifying a source of the speed value.

[0081] Upon selection of a generic model template **502** corresponding to the desired business objective, the smart gateway platform **302** allows the user to customize the template **502** by mapping each data item specified by the model template **502** with a source of the data item available from the user's own industrial assets. To this end, user interface component **314** can render interface displays on the user's client device **514** that present the relevant (generic) data items defined by the template **502** and allow the user to, for each data item, browse available data items discovered on the user's industrial assets **516**. Sources of data items may be discovered by the gateway platform's device interface component **304**, which can browse the plant network and identify smart objects **422**, data tags **508**, or other sources of industrial data across the industrial devices **402** that make up the user's industrial assets. The user's selections of specific industrial data sources to be mapped to each data item defined by the template **502** can be submitted as data mapping definitions **512**, which transform the model template **502** to a customized analytic model.

[0082] By leveraging encoded domain expertise, this guided data mapping process can also inform the user if certain items of sensory data relevant to the desired business outcome are not currently being measured in the user's current system implementation. For example, the end user may be unaware that the humidity level within a plant facility increases the risk of web breaks in a paper feed machine. However, this correlation may be known by domain experts and is therefore encoded in the model template **502** associated with the business objective of minimizing web breaks. Thus, when this model template **502** is selected by the user, the smart gateway platform **302** prompts for a source of humidity data during the data mapping process, informing the user of the need for this information and driving installation of a humidity sensor within the plant if such a sensor has not already been installed.

[0083] Once model template **502** has been customized, smart gateway platform **302** can leverage the resulting customized model to collect and structure the mapped data items for subsequent analysis. FIG. **7** is a diagram illustrating collection and structuring of industrial data by the smart gateway platform **302**. In this example, mapping of plant-floor data items to a selected model template **502**, as described above, has yielded a customized data model **702** that can be referenced by the smart gateway platform **302** in connection with collecting the specified subsets of available industrial data, as well as pre-modeling the collected data for subsequent AI analytics based on the desired business objective.

[0084] The smart gateway platform **302** collects data streams from a disparate collection of industrial devices **402** of different types, vendors, and models. Some of the industrial devices—such as industrial devices **402*a*** and **402*e***—may support generation of smart data, or data that has been contextualized with metadata in order to provide additional information regarding the context under which the data values were generated. For example, a motor drive that supports creation of smart data may produce a continuous stream of time-series data conveying a speed of a motor that drives a component of an industrial machine or asset. This motor speed data can yield additional valuable insights if the speed data is combined with the operating state of the device or machine (e.g., Running, Faulted, etc.) at the time the motor speed value was measured. In another example, electrical parameters of a device such as voltage, current, and power factor can be similarly linked to the operating state of the device at the time the parameters were measured to yield contextualized data. Embodiments of industrial devices **402** can support creation of such contextualized smart data and storage of this contextualized data in smart objects **422**. This smart data **706** can be obtained from smart objects **422** (if supported by the industrial device **402**) by the smart gateway platform **302** if the model **702** dictates that this data is relevant to the business objective to be evaluated.

[0085] Some industrial devices **402** can create contextualized data using special instructions and custom smart object data structures to perform computations and create names and structure for the contextualized data. FIG. **8** is an illustration of four example smart data types that can be supported by some industrial devices **402**. These data types can supplement other standard data types that are typically supported by industrial controllers or other industrial devices (e.g., integer, real, Boolean, string, floating point etc.). In general, data tags (both standard data tags and smart objects **422**) are data structures defined within an industrial device that reference a memory location within the device (e.g., an input value, an output value, or an internal data register) and correspond to respective data items. A data tag can be configured to be of a specified data type, such as Boolean, floating point, integer, double integer, string, etc. During development, controller tags can be created and maintained in a tag database of the industrial device **402**. The smart objects **422** described herein can be considered additional data types that are catered to industrial automation applications, and that supplement conventional data types.

[0086] In the illustrated example, the smart data types comprise four structured information data types—a State data tag **802**, a Rate data tag **804**, an Odometer data tag **806**, and an Event data tag **808**. Although the examples described herein assume that the supported smart objects comprise these four data types, it is to be appreciated that some embodiments may include other smart data types without departing from the scope of this disclosure.

[0087] Each smart object includes a field for storing the current value of the smart object (e.g., a state value, a rate value, an odometer value, and an event value) as well as one or more metadata fields configured to store user-defined configuration data for that smart object. The metadata values for each smart object can customize analytics, management, and presentation of the associated smart data value in accordance with the particular industrial asset or industrial application with which the smart object **422** is associated.

[0088] The value contained in a State data tag **802** can represent a current state of an industrial asset or device (e.g., a machine, a production line, a motor drive, etc.). The state data contained in a State data tag **802** can represent one of a set of predefined states representative of a current state or status of the associated industrial asset or device. For example, the State data tag may convey an S88 state (that is, states defined as part of the ANSI/ISA-88 batch process standard), a Packaging Machine Language state, a current state of a state machine defined for the asset, a state of a valve (e.g., OPEN or CLOSED), a state of a motor (e.g., RUNNING, IDLE, FAULTED, etc.), or other types of states.

[0089] User-configurable metadata associated with the State data tag **802** may define a state machine representing available states of the associated asset, where each defined state is configured to be invoked in response to a detected condition. For example, each defined state may be linked via the metadata to one or more other related data tags defined in the industrial device **402** (e.g., a data tag representing a state of a sensor or switch indicative of the defined state), such that the current state indicated by the State data tag **802** is a function of the current values of the related data tags. In general, such relationships between related data tags can be defined within smart object metadata to effectively yield a device-level model that can be leveraged by external analytic systems (e.g., AI analytic systems or traditional analytic systems) in order to quickly learn insights into the associated industrial process or machine operation. In some implementations, these device-level models—encoded by the smart objects and their associated metadata—can define complex correlations and relationships between data tags.

[0090] The value contained in a Rate data tag **804** can represent an integer or real value of a measured rate of a metric associated with the industrial asset or device. The rate value can be an instantaneous rate or a value representing a rate of change of the metric over time. For example, the rate value contained in the Rate data tag **804** can represent a temperature, a pressure, a velocity (e.g., a velocity of a conveyor or other motor-driven machine component), an overall equipment effectiveness (OEE), or other such metric.

[0091] User-configurable metadata associated with the Rate data tag **804** can define maximum and minimum values for the corresponding rate value, such that the value contained in the Rate data tag **804** will not deviate outside the window defined by the maximum and minimum value metadata. The metadata can also identify one or more data sources (e.g., one or more other data tags or input addresses) that determine the event. For example, the metadata for the Rate smart object **804** can define whether the corresponding rate value is an aggregation of multiple other values contained in other defined data tags. The rate value can be defined as an average or a sum of two or more identified data tags, or an integral of a data tag over time. Another metadata field can be used to designate an engineering unit to be associated with the rate.

[0092] The value contained in the Odometer data tag **806** can represent a cumulative quantity associated with an industrial asset. For example, the Odometer data tag **806** can be configured to represent cumulative quantity with a rollover value, such as a part count associated with the industrial asset. In such cases, the metadata associated with the Odometer data tag **806** can include a definition of the rollover value. The Odometer data tag **806** may also be configured to represent a quantity over a defined time interval, such as an energy consumption associated with the asset. In the case of quantities over a defined time interval, the metadata associated with the Odometer data tag **806** can include a definition of the time interval, which may be defined in terms of daily start and end times, in terms of a start time and a defined duration of the time interval, or as another time definition format. The metadata associated with the Odometer data tag **806** can also define one or more data sources that drive the odometer value. For example, the metadata may define a data tag associated with a Cycle Complete event, such that the odometer value will increment when the Cycle Complete data tag goes high. The odometer value may also be defined to be an aggregation of multiple values. In such cases, the metadata may identify two or more data tags whose values are to be aggregated or summed to yield the odometer value. The metadata can also define a unit of measure associated with the odometer value (e.g., bottles filled, operating cycles, megawatt-hours, etc.).

[0093] The value contained in the Event data tag **808** can represent an instantaneous or persistent event associated with an industrial asset. For example, an Event data tag **808** may represent an instantaneous event such as a push-button event (e.g., "Service Button Pushed"), a sensor event (e.g., "Part Present," "Person Detected," etc.), a safety device event (e.g., "Light Curtain Broken"), or another such instantaneous event. Persistent events that can be represented by Event data tag **808** can include, but are not limited to, events associated with an alarm status (e.g., "Alarm Unacknowledged," "Alarm Acknowledged," etc.). Other examples of persistent events that can be represented by an Event data tag **808** can include persistent events with an identifier and a state. For example, events associated with a batch process can include a batch number (an identifier) and an associated event (e.g., "Starting," "Executing," "Complete," etc.). User-configurable metadata associated with the Event data tag **808** can include identifiers of other data tags whose states, in aggregation, determine the event to be represented by the Event data tag **808**. Alternatively, if the event represented by Event data tag **808** is a function of only a single input (e.g., a push-button input), the metadata can identify the appropriate input address of the industrial device.

[0094] It is to be appreciated that the smart objects described above in connection with FIG. **8** are intended to be exemplary, and that other types of smart objects are also within the scope of one or more embodiments of this disclosure.

[0095] Returning now to FIG. **7**, smart gateway platform **302** discovers and collects, on a substantially real-time basis, the data items defined by model **702** based on the previously defined data mappings applied to the selected model template **502**. In the illustrated example, some industrial devices **402** (e.g., industrial device **402***a*) support contextualization of data at the device level, while other industrial devices **402** only generate uncontextualized raw data **708** stored in standard data tags **508**. Moreover, data from some industrial devices **402** is directly accessible by the smart gateway platform **302** via the plant network protocol (e.g., Network Protocol 1 or Network Protocol 3), while other third-party or legacy industrial devices **402** may be accessible only via middleware applications **710**, which wrap the device data in an industry standard wrapper (e.g. OLE for Process Control (OPC) or another middleware protocol). Streaming this raw data **708** over time creates unstructured big data if the data is not contextualized and modeled close to the data source. Accordingly, the platform's data modeling component **308** is configured to contextualize raw data **708** from disparate data sources by naming, combining, and aggregating the data in accordance with model **702**. The resulting transformed raw data can be stored together with any pre-contextualized smart data **706** from industrial devices that support smart data tags **422** to yield structured and contextualized data **704** suitable for collective AI or machine learning analysis.

[0096] In general, model **702** specifies the data that should be analyzed to yield insights into the desired business objective, and also informs data modeling component **308** how to organize and combine the specified data items into meaningful clusters that can drive the analytics. These clusters are based on the correlations and causalities between the data items as defined by the model **702**. Any raw data **708** that is not already pre-modeled and contextualized at the device level (e.g. by smart object metadata) is transformed by the data modeling component **308** into smart data before being fed to AI analytics as structured and contextualized data **704**. This creates a common representation of all the disparate data collected by the smart gateway platform **302**. In an example scenario, overall equipment effectiveness (OEE) data from machines of a production line may be in different formats, depending on the vendor, model, and/or age of the industrial devices from which the data is collected. Data modeling component **308** can normalize this disparate OEE data into common representations. Data modeling component **308** can also add metadata to the data collected from the machines to yield contextualized smart data. Data modeling component **308** determines what metadata is to be added to a given item of raw data based on data correlations or causalities defined by model **702**. For example, if the model **702** specifies that leak test result data from a leak test station that checks a manufactured engine block for porosity issues is partly a function of a die cast oven temperature at the time the engine block was formed, the data modeling component **308** can add this oven temperature value to the leak test result data as metadata.

[0097] In some embodiments, the metadata added to the collected smart and raw data by the data modeling component **308** can include AI metadata that guides subsequent AI or machine learning analysis of the data **704**. FIG. **9** is an example data schema depicting items of smart data **902** that have been augmented by the data modeling component to include AI fields **904** defining various AI properties. In some scenarios, model **702** may specify one or more key variables or measurements that are relevant to the business objective of interest, as well as the relationships of the key variables to other variables or measurements. These relationships represent key correlations or causalities relevant to the desired business objective, as gleaned from collective industry expertise. Based on these relationships defined in the model **702**, data modeling component **308** can augment the relevant smart data by adding AI contextualization metadata. This can involve adding new AI fields **904** to the smart data **902** that represents the key variable as well as to the related smart data **902** determined to have an impact on the key variable. Values of the new AI fields **904** can encode relationships between the key variable and its correlated variables (those variables that directly affect the value of the key variable), as well as other information that can place useful constraints on subsequent AI and machine learning analysis.

[0098] For example, a new AI field **904** can be added to the key variable smart object **422** that identifies the smart object **422** as representing a key variable. Additional AI fields **904** can identify the other smart objects **422** that affect the value of the key variable. If model **702** defines a mathematical relationship between the key variable and the other relevant variables (based on domain expertise encoded in the model **702**), this mathematical relationship can also be included in one or more of the AI fields **904** (e.g., as a mathematical function defining the relationship between flow output of a pump, power consumed by the pump, and water pressure).

[0099] In some embodiments, AI fields **904** can also define the type or class of analytic problem to be solved relative to the key variable (e.g., modeling, clustering, optimization, minimization, anomaly detection, OEE calculation, etc.). The type of analytic problem can be based on the selected business objective associated with the model **702** (e.g., determine reasons why product quality is falling outside acceptable tolerances, improve product output, minimize energy consumption, etc.). Encapsulating these problem statements in the structure of the smart data **902** can convey to AI analytic systems the nature of data analysis to be carried out on the data **704** on order to generate insights into the selected business objective. For example, an analytics system at a higher level can reference this AI field **904** and, based on the value of the field, trigger the recommended algorithm or machine analysis type. This is in contrast to conventional approaches whereby the analytics system runs an ensemble of predefined analytics algorithms for a given set of data and selects the best solution, which can be more processing intensive.

[0100] Since this analytic problem statement is embedded within the structure of the structured and contextualized data **704**, real-time analytics systems that interface with the data **704** can identify the prescribed type of analytics defined by the AI fields **904** and carry out the defined analysis with minimal user intervention regardless of the platform on which the AI analytics system executes (e.g., an edge device, a cloud platform, a server, an embedded platform, etc.). Enhancing the smart data **902** to append AI fields **904** that record relationships between variables of the modeled industrial system makes these relationships visible properties of the smart data **902**, which can be accessed and leveraged by analytic systems that process the data **704**.

[0101] In some embodiments, rather than adding the AI fields **904** at the gateway level, some or all of the AI modeling can be predefined at the device level within the industrial device **402**. In such embodiments, smart objects **422** at the device level can include AI fields **904** specifying the suitable type of algorithm or machine analysis for obtaining a meaningful insight from the associated smart data, based on the industrial application, vertical, or industrial asset represented by the tag. Industrial devices **402** (e.g., industrial controllers) designed to specify recommended problem formulations in the data structure at the device level in this manner can be easily integrated with enterprise-level analytic systems and reduce the amount of time and work that must be expended by those systems to converge on solutions and insights. Encapsulating problem descriptions at the device level can also provide a means for performing distributed/collaborative analytics and can simplify multi-vendor solutions.

[0102] Data modeling component **308** can also organize and aggregate the transformed data to yield structured and contextualized data **704**. In some embodiments, data modeling component **308** can model the data to reflect an industrial enterprise hierarchy within which the data sources reside. For example, since many industrial systems are modular and hierarchical, batch processing systems may be represented by a hierarchy comprising layers representing (from highest to lowest) the industrial enterprise, the plant site, the production area within the site, the cell within the production area, the unit within the cell, and the equipment or machine within the unit. Each area in a plant may comprise many machines and associated industrial devices **402**. Data from devices that are connected to a given machine can be aggregated at the machine level to produce meaningful contextualized data. This aggregated machine-level data can include, for example, the machine's uptime, throughput, energy consumption, and quality. Further aggregation of machine data at higher levels of the hierarchy can yield cell-level and site-level data. Each level of aggregation can lead to valuable insights into plant operation. These insights become possible due to the organization of the data at different levels of the plant's hierarchy. The smart gateway platform **302** can name, process, and annotate data according to a defined enterprise hierarchy (which may be part of model **702**, or may be separately defined and referenced by data modeling component **308**), driven by the desired business outcome to be served by the structured and contextualized data **704**.

[0103] Smart gateway platform **302** can also synchronize the data collected from the industrial devices **402** prior to storage as structured and contextualized data **704**. In general, related data items that drive the desired business outcome are collected synchronously and time-stamped to establish relevancy. For example, if the business objective is to optimize the energy consumed by a mixer that mixes cookie dough, smart gateway platform **302** can synchronize the start and stop times of the mixer with the power readings from a power meter to obtain relevant and accurate data for processing. Model **702** may also specify that data items representing the amount of dough, sugar, water, temperature, batch type, and batch sizes are to be correlated with energy. Smart gateway platform **302** can time-synchronize and structure this data accordingly for subsequent data processing and analytics.

[0104] In some embodiments, data modeling component **308** can also process raw data **708** to create new OEE data for machines that do not provide such data. For example, if model **702** indicates that machine run time is required for the desired business objective analytics, data modeling component **308** can calculate this run time by subtracting a raw data value representing the time that the machine was not running from another raw data value representing the planned production time. In another example, if model **702** indicates that power consumption is a required factor for the business objective analytics, data modeling component **308** can combine voltage and current data obtained from a motor drive to yield the required power data. The power calculation for all drives (and other devices) can be standardized to a common representation, since devices from different vendors may report current and voltage in different units and formats (e.g., volts, kilowatts, etc.).

[0105] In some embodiments, smart gateway platform **302** can also be configured to generate alarms and events that are triggered by limits on individual or combined data values. These notification data types can be named in the smart gateway platform **302**.

