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(54) SYSTEMS AND METHODS FOR ANALYZING STREAM-BASED DATA FOR ASSET OPERATION

(71) Applicant: **ROCKWELL AUTOMATION TECHNOLOGIES, INC.**, Mayfield Heights, OH (US)

(72) Inventors: **Edward A. Gray**, Olmstead Townshi, OH (US); **Norman A. Weatherhead**, Kitchener (CA); **Srikanth G. Mashetty**, Houston, TX (US)

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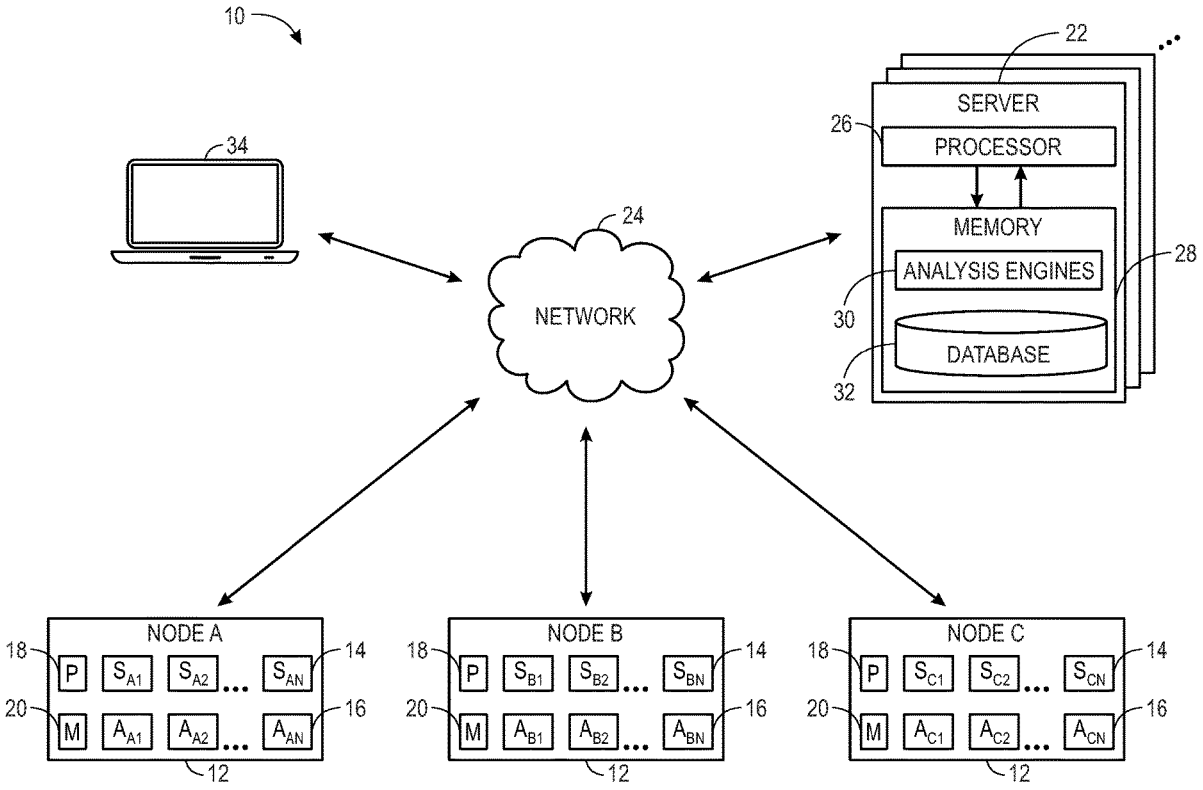
(57) **ABSTRACT**

A system includes a first asset disposed at a first location in an industrial system configured to perform one or more operations, a second asset disposed at a second location in the industrial system, and a server device communicatively coupled to the first asset and the second asset. The server device is configured to receive a first set of stream-based data from the first asset, receive a second set of stream-based data from the second asset, identify a first portion of the first set of stream-based data and a second portion of the second set of stream-based data, wherein the first portion and the second portion comprises a same type of data, determine whether the first portion of the first set of stream-based data corresponds to an expected range of values based on the second portion of the second set of stream-based data, and send a command to the first asset to adjust a first set of operations in response to the first portion of the first set of stream-based data not being within the expected range of values.