[0106] Some embodiments of data modeling component **308** can further model at least some of the raw data and smart data to conform to an object-oriented asset model if appropriate. Industrial plants typically operate many common industrial assets, including pumps, boilers, and compressors. Many such assets are deployed within the plant, and in some cases there may be many types and models of these assets. Some asset types can be described hierarchically. FIG. **10** is an example asset type hierarchy **1002** for industrial pumps. Pumps can be categorized according to two different types of pumps—dynamic and positive displacement. Dynamic pumps can be either centrifugal or special effect. Centrifugal pumps can be axial flow, mixed flow, or peripheral. A common type of centrifugal pump is an electrical submersible pump.

[0107] In some embodiments, the smart gateway platform **302** can transform items of data (either raw data or smart data) received from industrial assets to add object-oriented model metadata describing the asset's hierarchical path within the asset hierarchy (e.g. Pumps.Dynamic.Centrifugal.Peripheral). Such hierarchical data models can assist analytic systems to organize the data for analytics, presentation dashboards, or other such data manipulation. For example, if data from various types of pumps is modeled according to the pump type hierarchy depicted in FIG. **10**, analytic systems can easily compare the efficiency of two different pump types—e.g., axial flow pumps and mixed flow pumps—by segregating data for these two pump types and comparing the two resulting data sets. Such data modeling can also allow specific pump types to be selected for focused, type-specific data analytics. By utilizing such a hierarchical asset model, data associated with each pump (e.g., pressure, flow rate, liquid volume, energy loss, pump efficiency, etc.) is inherited by all child nodes in the hierarchical path for a given pump (e.g., a flow rate for a given axial flow pump is applied to the pump itself, as well as to the axial flow, centrifugal, dynamic, and pump hierarchical classifications). Connecting contextualized smart data to object-oriented asset models can yield relevant data from industrial controllers and devices that is mapped to assets for rapid transformation into business value by analytic systems.

[0108] In conventional big data analytics, data scientists spend a considerable amount of time pre-processing or "cleansing" data in preparation for analytics. Using some or all of the data management techniques described above—driven by initial selection of a desired business objective—the smart gateway platform **302** can eliminate the need for such data cleansing by transforming unstructured industrial data into contextualized and structured smart data that is conducive to AI and machine learning analytics and organized reporting, or to other functions.

[0109] Although the data modeling functions performed by data modeling component **308** have been described above within the contexts of modeling data at the level of the smart gateway platform **302**, some embodiments of industrial devices **402** can support performing any or all of the functions associated with the data modeling component **308** at the device level, yielding at least a portion of the contextualized smart data **706** obtained or streamed from those industrial devices **402**. Moreover, at least some of the device-level smart data modeling—e.g., defined by the smart object metadata as discussed above—can be pre-defined on the industrial device **402** based on domain expertise relevant to a business objective. In an example implementation, vertical-specific and application-specific templates **424** (which may be similar to model templates **502**) stored on industrial devices **402** that support smart objects **422** can pre-define known correlations between data points and encode these correlations in the smart object metadata. These correlations and relationships can be pre-defined based on industry expertise of the relevant vertical and application. The data structures of smart objects **422** can encapsulate both system information (e.g., the data structure for a boiler) as well as associated domain expertise relevant to analysis of the smart object's data (e.g., identities of other variables that should be monitored to ensure health of the boiler). In some embodiments, the smart objects **422** can also encapsulate relevant extrinsic data such as humidity, day of the week, solar activity, local temperature, etc. Pre-modeling industrial data at the device level based on such domain expertise can yield a workable analytic model more quickly relative to employing a data scientist with high cost, low availability, or limited relevant industry knowledge.

[0110] In general, smart objects **422** can be structured and organized at the device level according to reusable industry- and application-specific templates **424** that define known relationships and correlations according to pre-packaged domain expertise. Applications represented by templates **424** can include both industrial applications (e.g., sheet metal stamping, web tension control, die cast, etc.) as well as external software applications (e.g., product lifecycle management, CAD, etc.) that consume the data and that require data to be organized and formatted in certain ways. For example, application-specific templates **424** may identify a subset of available data relevant to energy, overall equipment effectiveness (OEE), etc., and define a pre-organization of this data—terms of relationships and correlations between data items—that can quickly lead external analytic systems to relevant insights in those areas. The reusable templates **424** can identify meaningful data based on role, function, or business value (e.g., predictive maintenance), and the subset of smart objects **422** that feed into a desired function. The resulting data models at the device levels can be replicated and translated at higher levels with less manual coding or preparation.

[0111] Pre-defined device-level templates **424** can also be associated with specific devices or industrial assets (e.g., drives, boilers, etc.), and can define clusters of smart objects **422** associated with the corresponding device **402**. These templates **424** can also define calculations for deriving meaningful statistics for the device **402** (e.g., KPIs), as well as recommended mashups, augmented reality overlays, or other types of visualizations suitable for presenting data associated with the device **402**. These various templates **424** can build domain expertise into the organization structure of the device data itself.

[0112] In some embodiments, device-level templates **424** can also be generated by an end user during development of the industrial device's control programming for storage on the device. In an example implementation, pre-configured equipment models may be made available within the integrated development interface (IDE) on which the control program is generated. These equipment models can be selected for inclusion in the program and simultaneously incorporated into the device-level data model to be used to contextualize data generated by the finalized program. Design-time modeling can also be achieved by interpreting digital drawings (e.g., P&ID drawings) imported into the IDE. Engineering drawings or other types of documentation generated during the bid/design/build cycle can suggest relationships between drives and other components, which can be identified by the IDE and incorporated into the device-level (or higher-level) data models. Other types of design documents from which a designer's intent can be inferred (e.g., CAD files) can also be imported and interpreted in this manner.

[0113] Since a given data tag may be used for different purposes (e.g., quality assessment, production etc.), there may be multiple templates **424** defined at the device level for the same data, with each template **424** specific to a different business or analytic objective. In some implementations, higher-level applications can select one of the available templates **424** as a function of the desired insight or business objective. In this way, device-level data modeling can encapsulate the data structures in different ways for customized consumption by multiple different higher-level applications, allowing the data to be consumed differently by multiple parties. Data can also be combined to yield a composite stream that flows upward through the enterprise layers.

[0114] In some embodiments, the industrial device's smart object configuration component **408** can also allow users to further augment selected smart objects **422** with custom metadata (e.g., via user interface component **414**) defining customer-specific correlations between data points, allowing end users to augment smart objects **422** with their own opinions or knowledge regarding which data items are most relevant to a desired business outcome (e.g., which boilers or other assets are most important to monitor to learn a desired insight). Analytic systems can subsequently use the pre-defined and user-defined smart object metadata to build analytic models that incorporate built-in domain expertise as well as user-provided application expertise, quickly and easily driving the data to desired business outcomes without the need for data janitors or extensive expert coding.

[0115] In some embodiments, contextualization metadata at the device level can be responsive to changes in system or asset reconfigurations. For example, if a machine or line is reconfigured in a manner that changes the associated data's organization, the smart object configuration component **408** of the corresponding industrial device **402** can update the device's smart objects **422** to reflect these contextual changes. Alternatively, end users can easily update the smart objects accordingly via user interface component **414**.

[0116] As noted above, the structured and contextualized data **704** generated by the smart gateway platform **302**—or obtained as pre-modeled data from the industrial devices **402** in the case of devices that support smart objects **422** and device-level data modeling—can be fed to an analytic system, which can perform AI or machine learning analytics on the structured data in order to glean insights and generate recommendations relating to the business objective associated with the model **702**. FIG. **11** is a diagram illustrating an example architecture in which the smart gateway platform **302** collects, contextualizes, and structures data from industrial devices **402** and provides the resulting structured and contextualized data **704** to an AI analytic system **1102**. Although FIG. **11** (and other examples described herein) depicts data **704** being fed to an AI analytic system **1102**, other types of analytics can be applied to the data **704** without departing from the scope of this disclosure, including but not limited to machine learning or statistical analysis. After model **702** has been customized by mapping the model's defined data items to specific data items on the industrial devices (e.g., smart objects **422** and/or standard data tags **508**), the smart gateway platform **302** begins collecting and transforming the data from the mapped data sources as described above to yield structured and contextualized data **704**. Since the collected data is contextualized and structured based on relevant correlations and causalities defined by the model **702**—that is, correlations and causalities defined as being relevant to the particular business objective being examined—these correlations and causalities are provided to the AI analytic system **1102** as metadata associated with the collected data items. The platform's analytics interface component **312** can be configured to exchange data with the AI analytic system **1102** and feed the data **704** to the analytics system **1102**.

[0117] Informing AI analytic system **1102** of relevant data correlations and causalities between the data items prior to application of data analytics can apply useful constraints on data analysis performed by the AI analytic system **1102**. These constraints can drive the analytic system **1102** to useful insights more quickly relative to unconstrained big data analysis, significantly reducing the amount of time required for the AI analytic system **1102** to discover insights and generate useful recommendations relative to the desired business objective. These predefined correlations and causalities can also mitigate discovery of spurious or irrelevant correlations between the data items by the AI analytic system **1102**. By limiting the set of data supplied to the AI analytic system **1102** to only those data items deemed relevant by the model **702**, and by structuring and contextualizing these data items based on predefined correlations and causalities derived from collective industry expertise, the smart gateway platform **302** narrows the data space to be analyzed by the analytic system **1102**, assisting the analytic system **1102** to discover useful insights and generate recommendations more quickly relative to unconstrained big data analysis. The limited set of collected data items can also simplify data life cycle management.

[0118] Subsets of the data items collected by the smart gateway platform **302**, as well as results of AI or machine learning analytics applied by analytic system **1102** on the data, can be delivered as visualization presentations **1104** to one or more client devices **1106** having permission to access the analytic results. Information rendered on visualization presentations **1104** can include recommendations or actionable insights about operation of the industrial devices relative to the business objective originally selected by the user. For example, if the originally selected model template **502** (on which model **702** is based) pertains to the business objective of maximizing product output of a certain type of industrial process, smart gateway platform **302** will collect, structure, and contextualize data items known to be relevant to obtaining actionable insights into this problem. This structured and contextualized data **704** is fed to AI analytic system **1102** (e.g., as streaming smart data), which performs AI or machine learning analysis on the smart data streams with the goal of determining root causes of productivity loss and generating recommended countermeasures or actionable insights. In this regard, reduction of the relevant data set by the smart gateway platform **302** to those data items known to be relevant to the business objective, as well as the known correlations and causalities between the data items encoded into the smart data based on model **702**, can lead the AI analytic system **1102** more quickly to actionable insights regarding the defined business objective.

[0119] In an example scenario, AI analytic system **1102** may determine, based on application of AI or machine learning to the structured and contextualized data **704**, that downtime of a particular production line (e.g., Line 5) that is part of the overall process is a significant cause of productivity loss. Accordingly, AI analytic system **1102** may determine, based on further AI analytics, one or more possible countermeasures for reducing the total accumulated downtime of Line 5 (e.g., reducing an operating speed, increasing a frequency of maintenance performed on Line 5, modifying an operating sequence, etc.). The discovered root cause and associated recommended countermeasures can be presented to the user via visualization presentations **1104**. If AI analytic system **1102** is designed to perform predictive analysis or trend analysis, the system **1102** may also identify indications within the data **704** that typically precede a downtime event, and continue monitoring the structured and contextualized data **704** for the presence of these indications. In response to determining that relevant items of data **704** satisfy the criteria indicating an impending downtime event, the analytic system **1102** may generate and deliver a notification to one or more client devices **1106** informing of the predicted downtime event.

[0120] In some embodiments, in addition to or as an alternative to rendering recommendations and actionable insights into solving the specified business objective, analytic system **1102** can generate and direct control outputs **1110** to one or more of the industrial devices **402** based on results of analytics applied to the data **704**. Control outputs **1110** can be configured to alter a configuration or operation of selected industrial devices **402** in a manner predicted to move operation toward the specified business objective. For example, if analytic system **1102** determines that reducing a speed setpoint of a motor drive will reduce downtime instances of a particular production line, thereby achieving the business objective of improving production output, system **1102** may direct a control output **1110** to the selected motor drive that alters the speed setpoint accordingly. Analytic system **1102** can deliver control outputs **1110** to the target industrial devices via any suitable means, depending on the system architecture. For example, if analytic system **1102** is an edge device that resides on the same plant network as the industrial devices, control outputs **1110** can be delivered directly via the network. In another example architecture, analytic system **1102** may deliver control outputs **1110** to the target industrial devices **402** via the smart gateway platform **302**.

[0121] As noted above, the structured and contextualized data **704** submitted to the analytic system **1102** by the gateway platform **302** is pre-modeled with data relationships and correlations based industry and user expertise encoded in one or both of model **702** or smart object metadata (based on templates **424**). In some embodiments, external AI analytics can also identify additional correlations in real-time during operation and feed these relationships back to the device-level or gateway models. In this way, the pre-packaged data models at the device level or on the gateway platform **302** can be refined according to the idiosyncrasies of a customer's unique system and application, as discovered by external analytics. Moreover, some embodiments can implement a hybrid self-driving AI approach that further enhances the device-level models based on response input from experts. For example, a domain expert can rank the quality of a clustering result, and this expert feedback can be used to modify the parameters for the clustering.

[0122] The AI analytic system **1102** to which smart gateway platform **302** feeds the structured and contextualized data **704** may execute on the smart gateway platform **302** itself (e.g., as gateway analytics component **310**), may execute on a separate edge device on the plant network **116**, or may execute at a higher level of the industrial enterprise or on a cloud platform. FIG. **12** is a diagram illustrating an example architecture in which smart gateway platform **302** provides structured and contextualized data to analytic systems at various levels of an industrial enterprise. As described above, the platform's data modeling component **308** contextualizes, models, and structures raw and/or smart data **1208** collected from industrial devices **402** in accordance with model **702**. The platform's analytics interface component **312** passes the resulting structured and contextualized data **704** to an analytics system for AI or machine learning analysis. The industrial environment depicted in FIG. **12** includes AI analytic systems that execute at various levels of the enterprise, including a local gateway analytics component **310** that is integrated with the smart gateway platform **302** itself, an edge-level analytic system **1210** that executes on an edge device **1206** (e.g., a network infrastructure device or other type of device that links the plant network to the cloud, the Internet, or another network), and a cloud-based AI analytics system **1204** that executes on a cloud platform. Any of these analytic systems can perform analytics on the structured and contextualized data **704** as described above. Each of these analytic systems can provide visualization presentations **1104** containing notifications, recommendations, or actionable insights to authorized client devices **1202** as also described above.

[0123] In some scalable analytic architectures, analytics systems can also execute on the device level and on the enterprise level on a local network, in addition to the analytic systems that execute on the smart gateway platform **302**, edge devices **1206**, and cloud platforms. FIG. **13** is a diagram of an example scalable industrial analytics architecture. Such multi-level analytic architectures—with smart gateway platform **302** serving as a source of aggregated, normalized, and pre-modeled data—can be designed such that AI analytics are performed on a device or level of the industrial enterprise most relevant to the type of analytics being performed.

[0124] In this example architecture, the OT environment (as distinct from the IT environment) is defined to encompass the industrial devices, machines, lines industrial servers, and edge devices on the plant floor. Many of these OT devices and systems have significant native processing capabilities. Data functions such as transformation of raw industrial data from the industrial devices **402** (including industrial controllers and lower level industrial devices **120**) into smart data, or performance of real-time analytics intended to regulate operation of the industrial devices **402**, are best performed on the OT level; e.g., on the smart gateway platform **302**, on the edge-level analytic system **1210**, or on device-level analytic systems **1304**. Real-time analytics are defined as analytics that occur in the OT domain that result in real-time actions, such as changing a set point of an industrial device or otherwise altering operation of an industrial process. Other higher level (enterprise level) analytics may be best suited for execution in the IT domain; e.g. by enterprise-level analytic systems **1302** or cloud-based analytics systems **1204**. Analytics in the IT or cloud domain typically produce higher-level insights for visualization on client devices using dashboards or other visual presentations. Such higher-level analytics are referred to as non-real-time analytics since they do not typically result in immediate feedback control of industrial assets. Non-real-time analytics may also be referred to as human real-time analytics, as opposed to machine real-time analytics. For manufacturing plants with significant computing resources throughout the OT environment, a majority of data processing and value extraction is likely to occur in the OT environment. For field-based assets with limited computing resources, most of the data processing may instead occur on the cloud platform **122**.

[0125] For simplicity, the example architecture depicted in FIG. **13** can be divided into three hierarchical levels: the device level, the system level, and the enterprise level. The enterprise level is part of the IT environment, while the device and system levels are part of the OT environment. Device-level analytics can perform such real-time functions as checking measured operating parameters against defined limits, which can provide useful insights into a device's operation. System-level analytics (e.g., performed by edge-level analytic system **1210** or gateway analytics component **310**) can derive insights relating to higher-level system operation, such as predicting that a trend in a paper web's tension is indicative of an impending web break within a few operating cycles. Operational insights obtained by device-level and system-level analytics, when implemented in controllers and industrial computers, enable real-time control actions intended to move system performance toward the business objective associated with model **702**. In general, real-time analytics result from processing real-time data in the OT environment. At the enterprise level, selected contextualized or smart data from the OT environment can be analyzed and combined with data from other parts of the industrial enterprise to develop data presentations (e.g., dashboards or other visual presentations) that deliver actionable insights to a user via a client device.

[0126] This approach of locating data processing and analytics functions in a scalable manner is well-suited to industrial Internet-of-Things (IoT) applications with varying time domains of processing (e.g., milliseconds, seconds, minutes, hours, etc.), asset locations (centralized and remote), and system relationships (e.g., autonomous, in-line, buffered, batched, etc.). Analytics and AI/machine learning at each of these three defined levels can optimize processes and operations in industrial plants to achieve desired business objectives.

[0127] Within an architecture comprising one or more device-level, system-level, and enterprise-level analytics systems, a device-level or system-level analytic system can perform analytics on the device or system level when appropriate (e.g., on industrial controllers or other industrial devices **402**, on low-level industrial devices **120**, on edge devices **1206**, etc.), and can shift analytics tasks to enterprise-level analytics systems to perform analytics scoped to the enterprise level as needed. Device-level analytic systems **1304** can perform local analytics on device data when device-level results are required. Device-level analytics performed by analytic systems **1304** can include, but are not limited to, determining whether a particular industrial device (e.g., a controller, sensor, drive, meter, etc.) is at risk of failure or should be replaced based on analysis of local data associated with that device (or data associated with a process or machine controlled by the device), determining a root cause of a device fault, etc.

[0128] Device-level analytic systems **1304** can also leverage the data modeling templates **424** and device-level models represented by smart objects **422** to optimize real-time operation. In an example scenario, after being placed in a shutdown state a production line may take some time to transition back to normal operation after being restarted due to the amount of time required for the line to rebalance. The time required for the line to rebalance itself and return to its normal workflow can adversely impact the line's overall equipment effectiveness (OEE). To address this, a template **424** may define a data modeling for optimizing production line start-up. The template **424** can identify, for example, which subset of available data elements (e.g., smart objects **422**) drive optimization of line start-up and the relationships between these data elements. The resulting device-level data modeling can be used by device-level analytic systems **1304** at the controller to determine an optimal start-up sequence that minimizes the time required to resume normal line operation. Driving computing services down to the lower levels of the architecture in this manner—using the device-level models to aid local analytics—can reduce communication bandwidth by performing optimization analytics at the device level rather than sending the data to higher level optimization systems. This approach can also reduce latency, making control-level analytics applications possible (e.g., identifying pump cavitation in a drive, making it possible to rapidly trim the pump speed).

[0129] Results of the device-level analytics can be consumed locally by the industrial device itself, or sent to a client device (e.g., as a notification or dashboard). For example, in response to a determination by a device-level analytic system **1304** that an industrial controller or device that hosts the analytic system **1304** is at risk of failure or an unacceptable loss of efficiency, and if the analytic system **1304** identifies an automated countermeasure that may mitigate or delay the device failure, analytic system **1304** can generate a control instruction that implements the countermeasure on the host device; e.g., by altering the device's operation in a manner that has a likelihood of mitigating the failure. Such countermeasures can include, but are not limited to, switching the device to a slow operation mode or stopped mode, switching the device to a backup power supply, changing a setpoint defined in the device, initiating execution of a different control program or sub-routine (in the case of industrial controllers or other programmable devices), or other such countermeasures.

[0130] In the case of system-level analytic systems **1210** or **310**, risks associated with operation of more complex industrial automation systems—rather than a single device—can be monitored and identified, and appropriate countermeasures scoped to the entire automation system can be implemented. In an example scenario, if a system-level analytic system **1210** or **310** predicts—based on analysis of structured and contextualized data **704** prepared by the smart gateway platform **302**—that a production line is at risk of producing an excessive amount of product waste (e.g., due to an increase in the number of part rejections, a discovered inefficiency in a process carried out by the production line, an indication of excessive wear on one or more devices that carry out the process, etc.), the system-level analytic system **1210**, **310** can implement a multi-device countermeasure intended to mitigate the risk of product waste. This can involve generating multiple sets of instruction data directed to devices that make up the automation system, where the instructions are configured to alter operation of the target devices in a coordinated manner to effect the countermeasure on the automation system as a whole, thereby reducing the risk of product waste. Such system-wide countermeasures can include, for example, reducing the rate of production on a production line, switching production of the product to an alternative production line (which may involve sending instructions to control devices of the current production line to cease production, sending further instructions to the new production line to begin production, and sending still further instructions to appropriate upstream systems to begin providing material or parts to the new production line), sourcing a production line with parts from an alternate production line or source, or other such countermeasures.

[0131] Although the smart gateway platform **302** is depicted in FIG. **13** as being embodied separately from edge device **1206**, some embodiments of smart gateway platform **302** can be embodied on an edge device **1206**. With this configuration, high-level or external applications can discover device-level data and associated models via gateway functionality implemented on an edge device **1206**, which then acts as a standardized interface that provides data and associated model information in a consistent manner regardless of the analytics package accessing the data. By implementing smart gateway functionality at the edge, edge devices **1206** can model third-party or legacy data from the device level, thereby generating smart objects from legacy controllers or other devices that do not support pre-created device-level models. In some scenarios, performing data modeling on legacy data is more beneficially performed at the edge layer than at higher layers such as the cloud, since the data model may lose context by the time the data reaches these higher layers. Moreover, the extra latency involved in moving unmodeled data to these higher levels can prevent accurate timestamping of the data. Accordingly, edge device **1206** can be configured to time-stamp data from the adjacent device-layer, ensuring accurate synchronization of data from the disparate devices.

[0132] In addition to monitoring devices and systems and implementing control modifications as needed, device-level, edge-level, and system-level analytic systems can also send analytic results to authorized client devices in the form of notifications, dashboards, or other graphical interfaces. In addition, when appropriate, the device-level, edge-level, or system-level analytic systems can send results of local analytics to the enterprise-level analytic system **1302** or cloud-based analytic system **1204** for enterprise level analysis. The device-level, edge-level, and system-level analytic systems can also send results of local analytics to other analytic systems on the same level or a different level of the enterprise. Analytic results sent from one of the analytic systems to another can be processed at the receiving system for further analytics. In this way, multi-level analytic systems can carry out inter-node collaborative analysis in connection with performing plant-level analytics, such that analytical tasks are carried out at the level of the enterprise deemed most suitable for the given analytical task. Analytics can also be scaled downward from higher levels to lower levels as appropriate.

[0133] In an example scenario, the decision to scale analytics upward or downward between analytic systems can be based on time-sensitivity of the analytics being performed. For example, if a system-level analytic system (e.g., edge-level analytic system **1210** or gateway analytics component **310**) is performing analysis on a current production run of a product in which the result of the analytics may determine how the current run is to be executed, the system-level analytic system may shift at least a portion of the analytic processing to a device-level analytic system **1304** hosted on an industrial controller or another industrial device **402** that is part of the automation system executing the production run. By shifting relevant analytics to the device-level analytic system **1304** hosted on a controller or device that participates in the control process, the analytic result generated by the device-level analytic system **1304** can be leveraged more readily by the control devices that control the industrial process. In general, analytic systems can be configured to identify criteria indicating that data or analytic results are to be scaled or transferred to another analytic system; namely, the particular device, group of devices, industrial assets, or systems affected by a result of the analysis. The decision to send analytic results or other locally available data to another analytic system can be based on a determination of whether the result or data satisfies a criterion indicative of an importance or relevance of the result or data to another portion or layer of the overall enterprise architecture.

[0134] In some embodiments, in addition to providing pre-modeled plant floor data that has been contextualized at the device level for higher-level analysis, industrial devices **402** that support smart objects **422** and associated device-level data modeling can allow their device-level data models to be discovered and integrated into higher-level analytic models. For example, device-level templates **424** or other device-level models on the industrial devices **402** can be discovered by higher-level systems (e.g., analytic systems **1210**, **1204**, or **1302**, ERP systems, maintenance systems, etc.) and integrated into high-level analytic models associated with these systems. In this way, smart objects **422** and their associated modeling metadata implement data engineering at the device level with the assistance of the modeling templates **424**, and the resulting device-level data models can be discovered by and pulled into higher-level systems without requiring manual configuration. Modeling data at the device layer in this way can facilitate automated integration into these higher-level systems in a manner that is agnostic to the type of system consuming the data. Smart objects **422** can also simplify integration of distributed analytic architectures by defining the input/output structures for communication between distributed systems and analytics engines.

[0135] In general, smart object modeling contextualizes data at low levels, and this contextualization is maintained—and enhanced—as the data moves to higher levels of the enterprise. For example, a smart object **422** associated with a pump or other industrial asset can be modeled in a controller with contextual metadata based on information available at the controller (e.g., relationships to other data tags as defined by the templates **424**, timestamps, device-level context, environmental data, etc.). At higher levels, the smart object's data and associated contextual metadata (including encapsulated domain expertise built into the structure of the smart object **422** itself) can be supplemented with maintenance data or other information available at the higher levels, thereby enhancing the data model as the data moves upward. Summing and contextualizing data at the lowest layers—e.g., the device layers—can ease integration of data with higher-level systems by removing the burden of learning correlations and contexts from these high-level systems. Propagating these device-level model—as represented by the device-level contextual metadata—to higher levels can also allow the device-level models to be consumed by these higher levels without the need to push data down to the device level for analysis.

[0136] This general approach can be used to progressively add layers of contextualization to industrial data as the data moves upward through the enterprise hierarchy. For example, when the gateway platform **302** receives modeled industrial data from the smart objects **422** of industrial devices—that is industrial data enhanced with device-level contextual metadata added by the industrial devices based on data modeling templates **424**—the gateway platform's data modeling component **308** can further enhance the device-level model by supplementing the device-level contextual metadata with further modeling metadata based on the selected model template **502** for a desired business objective. Analytics can then be performed on the resulting modeled data based on this aggregate data model. In an example scenario, the progressively modeled data—comprising the industrial data values, their associated device-level contextual metadata, and the further modeling metadata added by the gateway platform's modeling component **308**—can be analyzed by the gateway platform's gateway analytics component **310**. Alternatively, the gateway platform's analytics interface component **312** may send the progressively modeled data to another analytic system for analysis (e.g., a cloud-based analytic system, an enterprise-level analytic system, an edge-level analytic system, etc.). In either case, this progressive, layered data modeling can be leveraged by the analytic system quickly and accurately yield actionable insights into the controlled industrial process relative to defined business objectives for which the models were designed.

[0137] In some embodiments, insights obtained by higher-level analytic systems can also be fed back to the device-level models on the industrial devices **420**. For example, an AI engine or another type of analytic system at the enterprise level—or the gateway analytics component **310** of the gateway platform—may learn, based on AI analytics or traditional algorithms applied to smart object data, a key variable indicative of an overall performance of an industrial asset represented by a smart object cluster on the industrial device **402**. Accordingly, the AI engine (or the data modeling component **308** in the case of the gateway platform **302**) can adjust the data model structures of the smart objects to encode this key variable as part of the smart object architecture; e.g., by adding a new data field defining a key variable to be monitored, or by modifying the device-level modeling templates **424** to reflect the new insight discovered at the higher-level analytic system or gateway platform **302**. In this way, discoveries made by external or higher-level analytic systems are permanently encoded in the metadata of the relevant smart objects **422** at the device level, and this knowledge can be accessed by other analytic systems that reference the smart objects **422**.

[0138] In some embodiments, the high-level analytic systems or the gateway platform **302** can also replace, update, or shape device-level analytic algorithms (e.g., analytic algorithms executed by device-level analytic systems **1304**) based on insights obtained at these higher analytic levels. In some embodiments, this process can also work in the reverse direction—from the device-level to the higher levels—such that insights obtained by device-level analytic systems **1304** are fed upward to the higher-level analytic systems (e.g., edge-level analytic systems **1210**, gateway analytics, cloud-based analytic system **1304**, enterprise-level analytic system **1302**, etc.), which update their analytic algorithms accordingly to reflect the device-level insights.

[0139] In addition to collection and modeling of raw and smart data from industrial devices, some embodiments of smart gateway platform **302** can also be configured to collect and model data from other types of data sources if dictated by the model **702** (that is, if the model **702** specifies that this supplemental data is useful for learning actionable insights into the business objective represented by the model **702**). FIG. **14** is a diagram of an example industrial architecture in which a smart gateway platform **302** feeds structured and contextualized data **704** from disparate data sources throughout an industrial enterprise to a cloud-based analytic system **1204** executing on a cloud platform.

[0140] As described above, smart gateway platform **302** can normalize disparate structured data (e.g., from smart objects **422**) and unstructured data, and model the data to encode relationships (correlations, causalities, etc.) between the data based on industry domain expertise encoded in the model **702**. The platform **302** feeds this data **704** to AI analytic system **1204**, which generates outcomes based on analysis of the structured and contextualized data **704**. Data gathered by the smart gateway platform **302** can include both data from both plant floor devices and operational and supervisory software systems in the OT layer (e.g., MES systems, historians, inventory tracking systems, etc.). In the illustrated example, data collected by the smart gateway platform **302** for transformation and transmission to the cloud-based AI analytic system **1204** includes real-time control data **1414** generated by industrial devices **402**. This real-time control data can include analog and digital data stored in the devices' data tables or associated with the devices' data tags. The control data can represent, for example, measured telemetry or sensor values read from a controlled industrial process (e.g., temperatures, pressures, flows, levels, speeds, etc.), measured digital values (e.g., part present sensor values, safety device statuses, switch settings, etc.), controlled analog and digital output values generated by the devices **402** and directed to industrial output devices of the controlled system, calculated performance metrics, etc.

[0141] Other data collected by the smart gateway platform **302** can include, but is not limited to, log files **1412** from a data historian device **110** residing on the plant network **116**, spreadsheet files **1411** stored on a maintenance schedule server **1402** (residing on office network **108**) and containing information regarding maintenance schedules for various machines throughout the industrial facility, work order database files **1408** stored on a work order database **1404** and containing work order information relating to products produced at the industrial facility, inventory database files **1410** stored on an inventory database **1406** and containing information regarding current and/or expected product availability, or other such data files. Although the present example presumes specific types of information contained in these respective data file types—e.g., maintenance schedule information stored as spreadsheet files **1411**, work order information stored in work order database files **1408**, etc.—it is to be appreciated that these information types are only intended to be exemplary, and that other types of information can be stored in the various file types. These diverse sets of data can be collected and transformed by smart gateway platform **302** in accordance with model **702** (specifying the desired business objective) and sent to the cloud-based analytic system **1204** as structured and contextualized data **704**.

[0142] Since the smart gateway platform **302** normalizes and models the data collected from industrial devices **402**, the platform **302** can present the resulting structured and contextualized data **704** in a consistent model that can be automatically discovered by software applications—e.g., AI or machine learning analytic systems—designed to consume this data. This can greatly simplify acquisition and analytics of data relevant to a desired business objective. By referencing a customized model **702** that defines data items (e.g., sensory inputs, key performance indicators, machine statuses, etc.) that are relevant to a desired industry- and machine-specific business objective (e.g., minimization of machine downtime, optimization of operation efficiency, etc.), the smart gateway platform **302** can significantly reduce the amount of storage required for data collection and analysis relative to streaming and storing all available time-series data from the plant floor. Smart gateway platform **302** also uses the model **702** to predefine and preformat data for consumption by higher level analytic models (e.g., high level object-oriented models) and analytics software. Moreover, integration of containerized software and micro-services with the smart gateway platform **302** can add new value at the edge by further modeling, persisting, and analyzing the data for business value.

[0143] FIG. **15** illustrates a methodology in accordance with one or more embodiments of the subject application. While, for purposes of simplicity of explanation, the methodology shown herein is shown and described as a series of acts, it is to be understood and appreciated that the subject innovation is not limited by the order of acts, as some acts may, in accordance therewith, occur in a different order and/or concurrently with other acts from that shown and described herein. For example, those skilled in the art will understand and appreciate that a methodology could alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all illustrated acts may be required to implement a methodology in accordance with the innovation. Furthermore, interaction diagram(s) may represent methodologies, or methods, in accordance with the subject disclosure when disparate entities enact disparate portions of the methodologies. Further yet, two or more of the disclosed example methods can be implemented in combination with each other, to accomplish one or more features or advantages described herein.

[0144] FIG. **15** illustrates an example methodology **1500** for structuring industrial data and performing data analytics on the structured data to yield actionable insights relative to a desired business objective. Initially, at **1502**, selection data is received that selects a model template from a library of model templates associated with respective business objectives. The library of model templates can be stored on a smart gateway platform. Each model template can define, for a given business objective, a set of data items (e.g., sensor inputs, controller data tags, motor drive data tags, etc.) relevant to determining actionable insights into the associated business objective, as well as relationships (e.g., correlations, causalities, etc.) between the data items. The data items and the relationships therebetween are based on domain expertise or knowledge encoded into the model templates. Example business objectives for which model templates may be made available can include, but are not limited to, minimizing machine downtime, determining a cause of machine downtime, predicting machine downtime, increasing product output, optimizing energy efficiency, improving product quality, or other such objectives.

[0145] At **1504**, mapping data is received at the smart gateway platform that maps the data items defined by the model template selected at step **1502** to respective data tags on one or more industrial devices. The data tags to which the data items are mapped may be standard industrial data tags or may be smart objects that store smart data that has been pre-contextualized by its associated smart industrial device.

[0146] At **1506**, data is collected from the data tags by the smart gateway platform. In contrast to conventional big data analytic systems, only the data streams considered relevant to the desired business objective associated with the selected model template are collected. At **1508**, the data items collected at step **1506** are augmented with modeling metadata based on data correlations defined by the model as being relevant to the business objective associated with the model. This can include, for example, adding metadata to respective data items to define the associated data value's mathematical relationship to other data items, as determined based on the relationships defined by the model. Metadata may also be added that defines the type of analytic problem (e.g., modeling, clustering, optimization, minimization, etc.) to be solved by subsequent AI analysis of the data, which is a function of the specific business objective for which actionable insights are desired. This augmentation step can also include normalization of the data items to a common format in preparation for collective AI analysis.

[0147] At **1510**, a determination is made as to whether the data collected at step **1506** is pre-contextualized smart data from a smart industrial device. Such smart devices may be configured to pre-contextualize data items generated by the device with contextualization metadata that provides additional information regarding the context under which the data values were generated. This contextualization metadata may include, for example, an operating state of a machine at the time the data value was generated (e.g., running, idle, faulted, etc.), power statistics at the time the data was generated (e.g., voltages, currents, power consumption, etc.), or other such contextual metadata that may impart greater informational value to the data item.

[0148] If an item of the data collected at step **1506** is not pre-contextualized (NO at step **1510**), the methodology proceeds to step **1512**, where contextualization metadata is added to the data item by the smart gateway platform. In various embodiments, the smart gateway platform can select relevant items of contextualization data based on the model template selected at step **1502**, or based on a model of the industrial enterprise that defines functional relationships between machines and devices.

[0149] If the data is already pre-contextualized (YES at step **1510**), the methodology proceeds to step **1514** without adding contextualization metadata. At **1514**, the structured and contextualized data resulting from steps **1508**-**1512** is fed to an artificial intelligence analytic system. At **1516**, AI or machine learning analytics are applied to the structured and contextualized data to facilitate discovery of actionable insights relevant to the desired business objective. In some alternative embodiments, the structured and contextualized data can be fed to other types of analytics systems (e.g., a statistical analysis system) instead of an AI analytic system.

[0150] In some embodiments, with data models residing at the device level of an industrial enterprise using the data modeling templates **424** and smart objects **422** described above, data streams sourced by industrial devices **402** can be labeled at the device level and insights can be gleaned from these labeled data streams at higher levels (e.g., by analytic systems in the cloud, on edge devices, or at an enterprise level of an industrial enterprise). These contextualized and labeled data streams can be accessed using a publish-subscribe approach in some implementations, whereby contextualized data from the industrial devices **402** is provided to a broker system and labeled according to various topics. External systems, including analytic systems, can then subscribe to relevant topics, and the broker system will provide a subset of available data streams corresponding to the selected topics as a contextualized data stream.

[0151] FIG. **16** is a block diagram of an example industrial data broker system **1602** according to one or more embodiments of this disclosure. Industrial data broker system **1602** can include a device interface component **1604**, an analytic system interface component **1606**, a data stream publishing component **1608**, a data labeling component **1612**, one or more processors **1618**, and memory **1620**. In various embodiments, one or more of the device interface component **1604**, analytic system interface component **1606**, data stream publishing component **1608**, data labeling component **1612**, the one or more processors **1618**, and memory **1620** can be electrically and/or communicatively coupled to one another to perform one or more of the functions of the industrial data broker system **1602**. In some embodiments, components **1604**, **1606**, **1608**, and **1612** can comprise software instructions stored on memory **1620** and executed by processor(s) **1618**. Industrial data broker system **1602** may also interact with other hardware and/or software components not depicted in FIG. **16**. For example, processor(s) **1618** may interact with one or more external user interface devices, such as a keyboard, a mouse, a display monitor, a touchscreen, a smart phone, a tablet computer, an AR/VR wearable appliance, or other such interface devices. In some embodiments, broker system **1602** can serve as a logical entity that is embedded in another device, including but not limited to an edge device, an industrial controller, or an HMI terminal.

[0152] Device interface component **1604** can be configured to receive or obtain data streams from industrial devices (e.g., industrial devices **402**). In some scenarios, this data can comprise contextualized data that has been pre-modeled at the industrial device **402**; e.g., by metadata associated with smart objects **422**, from which the data is sourced, as described above. As such, the data streams include both data values associated with their corresponding data tags (e.g., time-series data) as well as pre-defined and learned correlations with other data tags or values which can assist AI systems to converge to actionable insights faster relative to uncorrelated data streams. The data streams received from the industrial devices may also be labeled according to one or more topics to which the data is relevant from an analytics perspective. The data streams may be published by the respective devices by data publishing components **410** associated with the devices in some embodiments, and can be received by device interface component **1604** via one or more secure network connections (e.g., a plant network, a cloud platform, public networks such as the internet, etc.).

[0153] Analytic system interface component **1606** can be configured to exchange data between the broker system **1602** and external analytic systems (e.g., analytic system **1102**). This can include receiving requests from these external systems to subscribe to one or more labeled data streams, and publishing of selected data streams to respective analytic systems in accordance with the subscriptions. Data stream publishing component **1608** can be configured to process data topic subscription requests from analytics systems (e.g., AI analytic systems, machine learning systems, etc.), and to selectively publish data streams to subscribing analytic systems according to topic.

[0154] Data labeling component **1612** can be configured to apply labels to incoming data from industrial devices in scenarios in which the data is received from the devices without a label. The one or more processors **1618** can perform one or more of the functions described herein with reference to the systems and/or methods disclosed. Memory **1620** can be a computer-readable storage medium storing computer-executable instructions and/or information for performing the functions described herein with reference to the systems and/or methods disclosed.

[0155] In an example scenario, a user can apply topic labels to selected smart objects **422** in an industrial controller or other industrial device **402** during control program development, along with other data tags to be used by the control program. FIG. **17** is a diagram illustrating configuration of smart objects in a tag database **1702** of an industrial device **402** that supports smart objects. Industrial device **402** may be, for example, an industrial controller (e.g., a programmable logic controller or other type of programmable automation controller) configured to execute an industrial control program **1704** to facilitate monitoring and control of an industrial machine or process. Industrial device **402** includes a tag database **1702** that stores data tag definitions **1714**, which may include definitions of both standard data tags and smart objects **422**. The data tag definitions **1714** can be configured by a user in tandem with development of control program **1704** (e.g., a ladder logic program, a sequential function chart program, etc.), and define data tags of various data types that are used to store and identify analog and digital data values generated and consumed by the control program **1704**. Example standard data types that can be represented by tag definitions **1714** can include, for example, integer data types, real data types, Boolean data types, etc. In addition to these standard data types, one or more of the data tags can include smart objects **422** as described above.

[0156] In this example scenario, a user can configure both the control program **1704** and the data tag definitions **1714** using a device configuration application **1708** that executes on a client device **1710** (e.g., a laptop computer, a desktop computer, a tablet computer, etc.) that is communicatively interfaced to the industrial device **402**. In various embodiments, client device **1710** can interface with the industrial device **402** over a hard-wired connection (e.g. a universal serial bus connection, an Ethernet connection, a serial connection, etc.) or over a wireless connection (e.g., near-field, WiFi, etc.) supported by user interface component **414**. Device configuration application **1708** can execute a program development environment that can be used to develop control program **1704** and its associated data tags, including any smart objects **422** to be associated with one or more industrial assets to be controlled using control program **1704**.

[0157] As described above, smart objects **422** included in the tag definitions **1714** can comprise metadata that pre-models and contextualizes the data for subsequent AI or machine learning analysis. At least some of this contextualization metadata can be based on predefined data modeling templates **424** as described above, such that the metadata defines relationships, correlations, and preferred analysis types to be performed on the smart object data as gleaned from industry expertise encoded in the templates **424**. Some of the contextualization metadata may also comprise user-defined contextualization set by a user as part of the smart object configuration data **1706**. Such user-defined contextualization may define customized relationships or correlations between data items to yield customized device-level models that conform to idiosyncrasies of the end user's particular industrial automation systems and equipment.

[0158] Using device configuration application **1708**, the user can also configure the metadata associated with respective smart objects **422** to define pre-processing to be performed on the smart object's data at the device level in accordance with a given industrial application. For example, for a smart object **422** that defines a state of a bottle filling machine to be controlled by industrial device **402**, the user may specify the various states to be represented by the tag (e.g., Running, Home, Abnormal, Idle, etc.). In some embodiments, the smart object configuration component **408** can support a number of pre-defined states that can be selected by the user and associated with a given smart object **422** representing a machine or device state. In addition or alternatively, the user can define the names of one or more of the states to be associated with the smart object **422**.

[0159] In another example, for a smart object **422** representing a velocity of a conveyor that feeds bottles to the filling machine, the user can specify maximum and minimum values for the velocity value. Accordingly, the smart object **422** will not generate a velocity value that is outside the range defined by the specified maximum and minimum values, and may generate an error or alarm output if the measured velocity value exceeds the defined maximum or falls below the defined minimum. Another smart object **422** representing an average temperature may be configured to average multiple analog temperature input values specified by the user in the metadata. For a smart object **422** representing a product count (e.g., the number of filled bottles output by the filling machine), the user can configure the associated metadata to define the data tag that triggers an increment of the product count value (e.g., an input tag or another smart object **422** representing a "fill cycle complete" event), as well as daily shift start and shift end times between which the value of the smart object **422** will increment before being reset to zero.

[0160] In addition to the tag configuration aspects discussed above, users can also associate selected smart objects **422** with a topic label indicative of a topic to which the associated data is relevant. To this end, device configuration application **1708** can include configuration tools that allow the user to associate selected tags with relevant topic labels, which are submitted as part of smart object configuration data **1706**. Example topics with which smart objects can be associated can include, but are not limited to product quality, energy consumption, product throughput, machine runtime, machine downtime, or other such topics. In this way, smart objects **422** can be pre-labeled at the device layer according to relevant topics and published to their own channel (or multiple different relevant channels).

[0161] Some labels can also be added to selected smart objects automatically by the smart object configuration component **408** based on inferences drawn from the automation layer. For example, smart object configuration component **408** may determine a relevant topic to which a given smart object **422** relates (e.g., product quality, maintenance, machine downtime, energy optimization, emissions reduction, OEE, lifecycle management, etc.) based on a determination of how the smart object **422** is used in the industrial control program **1704**, and label the smart object **422** with this topic. In some embodiments, smart object configuration component **408** may also automatically select a topic for a given smart object **422** based on explicit or implied relevant topics obtained from data model **702**. For example, in addition to the data modeling aspects described above, a data model **702** may define relevant topics associated with respective smart objects **422**, and smart object configuration component **408** can automatically assign appropriate topic labels to these smart objects **422** based on these template definitions. In some embodiments, smart object configuration component **408** may also infer relevant topics for respective smart objects **422** based on analysis of the data modeling defined by the models **702**.

[0162] FIG. **18** is a diagram illustrating example high-level data flows of an industrial publish-and-subscribe architecture facilitated by industrial data broker system **1602** in conjunction with smart objects **422**. According to this example architecture, industrial devices **402** send their contextualized and labeled smart object data to the broker system **1602** as data streams **1802**, which are received and stored by the broker system's device interface component **1604**. These data streams **1802** can include time-series data representing the values of their respective smart objects **422** over time, labels associated with each data stream, and pre-defined and learned correlations encoded by the smart object's metadata (e.g., based on templates **424** or user-defined correlations).

[0163] Broker system **1602** can publish the received data streams **1802** to their own channels, and allows users or external systems—including analytic systems such as AI analytic system **1102**—to subscribe to selected channels of interest according to topic. For example, an analytic system **1102** that seeks to optimize product quality of a given manufacturing line can submit subscription data **1804** to the broker system **1602** requesting to subscribe to a subset of available data streams having the Quality topic label. In this example, smart objects **422** and their associated data streams **1802** labeled with the Quality topic can encompass data that should be run through machine learning in order to optimize product quality. As described above, these tags can be pre-defined in the industrial devices **402** based on domain expertise as to which data values should be monitored or optimized to achieve best quality. The broker system's data stream publishing component **1608** processes the analytic system's subscription request and, in response, begins streaming a subset of the published data channels corresponding to the Quality label to the analytic system **1102** as a subscribed data stream **1806**. This topic-based publish-subscribe approach pre-filters the total set of available plant-floor data such that only data streams relevant to a desired business outcome are provided to the analytic system **1102**. Moreover, this filtered set of data streams is bundled with goal-specific contextualization information, relationships, and correlations in accordance with the device-level and/or gateway-level models, further reducing the time required for the analytic system **1102** to analyze the data streams **1806** and converge to an actionable outcome.

[0164] Although the example described above assumes that the data streams are labeled at the device level, in some configurations the data streams may be labeled by the broker system's data labeling component **1612**. This implementation may be appropriate for processing data streams received from legacy industrial devices that do not support tag labeling at the device level. In such scenarios, the data labeling component **1612** allows users to define topics to be associated with selected unmodeled data streams received at the device interface component **1604**, and applies appropriate topic labels to these data streams based on the user definitions prior to publishing. In some embodiments, the data labeling component **1612** may infer a relevant analytic topic for one or more items of unlabeled industrial data and label the data items with this inferred topic. The inferred topic for a given item of data may be learned based on a determination of the data item's role or relationships to other received data items, an analysis of the data model **702** (if accessible by the broker system **1602**), an analysis of contextual metadata received from other related data items, an identity of the industrial device **402** from which the data item was received, or by other such inference techniques.

[0165] In some embodiments, smart objects **422**, or the **424** templates used to configure smart objects, can be used to also configure which entities are permitted to see given sets of data. For example, owners of industrial devices **402** can configure not only topic labels for respective smart objects, but also identities of subscribers (e.g., OEMs) permitted to receive data streams from these smart objects **422**. Alternatively, security for a data stream can be defined in an exclusionary manner by identifying subscribers who are not permitted to view the data. This subscriber permission information can be included in the smart object metadata. On the broker side, when subscription data **1804** requesting to subscribe to a labeled data stream is received, data stream publishing component **1608** can first determine whether the requested data steam is labeled with a subscription limitation—that is whether permitted subscriptions to the requested data stream are to be limited to identified subscribers, or whether any subscribers are precluded from receiving the data stream—and establish a data channel to the subscribing entity only if the entity is permitted to receive the data stream.

[0166] This approach can allow different types of entities—end customers, OEMs, systems integrators, etc.—to share project or system runtime information in a secure manner that protects proprietary data. For example, an owner of an industrial asset built by an OEM may hold intellectual property on how that machine is run within their facility as part of a propriety industrial control process. Smart object labeling can be used to organize selected sets of data that drive business outcomes that the OEM is to deliver. Broker system **1602** can leverage these smart object labels to deliver this subset of data to the OEM by allowing the OEM to subscribe only to sets of data that the owner of the asset permits them to receive. In another example, OEMs that sell robots or other machines to various customers can remotely collect data anonymously from the machines they sell (e.g., for quality purposes, so that the OEM can engineer their machines for minimal downtime) without obtaining data relating to each customer's particular application.

[0167] In some embodiments, industrial data broker system **1602** can reside at the plant facility (e.g., embodied on an edge device) at which the industrial devices operate. Alternatively, broker system **1602** can be embodied on a cloud platform and execute as a cloud service, providing industrial data brokering services to a wide base of data publishers and subscribers across different industrial facilities.

[0168] FIG. **19** illustrates a methodology in accordance with one or more embodiments of the subject application. While, for purposes of simplicity of explanation, the methodology shown herein is shown and described as a series of acts, it is to be understood and appreciated that the subject innovation is not limited by the order of acts, as some acts may, in accordance therewith, occur in a different order and/or concurrently with other acts from that shown and described herein. For example, those skilled in the art will understand and appreciate that a methodology could alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all illustrated acts may be required to implement a methodology in accordance with the innovation. Furthermore, interaction diagram(s) may represent methodologies, or methods, in accordance with the subject disclosure when disparate entities enact disparate portions of the methodologies. Further yet, two or more of the disclosed example methods can be implemented in combination with each other, to accomplish one or more features or advantages described herein.

[0169] FIG. **19** illustrates an example methodology **1900** for establishing contextualized data streams from industrial devices to external systems, including but not limited to AI or machine learning analytic systems. Initially, at **1900**, industrial data is received from one or more industrial devices; e.g., at an industrial data broker system. The data can be received, for example, by an industrial data broker system. The industrial data can be sourced by smart objects residing on the devices, and can be augmented with modeling metadata defining relationships and correlations between items of the data relevant to a business objective. Respective items of the received data can further be augmented with labels identifying topics to which the respective data items are relevant from an analytics perspective. Example topics can include, but are not limited to, product quality, energy consumption, product throughput, machine runtime, emissions reduction, OEE, lifecycle management, or other such topics.

[0170] The data may be received by an industrial data broker system, which may reside at a plant facility in which the devices reside, or may execute as a cloud-based service to provide industrial data brokering services to a wide base of data publishers and subscribers. As an alternative to receiving the industrial data that has been pre-labeled and pre-modeled with modeling metadata, the broker system itself may apply labels and/or modeling metadata to the industrial data as it is received in accordance with data modeling templates maintained by the broker system.

[0171] At **1904**, subscription data is received from an external system. The subscription data requests a subscription to a selected topic of the one or more topics represented by the labels. In an example scenario, the subscription data may be received from an external analytic system (e.g., an AI or machine learning system) tasked with analyzing data from an industrial system with a view to learning actionable insights with regard to a specified business goal (e.g., reducing emissions of the industrial system, improving product quality or throughput, optimizing energy utilization, etc.). In another example, the external system may be a data collection system associated with an entity external to the plant that owns the industrial devices, such as an OEM or systems integrator.

[0172] At **1906**, a determination is made as to whether the external system is permitted to subscribe to the topic for which the subscription is requested at step **1904**. This can be determined by the broker system based on security metadata associated with the respective items of industrial data, which can define limits on the entities permitted to view data labeled under a given topic. If the external system is permitted to subscribe (YES at step **1906**), the methodology proceeds to step **1908**, where a data channel is established that streams a subset of the industrial data that is labeled with the specified topic to the external system. The data streams can include both the data values associated with the data items labeled under the topic (e.g., time-series values associated with the corresponding smart objects at the industrial devices) as well as the modeling metadata, which structures and contextualizes the data to assist the subscribing system to more quickly and accurately converge on a relevant actionable insight. If the external system is not permitted to subscribe (NO at step **1906**) the methodology returns to step **1902** without establishing the data channel.

[0173] As made clear in the example architectures discussed above, pre-modeling and contextualization of industrial data at the device level or gateway level can facilitate efficient migration of relevant industrial data to higher-level analytic systems, and can also assist such analytic systems to arrive at useful insights more quickly, and with less computational overhead, relative to conventional big data analysis. In the case of device-level data modeling, creation of smart objects **422** on industrial devices **402** is a key configuration step of this approach. As noted above in connection with FIG. **17**, data tag definitions **1714**—which can include smart object definitions—can be configured by a system designer in tandem with development of the control program **1704** to be downloaded and executed on industrial device **402** (e.g., an industrial controller such as a PLC). The resulting program file defines both the control program **1704** to be executed by the industrial device **402** and the data tag definitions that are leveraged by the industrial device **402** to create tag database **1702**.

[0174] To automate and simplify the process of generating an industrial control program **1704** and associated tag definitions **1714** for an industrial device **402**, as well as to more easily integrate the industrial device **402** with high-level analytic systems that consume the device's data, a program development system can be configured to receive, as design input, digital engineering drawings—e.g., computer-aided design (CAD) drawings—and generate at least a portion of the device's control programming and tag definitions **1714** based on analysis of these engineering drawings.

[0175] FIG. **20** is a block diagram of an example program development system **2002** capable of translating engineering drawings into executable control programming and associated data tag definitions according to one or more embodiments of this disclosure. Program development system **2002** can include a user interface component **2004**, a drawing import component **2006**, a program generation component **2008**, a program export component **2010**, one or more processors **2018**, and memory **2020**. In various embodiments, one or more of the user interface component **2004**, drawing import component **2006**, program generation component **2008**, program export component **2010**, the one or more processors **2018**, and memory **2020** can be electrically and/or communicatively coupled to one another to perform one or more of the functions of the program development system **2002**. In some embodiments, components **2004**, **2006**, **2008**, and **2010** can comprise software instructions stored on memory **2020** and executed by processor(s) **2018**. Program development system **2002** may also interact with other hardware and/or software components not depicted in FIG. **20**. For example, processor(s) **2018** may interact with one or more external user interface devices, such as a keyboard, a mouse, a display monitor, a touchscreen, a smart phone, a tablet computer, an AR/VR wearable appliance, or other such interface devices.

[0176] User interface component **2004** can be configured to receive user input and to render output to a user in any suitable format (e.g., visual, audio, tactile, etc.). In some embodiments, user interface component **2004** can render interactive display screens on a display device (e.g., a display device associated with a desktop computer, a laptop computer, a tablet computer, a smart phone, etc.), where the display screens serve as the interface for an industrial device programming and configuration platform. In some embodiments, the user interface component **2004** can render selectable design tools and receive programming and device configuration input via interaction with the tools.

[0177] Drawing import component **2006** can be configured to import a digital engineering drawing or model into the system **2002**. Example drawings that can be imported can include, for example, mechanical drawings and/or electrical drawings of an industrial automation system, piping and instrumentation diagrams (P&ID), flow diagrams, or other types of drawings. Mechanical drawings that can be imported into the system **2002** can comprise two-dimensional mechanical drawings or, in some embodiments, three-dimensional mechanical models of the automation system.

[0178] Program generation component **2008** can be configured to generate, based on the design input received via the user interface component **2004**, an industrial device configuration file or other type of configuration output capable of execution on an industrial device **402** (e.g., an industrial controller). This configuration output can comprise an executable control program, associated data tag definitions (including contextualized smart data tag definitions), and other device configuration settings. Program generation component **2008** can generate at least portions of the control program and data tag definitions based on analysis of the engineering drawings for the automation system being designed, which were imported by the drawing import component **2006**. Program generation component **2008** can also leverage data modeling templates **424** selected from a library **320** of templates **424** stored on memory **2020** in connection with generating suitable contextualized data tag definitions that are contextualized for a selected business objective.

[0179] Program export component **2010** can be configured to export or download the resulting configuration output created by the program generation component **2008**. For example, program export component **2010** can download the control program, data tag definitions, and device configuration settings to the target industrial device **402** to facilitate configuring and programming the device, or may export the resulting configuration file to another storage location.

[0180] The one or more processors **2018** can perform one or more of the functions described herein with reference to the systems and/or methods disclosed. Memory **2020** can be a computer-readable storage medium storing computer-executable instructions and/or information for performing the functions described herein with reference to the systems and/or methods disclosed.

[0181] FIG. **21** is a diagram illustrating translation of digital engineering drawings into industrial control programming and data tag definitions by a program development system **2002** according to one or more embodiments. Similar to device configuration application **1708**, program development system **2002** can execute on a client device **1710** (e.g., a laptop computer, a desktop computer, a tablet computer, etc.) and can be used by a system designer to develop control programming, tag definitions, and other configuration aspects for an industrial device **402** to be configured.

[0182] In the illustrated example, engineering drawings in the form of CAD files **2106** are provided to the program development system **2002**. In some scenarios, CAD files **2106** can be developed in a separate CAD system **2102** used to develop engineering drawings for an industrial automation system. These engineering drawings can comprise, for example, two-dimensional or three-dimensional mechanical drawings, electrical schematics (e.g., power distribution drawings, I/O drawings, etc.), P&ID drawings, flow diagrams, or other such drawings.

[0183] As will be described in more detail below, program development system **2002** can infer at least some of the control aspects to be carried out by the industrial device **402** based on analysis of the drawings represented in CAD files **2106**, and generate corresponding portions of control program **1704** to carry out these control functions. As part of this program generation process, the program development system **2002** can generate appropriate data tags of various data types to support the automatically generated program routines. At least some of these data tags can comprises smart objects **422** that model and contextualize their corresponding data items for processing by a high level analytic system **1102**, thereby aiding the analytic system **1102** in deriving insights into the controlled industrial process to be carried out by the industrial device **402** as described in previous examples. The contextualization metadata associated with each smart object **422** generated in this manner (e.g., AI metadata in AI fields **904**, type-specific metadata as discussed in connection with FIG. **8**, etc.) can be based on control contexts inferred by analyzing the CAD files **2106**, as well as selected data modeling templates **424** corresponding to one or more business objectives or desired analytic insights. Once development of the control program **1704** and its associated smart objects **422** is complete, the program **1704** and its associated tag definitions can be downloaded to one or more industrial devices **402** for execution. In some scenarios, one or more templates **424** used to model the smart objects **422** can also be downloaded to the industrial device **402**.

[0184] FIG. **22** is a diagram illustrating generation of a control program file **2202** by program development system **2002** based on analysis of one or more digital engineering drawings, as well as one or more selected data modeling templates **424**. Program development system **2002** can support device configuration and programming functions similar to those ascribed to device configuration application **1708** described above. For example, program development system **2002** can render and support a program development environment that can be used to develop a control program **1704** and its associated data tags, including smart objects **422**. In addition, program development system **2002** includes drawing import component **2006** and program generation component **2008**, which facilitate automatic generation of at least portions of the control program **1704** and tag definitions **1714** (including smart object definitions) based on analysis of imported digital engineering drawings representing the automation system to be controlled by the industrial device **402** for which the control program **1704** is being developed.

[0185] In the example depicted in FIG. **22**, engineering drawing data is submitted to the program development system **2002** as one or more CAD files **2106** (e.g., a DWG file, a DWT file, a DXF file, etc.). However, embodiments of the program development system **2002** can also be configured to process engineering drawing data submitted in other formats. Engineering drawing data submitted to the system **2002** can represent substantially any aspect of the automation system to be controlled by the industrial device **402**. Example engineering drawing data that can be submitted to and processed by the program development system **2002** can include, but are not limited to, 2D mechanical drawings or 3D mechanical models of machines and structures that make up the automation system (e.g., industrial robots, machining stations, conveyors, operator workstations, motion devices, motors, pneumatic actuators, safety gates, etc.); electrical schematics such as power distribution drawings or I/O drawings that define the digital and analog inputs and outputs between the industrial device **402** and devices in the field; P&ID drawings; panel layout drawings depicting an arrangement of electrical components and control devices within a control cabinet; or other types of engineering drawings.

[0186] Drawing import component **2006** can import the CAD file **2106** (or other type of engineering drawing data) for processing by the program generation component **2008**. In an example scenario, CAD file **2106** may be developed using a separate engineering drawing application, and a system designer can import the CAD file **2106** into the program development system **2002** using interactive import tools provided by the program development environment. Alternatively, program development system **2002** may be a subsystem of a comprehensive design platform that supports parallel development of engineering drawings and control programming within the same development environment. In such embodiments, the CAD file **2106** can be shared between the drawing development platform and the program development system within the same development environment.

[0187] Once the CAD files **2106** have been imported, program generation component **2008** can analyze the drawing data contained in the CAD files **2106** and infer control intentions or requirements based on results of the analysis. The program generation component **2008** can then generate at least a portion of the control program **1704** being developed (e.g., ladder logic programming, a function block diagram, a sequential function chart, structured text programming, etc.) based on these inferred control intentions or requirements.

[0188] In an example translation, CAD files **2106** may include one or more of a digital P&ID drawing, a 2D or 3D mechanical drawing, and or an electrical I/O drawing. Program generation component **2008** can analyze these drawings to identify machines, devices, or other industrial assets represented in the drawings. These identified assets can include, but are not limited to, tanks, pumps, conveyors, motor drives, motor contactors, actuators (e.g., stoppers, pushers, grippers, etc.), industrial robots, safety input devices (e.g., light curtains, emergency stop pushbuttons, safety mats, etc.), manual control panel devices (e.g., push buttons, position switches, illuminated indicators, etc.), solenoid valves, digital input devices (e.g., photosensors, proximity switches, etc.), telemetry devices (e.g., meters, sensors, etc.), or other such components of the automation system. Program generation component **2008** can also recognize, within the drawing data, representations of the industrial device **402** for which the control program is being developed, including representations of the device's location within the industrial environment (e.g., based on panel layout drawings), representations of the input and output devices connected to the device's digital and analog I/O (e.g., based on electrical I/O drawings), or other aspects of the control device **402** and its relationship to other devices and assets that make up the automation system.

[0189] Program generation component **2008** can also identify relationships between these identified devices, machines, and industrial assets based on further analysis of the drawings. As part of this analysis, program generation component **2008** can identify different representations of the same elements (e.g., industrial assets, machines, and devices) across different drawings. For example, the electrical I/O drawings can be analyzed to identify input and output devices in the field (e.g., solenoid valves, pneumatic actuators, motor contactors, push buttons, proximity switches, photodetectors, telemetry devices, motor drives, etc.) that are electrically connected to the I/O of the industrial device **402** (e.g., industrial controller) to be programmed, as well as the I/O addresses associated with each connected input or output device. Program generation component **2008** can also identify physical or functional relationships between these input and output devices, or between these devices and other machines or assets, based on analysis of the mechanical drawings in which these devices and assets are represented.

[0190] Some of these inferred relationships can be determined based on a correlation between different types of engineering drawings. For example, as noted above, I/O drawings can be analyzed to identify input and output devices that are connected to an industrial controller being programmed, as well as the I/O addresses to which each input or output device is connected (e.g., in terms of the analog or digital I/O module, and the particular I/O point on the module, to which the I/O device is connected). Program generation component **2008** can further correlate this information with a submitted mechanical drawing or 3D model of the automation system, which defines physical locations and relationships between machines, devices, and other industrial assets that make up the automation system. Based on the arrangements of machines, devices, and/or industrial assets defined in the mechanical drawings or models, program generation component **2008** may infer a type of industrial process or application that is to be carried out by at least a subset of the machines and devices represented by the mechanical information (e.g., a type of batch process, a flow control application, conveyor control, web tension control, palletizing, sheet metal stamping, water treatment, etc.), and generate a suitable control program routine capable of carrying out the identified control functions. As part of this automated program creation process, program generation component **2008** can refer to the I/O drawing data to determine correct I/O device addressing for each input and output device involved in the control routine, and customize the control programming using these learned I/O addresses. In some embodiments, the identities, functions, and/or relationships of the various industrial assets represented in an engineering drawing can also be identified based on metadata embedded in the drawing elements representing these assets.

[0191] In another example scenario, the program generation component **2008** can infer permissives and interlocks that serve as necessary preconditions for starting a machine based on analysis of electrical or mechanical drawings imported by the drawing import component **2006**, and generate a portion of the control program **1704** responsible for initiating start-up the machine based on these inferred permissives and interlocks. For example, the program generation component **2008** can generate this portion of the control program **1704** such that the state of the controller output responsible for starting the machine is made contingent on each permissive or interlock being in its appropriate state. These permissives may be, for example, open or closed states of respective valves, operating modes of other machines, home positions of respective actuators (e.g., pushers, stoppers, grippers, etc.), locked states of safety gates, or other such permissives.

[0192] To facilitate automatic generation of control programming based on analysis of CAD files **2106**, some embodiments of program development system **2002** can store a library of predefined code segments **2208** defining standardized control code for executing common industrial tasks or applications (e.g., palletizing, flow control, web tension control, pick-and-place applications, conveyor control, etc.). In some embodiments, code segments **2208** can be categorized according to an industrial vertical (e.g., automotive, food and drug, oil and gas, textiles, marine, pharmaceutical, etc.), an industrial application, or a type of machine or device to which the code segment **2208** is applicable. In some embodiments, program generation component **2008** can infer, based on an arrangement or configuration of industrial assets recorded in the engineering drawings, that a portion of the automation system is designed to carry out a common control task for which a predefined code segment **2208** is available. In response to this determination, program generation component **2008** can retrieve the relevant code segment **2208** and integrate the code segment **2208** into the control program **1704** being developed.

[0193] As part of this code integration, program generation component **2008** can customize the code segment **2208** as needed to accurately integrate the code segment **2208** into the designer's system-specific control program **1704**. For example, a code segment **2208** stored in the code segment library may use generic placeholders within the code segment programming in place of application-specific digital and analog data tags or I/O addresses whose values correspond to the industrial controller's inputs and outputs. These generic placeholders can represent, for example, metered values generated by a telemetry device (e.g., tank fill levels, oven temperatures, flow rates, metered power values, etc.), output commands directed to a control device known to be used in the common control task (e.g., a motor drive that controls the speed of a conveyor, a solenoid value, a pneumatic actuator such as a pusher or gripper, etc.), or other such controller inputs and outputs. To customize this code segment **2208**, the program generation component **2008** can analyze the submitted I/O drawings to identify I/O devices corresponding to the generic placeholder values, and replace the generic placeholders within the code segment **2208** with the program-specific controller I/O addresses or data tag names indicated for those devices within the I/O drawings.

[0194] In some embodiments that support the use of automation objects **2206**, program generation component **2008** can generate control code for an industrial asset identified in the engineering drawings based on control programming attributes of an automation object **2206** corresponding to the identified asset. The automation object **2206** for a given industrial machine or asset can be retrieved from a library of such automation objects **2206** maintained by the system **2002**. In general, automation objects **2206** serve as the building block for this object-based development architecture. FIG. **23** is a diagram illustrating several example automation object properties that can be leveraged by the program development system **2002** in connection with generating portions of control program **1704** based on identification of industrial assets represented in CAD files **2106**. Automation objects **2206** can be created and augmented during design, integrated into larger data models, and consumed during runtime. These automation objects **2206** provide a common data structure across the program development system **2002** and can be stored in an object library (e.g., part of memory **2020**) for reuse. The object library can store predefined automation objects **2206** representing various classifications of real-world industrial assets **2302**, including but not limited to pumps, tanks, values, motors, motor drives (e.g., variable frequency drives), industrial robots, actuators (e.g., pneumatic or hydraulic actuators), or other such assets. Automation objects **2206** can represent elements at substantially any level of an industrial enterprise, including individual devices, machines made up of many industrial devices and components (some of which may be associated with their own automation objects **2206**), and entire production lines or process control systems.

[0195] An automation object **2206** for a given type of industrial asset can encode such aspects as 2D or 3D visualizations, alarms, control coding (e.g., logic or other type of control programming), analytics, startup procedures, testing protocols, validation reports, simulations, schematics, security protocols, and other such properties associated with the industrial asset **2302** represented by the object **2206**. Automation objects **2206** can also be geotagged with location information identifying the location of the associated asset. During runtime, the automation object **2206** corresponding to a given real-world asset **2302** can also record status or operational history data for the asset. In general, automation objects **2206** serve as programmatic representations of their corresponding industrial assets **2302**, and can be incorporated into an automation system project as elements of control code, a 2D or 3D visualization, a knowledgebase or maintenance guidance system for the industrial assets, or other such aspects.

[0196] Some automation objects **2206** can also encode automated learning attributes that can be used, during runtime, to perform automated sensor validation or to verify sensor data constancy. For example, an automation object **2206** representing a type of industrial asset can specify, as part of an automated learning attribute for the asset, two or more measured variables whose relationship (e.g., a ratio, a difference, etc.) should remain within a consistent range during normal operation. In some scenarios, the expected relationship between the specified measured variables can be explicitly defined by the automation object **2206**, as determined based on known operating characteristics of the industrial asset. Alternatively, the automation object **2206** can be configured to monitor and learn an empirical baseline relationship between the measured variables during runtime, thereby allowing for variations between different implementations of the industrial asset. In either scenario, the industrial device **402** that executes a control program **1704** that includes such an automation object **2206** can monitor the sensor values corresponding to the specified measured variables in accordance with the automated learning attribute, and generate an alert in response to detecting that the measured relationship between these measured variables deviates from the baseline range specified by the automation object **2206**, which may be indicative of a failure or fault on one of the sensors.

[0197] Automated learning attributes can also define other types of automated learning problems that should be formulated and assessed in connection with determining and monitoring normal performance of the industrial asset represented by the object. These automated learning problems can be applied to sensor data in connection with automated sensor ranging as discussed above. In another example, this automated learning can be applied to subsets of industrial data representing key variables of a machine or process in order to learn suitable operating ranges (e.g., maximum values, minimum values, typical values, etc.) of these key variables. Once these operating ranges are learned, the automation objects **2206** can set limits on these key variables based on the learned operating ranges (e.g., maximum and minimum setpoints) such that the industrial device **402** will generate an alert or execute a countermeasure in response to determining that the key variables have deviated from the learned ranges. In another example, automation objects **2206** can allow maximum, minimum, or typical values to be defined by the user for selected operating variables rather than inferred. In such cases, the automated learning attribute of the automation object **2206** can serve as a checking mechanism during runtime to ensure that these limits are maintained, and can generate an alarm in response to determining that the key variables have deviated from the user-defined limits.

[0198] Returning now to FIG. **22**, program generation component **2008** can leverage automation objects **2206**, if available, in connection with generating portions of control program **1704**. For example, program generation component **2008** can analyze mechanical and electrical drawings represented in the CAD files **2106** to determine whether a recognized type of industrial asset is represented in the drawings. If a recognized industrial asset is found for which a corresponding automation object **2206** is available, program generation component **2008** can retrieve the automation object **2206** corresponding to the industrial asset type from the library of automation objects and generate a portion of the control program **1704** for monitoring and controlling the industrial asset based on control code (e.g., ladder logic, function block diagrams, structured text, etc.) associated with the automation object **2206**. The control code associated with the automation object can comprise pre-tested and verified code that can be used to monitor and control industrial assets of the type corresponding to the automation object **2206**.

[0199] In the case of automation objects **2206** that include automated learning attributes as discussed above, the engineering drawings can be referenced to determine suitable learning problems that should be formulated and assessed in order to ascertain normal or preferred performance of industrial assets that make up the automation system. For example, some digital engineering drawings can include embedded labels that define key performance variables whose values are indicative of normal or preferred performance of an industrial asset represented in the drawings, and which therefore should be defined as targets for automated learning. Program generation component **2008** can identify these embedded labels within the CAD files **2106** and, based on automated learning models defined in an automation object **2206** corresponding to the industrial asset's type or classification, generate sensor validation models that identify the key variables and corresponding sensor inputs. The program generation component **2008** can also formulate, based on the automation object **2206**, an automated learning problem to be applied to these sensor inputs in order to assess whether the sensors are generating valid data, or whether the asset is operating properly. The resulting models can be included in the control program file **2202** for execution on the target industrial controller. In some embodiments, the automation object **2206** can also generate and issue certificates of reliability for the resulting information models. These certificates can be associated with the models such that the certificates travels with the models if the models are transferred to other devices or entities. The certificate can be understood by these other devices or entities as verifying the reliability and accuracy of the model.

[0200] As part of the program generation process, program generation component **2008** also generates tag definitions **1714** that define smart objects **422** (and other tags) used by the program **1704**. As noted above, these smart objects **422**, when defined on the target industrial device **402**, store and identify analog or digital data values generated and consumed by the control program **1704**. Each smart object **422** also comprises metadata that pre-models and contextualizes the data stored in that tag **422** for subsequent analysis by higher level analytic systems (e.g., system **1102**). Similar to examples described above, at least some of the contextualization metadata assigned to respective smart objects **422** can be based on one or more selected data modeling templates **424**, such that the metadata for a given smart object **422** defines relationships, correlations, or preferred types of analysis to be performed on the smart object's data, as determined from industry expertise encoded in the selected templates **424**.

[0201] To facilitate automated definition of smart objects **422** in tandem with generation of control program **1704**, program generation component **2008** can select and retrieve one or more data modeling templates **424** to be used as a basis for device-level modeling of the smart object data. To this end, program development system **2002** can maintain a library of vertical-specific or application-specific data modeling templates **424** similar to those described above. Each modeling template **424** is specific to a particular business objective, and defines key variables as well as relationships and correlations between data items relevant to the corresponding business objective. Example business objectives for which modeling templates **424** can be defined can include, but are not limited to, reduction in total machine downtime or number of machine failures; minimization of machine power consumption; optimization of operational efficiency (e.g., amount of machine output relative to an amount of energy consumed by the machine); minimization of emissions; improvement of product quality; identification of factors that yield maximum product output, minimal machine downtime, or maximum product quality; lifecycle management analysis; overall equipment effectiveness analysis; predictive maintenance analysis; or other such objectives. Since some data relationships for a given business objective may depend on the vertical in which the automation system operates (e.g., automotive, oil and gas, food and drug, textiles, etc.), some embodiments of program development system **2002** can organize the stored templates **424** according to industrial vertical. Also, some of the data modeling templates **424** relevant to a particular type of industrial asset may be associated with an automation object **2206** corresponding to the asset type.

[0202] In some embodiments, the user can select one or more data modeling templates **424** to be used by the program generation component **2008** to model and contextualize the program's smart objects **422**. To this end, the development platform interfaces that are generated by user interface component **2004** can include tools that allow the user to submit model selection input **2204** identifying a template **424** to be used to contextualize the program's smart objects **422**. For example, the user interface component **2004** can prompt the user to select a desired business objective corresponding to a type of insight to be obtained by high level analytic system **1102**. Program generation component **2008** can then select a stored modeling template **424** corresponding to the indicated business objective.

[0203] Alternatively, some embodiments of program generation component **2008** can be configured to infer one or more business objectives based on analysis of the engineering drawings represented by CAD files **2106**. For example, program generation component **2008** may infer, based on the configuration of industrial assets indicated by the mechanical and/or electrical drawings represented by CAD files **2106**, an industrial application that the automation system is designed to carry out (e.g., fluid transfer, paper feeding, sheet metal stamping, palletizing, engine block machining, etc.). Program generation component **2008** may also infer an industrial vertical to which the automation system relates based on this analysis of the CAD files **2106**. Based on this inferred information, program generation component **2008** may identify one or more business objectives that are commonly of interest to owners of similar automation systems, and select one or more modeling templates **424** corresponding to the business objectives and industrial vertical.

[0204] In embodiments of program development system **2002** that are implemented on a cloud platform as a cloud-based service accessible to multiple end user entities, the system **2002** can also infer a suitable data modeling template **424** for a given industrial application based on analysis of multiple sets of design data submitted by respective multiple end users. For example, given an inference of a type of industrial application that will be carried out by the automation system represented by CAD files **2106**, program generation component **2008** can identify a type of device-level data modeling most often selected by other designers of similar automation systems (that is, systems designed to carry out a similar industrial application), and select a modeling template **424** corresponding to this preferred data modeling.

[0205] Based on the selected data modelling templates **424**, as well as analysis of the CAD files **2106**, program generation component **2008** generates tag definitions **1714** that define smart objects **422** (and other data tags) for the control program **1704** being developed. Similar to other modeling templates described above, each model template **424** encodes domain expertise applicable to the selected industry- or application-specific business objective, in terms of which data items (represented by smart objects **422**) are relevant to the problem to be solved and known correlations and causalities between these data items. Each modeling template **424** specifies which data inputs from the industrial device **402** being programmed should be examined by high-level analytic systems (e.g., system **1102**) in order to learn causes and possible solutions for the problem represented by the selected business objective. The model templates **424** can also define, where appropriate, correlations and causations between these data inputs that are relevant to the business objective.

[0206] Once program generation component **2008** has identified the available machines and devices that make up the automation system based on analysis of the CAD files **2106** (e.g., based on 2D mechanical drawings or 3D mechanical models of the automation system), and has also identified data available to the industrial device **402** from these machines and devices (e.g., based on I/O drawings included in the CAD files **2106**), the program generation component **2008** can correlate the selected modeling templates **424** with these learned aspects of the automation system in order to generate tag definitions **1714** that define suitable smart objects **422** with appropriate contextualization metadata. For example, program generation component **2008** can intelligently map generic data item placeholders defined in a selected modeling template **424** (e.g., flow rates, conveyor speeds, product counts, temperatures, power measurements, etc.) with specific data items (smart objects **422**) defined for the control program **1704**. This mapping can be based on an inference of which specific data items of the control program **1704** correspond to the generically defined data items defined in the template **424**. This mapping process is broadly similar to the manual data mapping between data items defined in a template and sources of data described above in connection with FIG. **5**. However, in this case the mapping is performed by the program development system **2002** based on analysis of the CAD files **2106**. In general, program generation component **2008** performs this analysis by identifying the data items available from the automation system represented by the CAD files **2106**, correlating these data items with the generic data items defined in the selected modeling template **424**, and generating tag definitions **1714** that define and contextualize smart objects **422** in accordance with the correlations and causalities defined by the template **424**.

[0207] Contextualization metadata added to smart objects **422** by program generation component **2008** can include AI metadata, as described above in connection with FIG. **9**. For example, based on the selected data modeling templates **424**, program generation component **2008** can add values of AI fields **904** of selected smart objects **422** that define relationships between a smart object **422** representing a key variable and other smart objects **422** representing variables known to be correlated with the key variable, as defined by a selected template **424**. Program generation component **2008** can also set AI fields **904** of selected smart objects **422** to specify a type of algorithm or machine analysis to be carried out by external analytic systems (e.g., analytic system **1102**) in order to obtain meaningful insights from the associated smart data provided by those tags **422**. These various types of device-level data modeling can place useful constraints on subsequent AI and machine learning analysis performed by high-level analytic systems **1102** during operation of the automation system.

[0208] In some embodiments, program generation component **2008** can also label selected smart objects with topic labels as discussed above in connection with FIGS. **17** and **18**. These labels allow a broker system **1602**, during runtime, to provide data streams corresponding to a selected topic to subscribing external systems as contextualized data streams. In such embodiments, program generation component **2008** can determine appropriate topic labels (e.g., product quality, maintenance, machine downtime, energy optimization, emissions reduction, OEE, lifecycle management, etc.) to be assigned to selected smart objects **422** based on explicit or implied relevant topics defined in the selected data modeling template **424**, or by inferring relevant topics based on analysis of the engineering drawings defined by the CAD files **2106**. For example, it may be known that particular topics—e.g., emissions tracking, energy consumption statistics, etc.—are commonly of interest for certain types of industrial applications. Accordingly, program generation component **2008** can determine, based on analysis of CAD files **2106**, that the automation system represented by the engineering drawings is designed to carry out one of these industrial applications known to be associated with a particular topic of interest. Based on this determination, program generation component **2008** can set the tag definitions **1714** to add the appropriate topic labels to selected smart objects **422**. As discussed above in connection with FIG. **18**, these labels allow data from these smart objects **422** to be streamed by a data broker system **1602** to entities that are subscribed to the corresponding topic indicated by the label.

[0209] In some embodiments, program generation component **2008** can also infer, based on analysis of CAD files **2106**, pre-processing to be performed on the data of one or more smart objects **422** at the device level, and to set the metadata for these smart objects to define this pre-processing. For example, based on a determination that the mechanical drawings and/or electrical schematics for an automation system include a representation of a known type of machine (e.g., a bottle filling machine) that is associated with a known set of operating states, the program generation component **2008** can define, as part of the tag definitions **1714**, a state smart object **422** (e.g., similar to state data tag **802** discussed above in connection with FIG. **8**) representing a state of the machine, and set the metadata for this smart object **422** to define the known states for the identified machine (e.g., Running, Home, Abnormal, Idle, etc.). Program generation component **2008** can also link this smart object **422** to the appropriate industrial controller inputs representing the various states, as determined based on analysis of the electrical I/O drawings submitted to the system **2002**. During runtime, this smart object **422** will indicate which of the defined states is the present state of the machine.

[0210] In another example, program generation component **2008** may determine that the automation system includes a conveyor based on analysis of the mechanical and/or electrical drawings included in the CAD files **2106**. Based on this determination, the program generation component **2008** can generate control programming for controlling this conveyor (e.g., by selecting an appropriate predefined code segment **2208** for conveyor control, or by generating the control code by other means), and can also generate a smart object **422** (e.g., a rate data tag **804** as discussed above in connection with FIG. **8**) representing the velocity of the conveyor. The program generation component **2008** can link this smart object **422** to the appropriate analog input corresponding to the conveyor's velocity signal, as determined based on analysis of the I/O drawings. The program generation component **2008** can also infer appropriate metadata values for the smart object **422**, such as maximum and minimum values for the conveyor velocity, and set the metadata for the smart object **422** accordingly. In general, values of any of the smart object metadata values discussed above (e.g., the metadata values discussed in connection with FIG. **8**) can be inferred and set by the program generation component **2008** based on analysis of the CAD files **2106**.

[0211] The approach implemented by embodiments of the program development system **2002** can facilitate design-time modeling by interpreting digital engineering drawings imported into the system's program development platform. Engineering drawings or other types of documentation generated during the bid/design/build cycle can suggest relationships between industrial machines, devices, and assets, and these relationships can be identified by the program development system **2002** and incorporated into the device-level data models. Other types of design documents from which a designer's intent can be inferred can also be imported into the program development system **2002** and interpreted in this manner.

[0212] Based on the drawing analyses discussed above, program generation component **2008** generates at least a portion of control program **1704** and associated tag definitions **1714** defining the smart objects **422** (and other data tags) that will be used by the control program **1704**. Prior to finalizing the program, the designer may generate additional control programming to include in control program **1704**, or may modify portions of the control programming that were automatically generated by the program generation component **2008**. These program additions or modifications can be implemented using the programming tools offered by the development platform supported by the program development system **2002**. In an example scenario, the program generation component **2008** can generate at least skeletal programming code based on analysis of the CAD files **2106**, and this skeletal code can be enhanced by the developer with additional programming details as needed.

[0213] In some embodiments, program development system **2002** can maintain a log of manual edits performed on the control program **1704** and tag definitions **1714** by a system designer, and can use this edit log to learn design preferences for the control project. For example, if a system designer modifies the control program **1704** or its associated tag definitions **1714** in a manner that overrides an automated design choice that had been implemented by the program generation component **2008**—e.g., by modifying a control routine, changing an I/O address associated with a data tag or smart objects, changing contextual metadata associated with a selected smart object, etc.—program development system **2002** can create records of these edits for reference during subsequent automated design iterations. If a subsequent iteration of automated program generation is performed—e.g., in a scenario in which the engineering drawings represented by the CAD files **2106** are updated to reflect a design change, necessitating a corresponding update of the control program **1704** or tag definitions **1714**—program generation component **2008** can reference the edit log to determine whether manual design edits had been made to the previous version of the control program **1704** or tag definitions **1714** and maintain these edits in the new version of the control program file **2202**.

[0214] Program generation component **2008** packages or compiles the resulting control program **1704** and associated tag definitions **1714** into a control program file **2202** that can be exported to and executed on a target industrial device **402** (e.g., an industrial controller). FIG. **24** illustrates export of the resulting control program file **2202** to an industrial device **402**. Once the control program file **2202** is complete, program export component **2010** can export or download the program file **2202** to a target industrial device **402** for storage and execution. Execution of the control program file **2202** on the industrial device causes a tag database (e.g., similar to tag database **1702** depicted in FIG. **17**) to be created on the industrial device **402** in accordance with the tag definitions **1714**, and programs the industrial device **402** in accordance with the control program **1704**. In some embodiments, program export component **2010** can also export, to the industrial device **402**, the one or more data modeling templates **424** that were used by the program development system **2002** to model and contextualize the smart objects **422**. In various example scenarios, program development system **2002** may interface with the industrial device **402** via a direct communicative connection between the system **2002** and the device **402**, or via one or more networks (e.g., a plant network). In embodiments in which program development system **2002** executes on a cloud platform as a cloud-based service, the program export component **2010** may export the program file via a secured public or private network accessible to the cloud platform and the industrial device **402**.

[0215] In some design scenarios, the program generation techniques described above can be used to generate multiple control program files **2202** for respective multiple industrial controllers that are part of a common automation system or collection of automation systems represented by the CAD files **2106**. For example, if program generation component **2008** determines that multiple industrial controllers are represented in the CAD files **2106**, with each controller being responsible for monitoring and controlling a subsystem of a larger automation system or environment, program generation component **2008** can determine, for each identified controller, which portion of the automation system represented by the CAD files **2106** is monitored and controlled by that controller. Based on this information, the program generation component **2008** can generate a customized control program **1704** and associated tag definitions **1714** for each controller based on analysis of the subset of the CAD file data corresponding to the industrial assets that are to be monitored and controlled by that controller. Upon completion of these control program files **2202**, the program development system **2002** can deploy these files to their respective controllers. FIG. **25** is a diagram illustrating deployment of multiple control program files **2202***a*-**2202***c* to respective industrial controllers (industrial devices **402***a*-**402***c*) by the program export component **2010** of the program development system **2002**. In this example, the program export component **2010** deploys the respective control program files **2202** to the controllers via the plant network **116** on which the controllers reside.

[0216] FIG. **26** illustrates a methodology in accordance with one or more embodiments of the subject application. While, for purposes of simplicity of explanation, the methodology shown herein is shown and described as a series of acts, it is to be understood and appreciated that the subject innovation is not limited by the order of acts, as some acts may, in accordance therewith, occur in a different order and/or concurrently with other acts from that shown and described herein. For example, those skilled in the art will understand and appreciate that a methodology could alternatively be represented as a series of interrelated states or events, such as in a state diagram. Moreover, not all illustrated acts may be required to implement a methodology in accordance with the innovation. Furthermore, interaction diagram(s) may represent methodologies, or methods, in accordance with the subject disclosure when disparate entities enact disparate portions of the methodologies. Further yet, two or more of the disclosed example methods can be implemented in combination with each other, to accomplish one or more features or advantages described herein.

[0217] FIG. **26** illustrates an example methodology **2600** for generating industrial controller programming and associated smart object definitions based on analysis of digital engineering drawings. The methodology **2600** can be implemented on a program development system that executes on a local client device, on a server or other type of computing system accessible to a client device, or on a cloud platform as a cloud-based service. Initially, at **2602**, one or more digital engineering drawings are received by an industrial program development system. The engineering drawings can represent at least one of mechanical or electrical aspects of an industrial automation system, and may comprise 2D mechanical drawings, a 3D mechanical model, electrical power distribution drawings, electrical I/O drawings, control panel layout drawings, P&ID drawings, or other such engineering drawings.

[0218] At **2604**, industrial assets that make up the industrial automation system are identified based on analysis of the digital engineering drawings received at step **2602**. For example, the industrial program development system can identify one or more machines or other industrial assets that make up the system, including but not limited to conveyors, vats, ovens, mixers, machining stations, industrial robots, vision systems or other quality check systems, stamping presses, or other such assets. At **2606**, I/O devices that provide input signals to and receive output signals from an industrial controller that will be monitoring and controlling the industrial automation system are identified based on further analysis of the digital engineering drawings received at step **2602**. Example input devices that can be identified in this manner can include, but are not limited to, photo-sensors, proximity switches, push-buttons, switches, safety input devices (e.g., light curtains, safety mats, etc.), telemetry devices (e.g., flow meters, temperature meters, pressure meters, fill level meters, etc.), or other such input devices. Example output devices that can be identified in this way can include, but are not limited to, solenoid valves, motor contactors or motor drives, actuators (e.g. pushers, stoppers, etc.), illuminated indicators, or other such output devices.

[0219] At **2608**, a determination is made as to whether an industrial vertical or an industrial application type is recognized based on analysis of the engineering drawings. In this regard, the industrial program development system may recognize that the automation system represented by the engineering drawings is designed to carry out an recognized type of industrial application (e.g., fluid transfer, sheet metal stamping, web tension control, a particular type of batch process, flow control, conveyor control, palletizing, water treatment, etc.), or is intended to perform functionality specific to a particular industrial vertical (e.g., automotive, pharmaceutical, food and drug, oil and gas, textiles, mining, marine, etc.). The program development system can make this determination based, for example, on the collection of industrial assets represented in the drawings and the relationship between these assets, which may be indicative of a specific industrial application or industrial vertical.

[0220] If an industrial vertical or industrial application type is recognized (YES at step **2608**), the methodology proceeds to step **2610**, where a data modeling template is selected from a library of templates based on the industrial vertical or application type recognized at step **2608**. The selected template will be used by the program development system to contextualize data generated by the industrial controller that is to monitor and control the automation system. The library of templates can include modeling templates that are specific to certain industrial verticals or types of industrial applications. Each template can define, for a given business objective commonly associated with the vertical or application type, a set of data items (e.g., sensor inputs, controller data tags, motor drive data tags, etc.) relevant to determining actionable insights into the associated business objective, as well as relationships (e.g., correlations, causalities, etc.) between the data items. The data items and the relationships therebetween are based on domain expertise or knowledge encoded into the modelling templates. In some embodiments, rather than selecting a modeling template based on an inferred vertical or application type, the template can be selected manually by a system designer for use in connection with contextualizing smart objects.

[0221] At **2612**, a control program and associated smart object definitions are generated by the program development system based on the identification of the industrial assets at step **2604**, the identification of the I/O devices at step **2606**, and the data modeling template selected at **2610**. In some embodiments, the system can infer the type of monitoring and control to be performed on the industrial assets identified at step **2604** based on the identities and relationships between the industrial assets, and generate portions of the control programming to perform this monitoring and control. The program development system can also determine appropriate I/O address referencing for the generated control programming based on I/O drawings submitted at step **2602**. For the smart object definitions, the program development system can generate a set of smart objects considered necessary to support the control program, and can also set contextualization metadata for these smart objects in accordance with the data modeling template selected at step **2610**.

[0222] In some embodiments, industrial devices **402** or the smart gateway platform **302** can leverage the contextualized data and associated metadata associated with smart objects **422** or automation objects **2206** to integrate portions of the control program file **2202** with analytic models used by the analytic systems (e.g., the analytic systems depicted in FIG. **12**). The contextualized data can include not just related data but the causal relationships as well. FIG. **27** is a diagram illustrating an example architecture in which analytic systems on any level of the enterprise can leverage the smart objects **422** or automation objects **2206** defined by the control program file **2202** to create or refine analytic models **2702** used to carry out analytics on the industrial data. In this example, control program file **2202** may be a file created by the program generation component **2008**, or may be a program file generated by other means (e.g., via manual development). Similar to the architecture described above in connection with FIG. **12**, the industrial environment depicted in FIG. **27** includes analytic systems that execute at various levels of the enterprise, including a local gateway analytics component **310** that is integrated with the smart gateway platform **302** itself, an edge-level analytic system **1210** that executes on an edge device **1206** (e.g., a network infrastructure device or other type of device that links the plant network to the cloud, the Internet, or another network), and a cloud-based AI analytics system **1204** that executes on a cloud platform. Any of these analytic systems can perform analytics on the structured and contextualized data **704** as described above. Each of these analytic systems can provide visualization presentations **1104** containing notifications, recommendations, or actionable insights to authorized client devices **1202** as also described above.

[0223] In this example, the analytic systems employ analytic models **2702** to perform one or more types of analytics on the contextualized data generated by the industrial device **402** (e.g., an industrial controller). Example analytic models **2702** can include, but are not limited to, models for performing predictive analysis (e.g., predicting machine downtime events, predicting production outcomes, predicting energy utilization, etc.), for assessing current performance of the controlled industrial process relative to one or more key performance indicators, for performing root cause analysis of operational abnormalities or faults, or for yielding other such insights into the controlled industrial process. Analytic models **2702** may be designed to accept, as inputs, values of specified smart objects **422** or automation objects **2206** deemed relevant to the desired insight, and generates outputs based on analysis of these inputs, where the outputs may be performance metrics (e.g., key performance indicators), predicted events (e.g., an expected machine downtime occurrence, an expected time at which a production goal or business objective will be achieved, etc.), or other such insights. Some analytic models **2702** may also be designed to output recommended operational modifications that may drive operation of the controlled industrial process toward a desired production goal or business objective.

[0224] Smart objects **422**, automation objects **2206**, and or templates **424** can simplify integration of the contextualized data generated by the control program file **2202** and analytic models **2702** at any level of the enterprise. As noted above, industrial devices **402** that support smart objects **422** or automation objects **2206** and associated device-level data modeling can allow their device-level data models to be discovered and integrated into these higher-level analytic models **2702**. For example, device-level templates **424** or other device-level models on the industrial devices **402** can be discovered by any of the higher-level analytic systems (e.g., analytic systems **310**, **1210**, **1204**, or **1302**) and integrated into the analytic models **2702** associated with these systems. In this way, smart objects **422** or automation objects **2206** and their associated modeling metadata can implement data engineering at the device level with the assistance of the modeling templates **424**, and the resulting device-level data models can be discovered by and pulled into higher-level analytic systems without requiring manual configuration. Modeling data at the device layer in this way can facilitate automated integration into these higher-level systems in a manner that is agnostic to the type of system consuming the data. Smart objects **422** and automation objects **2206** can also simplify integration of distributed analytic architectures by defining the input/output structures for communication between distributed systems and analytics engines.

[0225] In an example scenario, smart objects **422** (or automation objects **2206**) can include metadata defining correlations and relationships between the smart objects **422** relevant to a specified business objective, as described above. These correlations and relationships are defined by the vertical-specific and objective-specific templates **424** selected by the user. The data publishing component **410** of the industrial device **402** (e.g., the industrial controller on which control program file **2202** executes) can expose these smart objects **422** and their associated data modeling metadata to any of the analytic systems (e.g., cloud-based analytic system **1204**, edge-level analytic system **1210**, etc.), which can create or refine their analytic models **2702** based on the correlations and relationships defined by the smart object metadata. This can include, for example, setting the data inputs to the models **2702** based on the key variables identified by the metadata (e.g., key variables specified by the AI fields **904**), and defining analytics performed on these key variables based on the type or class of analytic problem to be solved relative to the key variable (e.g., modeling, clustering, optimization, minimization, anomaly detection, OEE calculation, etc.), as also defined by the metadata. In this way, the smart objects **422** themselves can convey to the higher-level analytic systems the nature of data analysis to be carried out on the structured and contextualized data generated by the industrial device **402** (e.g., structured and contextualized data **704**) in order to generate insights into the business objective corresponding to the selected template **422**, and the analytic systems can create or refine their analytic models **2702** in accordance with the recommended data analysis, relevant key variables, and relationships between the key variables and other data items.

[0226] In some embodiments, the automated learning attributes associated with some types of automation objects **2206**, as discussed above, can also be exposed to the analytic systems and used by those systems to refine their analytic models **2702**. For example, as noted above, automated learning attributes associated with an automation object **2206** representing an industrial asset can define types of automated learning problems that should be formulated and assessed in connection with determining and monitoring normal performance of the asset. The data publishing component **410** of the industrial device **402** can expose these automated learning attributes to any of the analytic systems, which can update their associated analytic models **2702** to carry out the learning problems defined by the automation object **2206**. Since the automation object's learning attribute can also define the key variables on which these learning problems should be applied, the analytic systems can define the inputs to the analytic models **2702** to correspond to these key variables. Outputs of the analytic models **2702** can be set to correspond to the key performance metrics identified by the automation object's automated learning attribute.

[0227] After development and refinement of the analytic models **2702** based on the device-level models (e.g., the contextualization metadata of smart objects **422**, or the analytic information associated with the automation object **2206**), the analytic systems can be fed with relevant subsets of structured and contextualized data **704** (see, e.g., FIG. **14**) or with smart object data streams **1802** (see, e.g., FIG. **18**) during operation of the industrial system, and the analytic systems can apply the analytic models **2702** to the real-time data. Any of the example analytics described above can be carried out using analytic models **2702** developed in this manner. Since the inputs to the analytic models **2702** are defined based on the key variables and associated correlations and relationships defined by the device-level models, the analytic systems can limit collection of the device-level data to only those data items (e.g., smart object or automation object data) defined by the analytic models **2702** as being relevant to the desired analytic outcome or business objective (e.g., predictive analysis, root cause analysis, performance optimization analysis, energy analysis, etc.). This can both reduce the amount of data that is sent to the analytic system without impacting reliability of the analytic results, while also applying useful pre-defined constraints on data analysis performed by the analytic systems. These constraints are informed by analytic guidance provided by the industrial device **402** itself.

[0228] As noted above, in addition to the contextualization metadata set based on the device-level templates **424**, the industrial device's smart object configuration component **408** can allow users to further augment selected smart objects **422** with custom metadata defining customer-specific correlations between data points, allowing end users to augment smart objects **422** with their own opinions or knowledge regarding which data items are most relevant to a desired business outcome (e.g., which boilers or other assets are most important to monitor to learn a desired insight). This allows the end user to customize the device-level models as desired. As also noted above, contextualization metadata at the device level can be responsive to changes in system or asset reconfigurations. For example, if a machine or line is reconfigured in a manner that changes the associated data's organization, the smart object configuration component **408** of the corresponding industrial device **402** can update the device's smart object **422** and associated metadata to reflect these contextual changes. Accordingly, in some embodiments, data publishing component **410** can be configured to identify when the contextualization metadata for a smart object **422** has been updated, either by manual modification or in response to a system reconfiguration, and in response, send a notification to any analytic systems that are currently subscribed to consume and analyze data from the industrial device **402**, informing these higher-level systems that the device-level model has been modified. In response to this notification, these higher-level analytic systems can update their analytic models to reflect the change to the device-level model.

[0229] FIG. **28** is a diagram illustrating another example architecture in which data model **702** on the smart gateway platform **302** is used by an analytic system **1102** to generate or refine an analytic model **2702**. As described above, data model **702** is created by mapping plant-floor data items (e.g., data tags, smart objects **322**, or automation objects **2206**) to a selected model template **502**. The resulting model specifies data that should be analyzed to yield insights into a desired business objective corresponding to the selected model template **502**, and also informs the gateway platform's data modeling component **308** how to organize and combine the specified data items into meaningful clusters that can drive the analytics. This data model **702** can be referenced by the smart gateway platform **302** in connection with collecting subsets of available industrial data specified by the model **702**. Smart gateway platform **302** can also pre-model the collected data for subsequent analytics based on the desired business objective corresponding to the selected model template **502**.

[0230] In the implementation illustrated in FIG. **28**, rather than exposing the device-level models directly to the analytic system **1102** for creation of analytic models **2702** (as illustrated in FIG. **27**), smart gateway platform **302** can expose data model **702** to the analytic system **1102**, which creates or updates analytic model **2702** based on the key data items and relationships therebetween defined by the data model **702**. In this way, the correlations, relationships, and mathematical functions defined by the gateway platform's data model **702**—which are a function of encoded industrial expertise—are used to shape the analytic models **2702** used by higher-level analytic systems **1102** to generate insights into operation of the controlled industrial system.

[0231] FIG. **29** illustrates an example methodology **2900** for conveying device-level data models to external analytic systems for development of industrial analytic models. The methodology **2900** can be implemented on an industrial device (e.g., an industrial controller) that feeds industrial data to the external analytic system, which performs predictive analytics, performance assessments, root cause analysis, or other such analytics. Initially, at **2902**, contextualization metadata associated with respective smart objects stored in a tag database of an industrial device is set. The contextualization metadata defines correlations between the smart objects relevant to a defined business objective. As described in previous examples, the contextualization metadata can be set based on a selected device-level modeling template associated with a desired business objective, or may be set manually by a system designer.

[0232] At **2904**, the contextualization metadata set in step **2902** is sent to an external analytic system that performs analytics on industrial data stored in the smart objects. Sending the contextualization metadata to the analytic system, or otherwise exposing the contextualization metadata to the analytic system, causes the analytic system to update an analytic model used by the analytic system to perform the analytics on the industrial data. This can include, for example, defining the inputs and outputs of the analytic model, defining functional relationships between the inputs and outputs, setting types of machine learning to be applied to the industrial data, or defining other such analytic attributes.

[0233] At **2906**, an industrial control program is executed that reads data values from and writes data values to the smart objects. At **2908**, selected subsets of the industrial data are sent to the external analytic system in accordance with the analytic model. In some scenarios, these selected subsets can correspond to the model inputs defined for the analytic model.

[0234] At **2910**, a determination is made as to whether the contextualization metadata has been updated on the industrial device. The contextualization metadata may be updated, for example, based on manual input defining a new correlation between items of industrial data stored in the smart objects, or based on a reconfiguration of the industrial device or an automation system that is monitored and controlled by the industrial device. If the contextualization metadata is not updated (NO at step **2910**), the methodology returns to step **2906**. Steps **2906**-**2910** are repeated until the contextualization metadata is updated. When the contextualization metadata is updated (YES at step **2910**), the methodology proceeds to step **2912**, where the updated contextualization metadata is sent to the external analytic system so that the analytic model can be updated in accordance with the modified contextualization metadata.

[0235] Embodiments, systems, and components described herein, as well as control systems and automation environments in which various aspects set forth in the subject specification can be carried out, can include computer or network components such as servers, clients, programmable logic controllers (PLCs), automation controllers, communications modules, mobile computers, on-board computers for mobile vehicles, wireless components, control components, AR/VR headsets, and so forth which are capable of interacting across a network. Computers and servers include one or more processors—electronic integrated circuits that perform logic operations employing electric signals—configured to execute instructions stored in media such as random access memory (RAM), read only memory (ROM), hard drives, as well as removable memory devices, which can include memory sticks, memory cards, flash drives, external hard drives, and so on.

[0236] Similarly, the term PLC or automation controller as used herein can include functionality that can be shared across multiple components, systems, and/or networks. As an example, one or more PLCs or automation controllers can communicate and cooperate with various network devices across the network. This can include substantially any type of control, communications module, computer, Input/Output (I/O) device, sensor, actuator, and human machine interface (HMI) that communicate via the network, which includes control, automation, and/or public networks. The PLC or automation controller can also communicate to and control various other devices such as standard or safety-rated I/O modules including analog, digital, programmed/intelligent I/O modules, other programmable controllers, communications modules, sensors, actuators, output devices, and the like.

[0237] The network can include public networks such as the internet, intranets, and automation networks such as control and information protocol (CIP) networks including DeviceNet™, ControlNet™, safety networks, and EtherNet/IP™. Other networks include Ethernet, DH/DH+™, Remote I/O, Fieldbus, Modbus™, Profibus™, CAN™, wireless networks, serial protocols, and so forth. In addition, the network devices can include various possibilities (hardware and/or software components). These include components such as switches with virtual local area network (VLAN) capability, LANs, WANs, proxies, gateways, routers, firewalls, virtual private network (VPN) devices, servers, clients, computers, configuration tools, monitoring tools, and/or other devices.

[0238] In order to provide a context for the various aspects of the disclosed subject matter, FIGS. **30** and **31** as well as the following discussion are intended to provide a brief, general description of a suitable environment in which the various aspects of the disclosed subject matter may be implemented. While the embodiments have been described above in the general context of computer-executable instructions that can run on one or more computers, those skilled in the art will recognize that the embodiments can be also implemented in combination with other program modules and/or as a combination of hardware and software.

[0239] Generally, program modules include routines, programs, components, data structures, etc., that perform particular tasks or implement particular abstract data types. Moreover, those skilled in the art will appreciate that the inventive methods can be practiced with other computer system configurations, including single-processor or multiprocessor computer systems, minicomputers, mainframe computers, Internet of Things (IoT) devices, distributed computing systems, as well as personal computers, handheld computing devices, microprocessor-based or programmable consumer electronics, and the like, each of which can be operatively coupled to one or more associated devices.

[0240] The illustrated embodiments herein can be also practiced in distributed computing environments where certain tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules can be located in both local and remote memory storage devices.

[0241] Computing devices typically include a variety of media, which can include computer-readable storage media, machine-readable storage media, and/or communications media, which two terms are used herein differently from one another as follows. Computer-readable storage media or machine-readable storage media can be any available storage media that can be accessed by the computer and includes both volatile and nonvolatile media, removable and non-removable media. By way of example, and not limitation, computer-readable storage media or machine-readable storage media can be implemented in connection with any method or technology for storage of information such as computer-readable or machine-readable instructions, program modules, structured data or unstructured data.

[0242] Computer-readable storage media can include, but are not limited to, random access memory (RAM), read only memory (ROM), electrically erasable programmable read only memory (EEPROM), flash memory or other memory technology, compact disk read only memory (CD-ROM), digital versatile disk (DVD), Blu-ray disc (BD) or other optical disk storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, solid state drives or other solid state storage devices, or other tangible and/or non-transitory media which can be used to store desired information. In this regard, the terms "tangible" or "non-transitory" herein as applied to storage, memory or computer-readable media, are to be understood to exclude only propagating transitory signals per se as modifiers and do not relinquish rights to all standard storage, memory or computer-readable media that are not only propagating transitory signals per se.

[0243] Computer-readable storage media can be accessed by one or more local or remote computing devices, e.g., via access requests, queries or other data retrieval protocols, for a variety of operations with respect to the information stored by the medium.

[0244] Communications media typically embody computer-readable instructions, data structures, program modules or other structured or unstructured data in a data signal such as a modulated data signal, e.g., a carrier wave or other transport mechanism, and includes any information delivery or transport media. The term "modulated data signal" or signals refers to a signal that has one or more of its characteristics set or changed in such a manner as to encode information in one or more signals. By way of example, and not limitation, communication media include wired media, such as a wired network or direct-wired connection, and wireless media such as acoustic, RF, infrared and other wireless media.

[0245] With reference again to FIG. **30**, the example environment **3000** for implementing various embodiments of the aspects described herein includes a computer **3002**, the computer **3002** including a processing unit **3004**, a system memory **3006** and a system bus **3008**. The system bus **3008** couples system components including, but not limited to, the system memory **3006** to the processing unit **3004**. The processing unit **3004** can be any of various commercially available processors. Dual microprocessors and other multi-processor architectures can also be employed as the processing unit **3004**.

[0246] The system bus **3008** can be any of several types of bus structure that can further interconnect to a memory bus (with or without a memory controller), a peripheral bus, and a local bus using any of a variety of commercially available bus architectures. The system memory **3006** includes ROM **3010** and RAM **3012**. A basic input/output system (BIOS) can be stored in a non-volatile memory such as ROM, erasable programmable read only memory (EPROM), EEPROM, which BIOS contains the basic routines that help to transfer information between elements within the computer **3002**, such as during startup. The RAM **3012** can also include a high-speed RAM such as static RAM for caching data.

[0247] The computer **3002** further includes an internal hard disk drive (HDD) **3014** (e.g., EIDE, SATA), one or more external storage devices **3016** (e.g., a magnetic floppy disk drive (FDD) **3016**, a memory stick or flash drive reader, a memory card reader, etc.) and an optical disk drive **3020** (e.g., which can read or write from a CD-ROM disc, a DVD, a BD, etc.). While the internal HDD **3014** is illustrated as located within the computer **3002**, the internal HDD **3014** can also be configured for external use in a suitable chassis (not shown). Additionally, while not shown in environment **3000**, a solid state drive (SSD) could be used in addition to, or in place of, an HDD **3014**. The HDD **3014**, external storage device(s) **3016** and optical disk drive **3020** can be connected to the system bus **3008** by an HDD interface **3024**, an external storage interface **3026** and an optical drive interface **3028**, respectively. The interface **3024** for external drive implementations can include at least one or both of Universal Serial Bus (USB) and Institute of Electrical and Electronics Engineers (IEEE) 1394 interface technologies. Other external drive connection technologies are within contemplation of the embodiments described herein.

[0248] The drives and their associated computer-readable storage media provide nonvolatile storage of data, data structures, computer-executable instructions, and so forth. For the computer **3002**, the drives and storage media accommodate the storage of any data in a suitable digital format. Although the description of computer-readable storage media above refers to respective types of storage devices, it should be appreciated by those skilled in the art that other types of storage media which are readable by a computer, whether presently existing or developed in the future, could also be used in the example operating environment, and further, that any such storage media can contain computer-executable instructions for performing the methods described herein.

[0249] A number of program modules can be stored in the drives and RAM **3012**, including an operating system **3030**, one or more application programs **3032**, other program modules **3034** and program data **3036**. All or portions of the operating system, applications, modules, and/or data can also be cached in the RAM **3012**. The systems and methods described herein can be implemented utilizing various commercially available operating systems or combinations of operating systems.

[0250] Computer **3002** can optionally comprise emulation technologies. For example, a hypervisor (not shown) or other intermediary can emulate a hardware environment for operating system **3030**, and the emulated hardware can optionally be different from the hardware illustrated in FIG. **30**. In such an embodiment, operating system **3030** can comprise one virtual machine (VM) of multiple VMs hosted at computer **3002**. Furthermore, operating system **3030** can provide runtime environments, such as the Java runtime environment or the .NET framework, for application programs **3032**. Runtime environments are consistent execution environments that allow application programs **3032** to run on any operating system that includes the runtime environment. Similarly, operating system **3030** can support containers, and application programs **3032** can be in the form of containers, which are lightweight, standalone, executable packages of software that include, e.g., code, runtime, system tools, system libraries and settings for an application.

[0251] Further, computer **3002** can be enable with a security module, such as a trusted processing module (TPM). For instance with a TPM, boot components hash next in time boot components, and wait for a match of results to secured values, before loading a next boot component. This process can take place at any layer in the code execution stack of computer **3002**, e.g., applied at the application execution level or at the operating system (OS) kernel level, thereby enabling security at any level of code execution.

[0252] A user can enter commands and information into the computer **3002** through one or more wired/wireless input devices, e.g., a keyboard **3038**, a touch screen **3040**, and a pointing device, such as a mouse **3042**. Other input devices (not shown) can include a microphone, an infrared (IR) remote control, a radio frequency (RF) remote control, or other remote control, a joystick, a virtual reality controller and/or virtual reality headset, a game pad, a stylus pen, an image input device, e.g., camera(s), a gesture sensor input device, a vision movement sensor input device, an emotion or facial detection device, a biometric input device, e.g., fingerprint or iris scanner, or the like. These and other input devices are often connected to the processing unit **3004** through an input device interface **3044** that can be coupled to the system bus **3008**, but can be connected by other interfaces, such as a parallel port, an IEEE 1394 serial port, a game port, a USB port, an IR interface, a BLUETOOTH® interface, etc.

[0253] A monitor **3044** or other type of display device can be also connected to the system bus **3008** via an interface, such as a video adapter **3048**. In addition to the monitor **3044**, a computer typically includes other peripheral output devices (not shown), such as speakers, printers, etc.

[0254] The computer **3002** can operate in a networked environment using logical connections via wired and/or wireless communications to one or more remote computers, such as a remote computer(s) **3048**. The remote computer(s) **3048** can be a workstation, a server computer, a router, a personal computer, portable computer, microprocessor-based entertainment appliance, a peer device or other common network node, and typically includes many or all of the elements described relative to the computer **3002**, although, for purposes of brevity, only a memory/storage device **3050** is illustrated. The logical connections depicted include wired/wireless connectivity to a local area network (LAN) **3052** and/or larger networks, e.g., a wide area network (WAN) **3054**. Such LAN and WAN networking environments are commonplace in offices and companies, and facilitate enterprise-wide computer networks, such as intranets, all of which can connect to a global communications network, e.g., the Internet.

[0255] When used in a LAN networking environment, the computer **3002** can be connected to the local network **3052** through a wired and/or wireless communication network interface or adapter **3056**. The adapter **3056** can facilitate wired or wireless communication to the LAN **3052**, which can also include a wireless access point (AP) disposed thereon for communicating with the adapter **3056** in a wireless mode.

[0256] When used in a WAN networking environment, the computer **3002** can include a modem **3058** or can be connected to a communications server on the WAN **3054** via other means for establishing communications over the WAN **3054**, such as by way of the Internet. The modem **3058**, which can be internal or external and a wired or wireless device, can be connected to the system bus **3008** via the input device interface **3042**. In a networked environment, program modules depicted relative to the computer **3002** or portions thereof, can be stored in the remote memory/storage device **3050**. It will be appreciated that the network connections shown are example and other means of establishing a communications link between the computers can be used.

[0257] When used in either a LAN or WAN networking environment, the computer **3002** can access cloud storage systems or other network-based storage systems in addition to, or in place of, external storage devices **3016** as described above. Generally, a connection between the computer **3002** and a cloud storage system can be established over a LAN **3052** or WAN **3054** e.g., by the adapter **3056** or modem **3058**, respectively. Upon connecting the computer **3002** to an associated cloud storage system, the external storage interface **3026** can, with the aid of the adapter **3056** and/or modem **3058**, manage storage provided by the cloud storage system as it would other types of external storage. For instance, the external storage interface **3026** can be configured to provide access to cloud storage sources as if those sources were physically connected to the computer **3002**.

[0258] The computer **3002** can be operable to communicate with any wireless devices or entities operatively disposed in wireless communication, e.g., a printer, scanner, desktop and/or portable computer, portable data assistant, communications satellite, any piece of equipment or location associated with a wirelessly detectable tag (e.g., a kiosk, news stand, store shelf, etc.), and telephone. This can include Wireless Fidelity (Wi-Fi) and BLUETOOTH® wireless technologies. Thus, the communication can be a predefined structure as with a conventional network or simply an ad hoc communication between at least two devices.

[0259] FIG. **31** is a schematic block diagram of a sample computing environment **3100** with which the disclosed subject matter can interact. The sample computing environment **3100** includes one or more client(s) **3102**. The client(s) **3102** can be hardware and/or software (e.g., threads, processes, computing devices). The sample computing environment **3100** also includes one or more server(s) **3104**. The server(s) **3104** can also be hardware and/or software (e.g., threads, processes, computing devices). The servers **3104** can house threads to perform transformations by employing one or more embodiments as described herein, for example. One possible communication between a client **3102** and servers **3104** can be in the form of a data packet adapted to be transmitted between two or more computer processes. The sample computing environment **3100** includes a communication framework **3106** that can be employed to facilitate communications between the client(s) **3102** and the server(s) **3104**. The client(s) **3102** are operably connected to one or more client data store(s) **3108** that can be employed to store information local to the client(s) **3102**. Similarly, the server(s) **3104** are operably connected to one or more server data store(s) **3110** that can be employed to store information local to the servers **3104**.

[0260] What has been described above includes examples of the subject innovation. It is, of course, not possible to describe every conceivable combination of components or methodologies for purposes of describing the disclosed subject matter, but one of ordinary skill in the art may recognize that many further combinations and permutations of the subject innovation are possible. Accordingly, the disclosed subject matter is intended to embrace all such alterations, modifications, and variations that fall within the spirit and scope of the appended claims.

[0261] In particular and in regard to the various functions performed by the above described components, devices, circuits, systems and the like, the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component which performs the specified function of the described component (e.g., a functional equivalent), even though not structurally equivalent to the disclosed structure, which performs the function in the herein illustrated exemplary aspects of the disclosed subject matter. In this regard, it will also be recognized that the disclosed subject matter includes a system as well as a computer-readable medium having computer-executable instructions for performing the acts and/or events of the various methods of the disclosed subject matter.

[0262] In addition, while a particular feature of the disclosed subject matter may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application. Furthermore, to the extent that the terms "includes," and "including" and variants thereof are used in either the detailed description or the claims, these terms are intended to be inclusive in a manner similar to the term "comprising."

[0263] In this application, the word "exemplary" is used to mean serving as an example, instance, or illustration. Any aspect or design described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other aspects or designs. Rather, use of the word exemplary is intended to present concepts in a concrete fashion.

[0264] Various aspects or features described herein may be implemented as a method, apparatus, or article of manufacture using standard programming and/or engineering techniques. The term "article of manufacture" as used herein is intended to encompass a computer program accessible from any computer-readable device, carrier, or media. For example, computer readable media can include but are not limited to magnetic storage devices (e.g., hard disk, floppy disk, magnetic strips . . .), optical disks [e.g., compact disk (CD), digital versatile disk (DVD) . . .], smart cards, and flash memory devices (e.g., card, stick, key drive . . .).

What is claimed is:

1. An industrial device, comprising:

a processor, operatively coupled to a memory, that executes executable components stored on the memory, the executable components comprising:

a program execution component configured to execute an industrial control program, wherein the industrial control program reads data values from and writes data values to data tags stored on the memory, and at least a subset of the data tags comprise smart objects having associated contextualization metadata;

a smart object configuration component configured to set the contextualization metadata associated with the smart objects, wherein the contextualization metadata defines correlations between the smart objects relevant to a defined business objective to yield a device-level data model; and

a data publishing component configured to expose the contextualization metadata corresponding to the smart objects to an analytic system, wherein exposure of the contextualization metadata facilitates creation or updating, in accordance with the contextualization metadata, of an analytic model employed by the analytic system to perform analytic processing on subsets of data stored in the data tags.

2. The industrial device of claim **1**, wherein the business objective is at least one of maximization of product output, minimization of machine downtime, minimization of machine faults, optimization of energy consumption, prediction of machine downtime events, determination of a cause of a machine downtime, maximization of product quality, minimization of emissions, identification of factors that yield maximum product quality, identification of factors that yield maximum product output, or identification of factors that yield minimal machine downtime.

3. The industrial device of claim **1**, wherein the analytic processing performed by the analytic system based on the analytic model is at least one of predictive analysis, root cause analysis, or performance assessment analysis for an industrial system or process controlled by the industrial device.

4. The industrial device of claim **1**, wherein the creation or the updating of the analytic model comprises defining at least one of an input to the analytic model, an output of the analytic model, or a type of machine learning to be applied to the subsets of data stored in the data tags.

5. The industrial device of claim **1**, wherein

the contextualization metadata for one or more of the smart objects comprises an artificial intelligence field defining a type of analysis to be performed by the analytic system on the subsets of data stored in the data tags, and

the creation or the updating of the analytic model comprises configuring the model to apply the type of analysis indicated by the artificial intelligence tag.

6. The industrial device of claim **1**, wherein the data publishing component is further configured to, in response to detecting a change to the contextualization metadata associated with one or more of the smart objects, send a notification of the change to the analytic system.

7. The industrial device of claim **6**, wherein the change to the contextualization metadata is at least one of a manual modification to the contextualization metadata or a change to the contextualization metadata applied by the industrial device in response to a detected change to a configuration of an industrial system or process controlled by the industrial device.

8. The industrial device of claim **1**, the executable components further comprising

a smart object configuration component configured to set the contextualization metadata for the smart objects based on one or more data modeling templates stored on the memory, and

the one or more data modeling templates identify one or more of the smart objects representing key variables relevant to respective business objectives and correlations between the smart objects relevant to the respective business objectives.

9. The industrial device of claim **8**, wherein

the executable components further comprise a user interface component configured to receive custom metadata defining user-specified correlations between selected subsets of the smart objects, and

the smart object configuration component is further configured to update the contextualization metadata associated with the subsets of the smart objects in accordance with the custom metadata.

10. A method, comprising:

executing, by an industrial device comprising a processor, an industrial control program, wherein the industrial control program reads data values from and writes data values to data tags stored in a memory, and wherein at least a subset of the data tags comprise smart objects having associated contextualization metadata;

setting, by the industrial device, the contextualization metadata associated with the smart objects, wherein the contextualization metadata defines correlations between the smart objects relevant to a defined business objective to yield a device-level data model; and

exposing, by the industrial device, the contextualization metadata corresponding to the smart objects to an analytic system, wherein the exposing facilitates creation or modification, based on the contextualization metadata, of an analytic model used by the analytic system to perform analytic processing on subsets of data stored in the data tags.

11. The method of claim **10**, wherein the business objective is at least one of maximization of product output, minimization of machine downtime, minimization of machine faults, optimization of energy consumption, prediction of machine downtime events, determination of a cause of a machine downtime, maximization of product quality, minimization of emissions, identification of factors that yield maximum product quality, identification of factors that yield maximum product output, or identification of factors that yield minimal machine downtime.

12. The method of claim **10**, wherein the analytic model comprises a model used by the analytic system to perform at least one of predictive analysis, root cause analysis, or performance assessment analysis for an industrial system or process controlled by the industrial device.

13. The method of claim **10**, wherein the creation or modification of the analytic model comprises defining at least one of an input to the analytic model, an output of the analytic model, or a type of machine learning to be applied to the subsets of data stored in the data tags.

14. The method of claim **10**, wherein

the setting the contextualization metadata comprises setting an artificial intelligence field defining a type of analysis to be performed by the analytic system on the subsets of data stored in the data tags, and

the creation or modification of the analytic model comprises configuring the model to apply the type of analysis indicated by the artificial intelligence tag.

15. The method of claim **10**, further comprising:

detecting a modification to the contextualization metadata; and

in response to detecting the modification, sending, by the industrial device, a notification of the modification to the analytic system.

16. The method of claim **10**, further comprising:

detecting, by the industrial device, a change to a configuration of an industrial system or process controlled by the industrial device; and

in response to detecting the change to the configuration, updating, by the industrial device, the contextualization metadata based on the change to the configuration to yield updated contextualization metadata, and

sending, by the industrial device, a notification of the updated contextualization metadata to the analytic system.

17. The method of claim **10**, wherein

the setting the contextual metadata comprises setting the contextualization metadata associated with the smart objects based on one or more data modeling templates stored on the industrial device, and

the one or more data modeling templates identify one or more of the smart objects that represent key variables relevant to respective business objectives and correlations between the smart objects relevant to the respective business objectives.

18. A non-transitory computer-readable medium having stored thereon instructions that, in response to execution, cause an industrial device comprising a processor to perform operations, the operations comprising:

executing an industrial control program, wherein the industrial control program reads data values from and writes data values to data tags stored in a memory, and wherein at least a subset of the data tags comprise smart objects having associated contextualization metadata;

setting the contextualization metadata associated with the smart objects, wherein the contextualization metadata defines correlations between the smart objects relevant to a defined business objective to yield a device-level data model; and

sending the contextualization metadata associated with the smart objects to an analytic system,

wherein the exposing facilitates creation or modification, based on the contextualization metadata, of an analytic model used by the analytic system to perform analytic processing on subsets of data stored in the data tags.

19. The non-transitory computer-readable medium of claim **18**, wherein the business objective is at least one of maximization of product output, minimization of machine downtime, minimization of machine faults, optimization of energy consumption, prediction of machine downtime events, determination of a cause of a machine downtime, maximization of product quality, minimization of emissions, identification of factors that yield maximum product quality, identification of factors that yield maximum product output, or identification of factors that yield minimal machine downtime.

20. The non-transitory computer-readable medium of claim **18**, wherein the creation or modification of the analytic model comprises setting at least one of an input to the analytic model, an output of the analytic model, or a type of machine learning to be applied to the subsets of data stored in the data tags.

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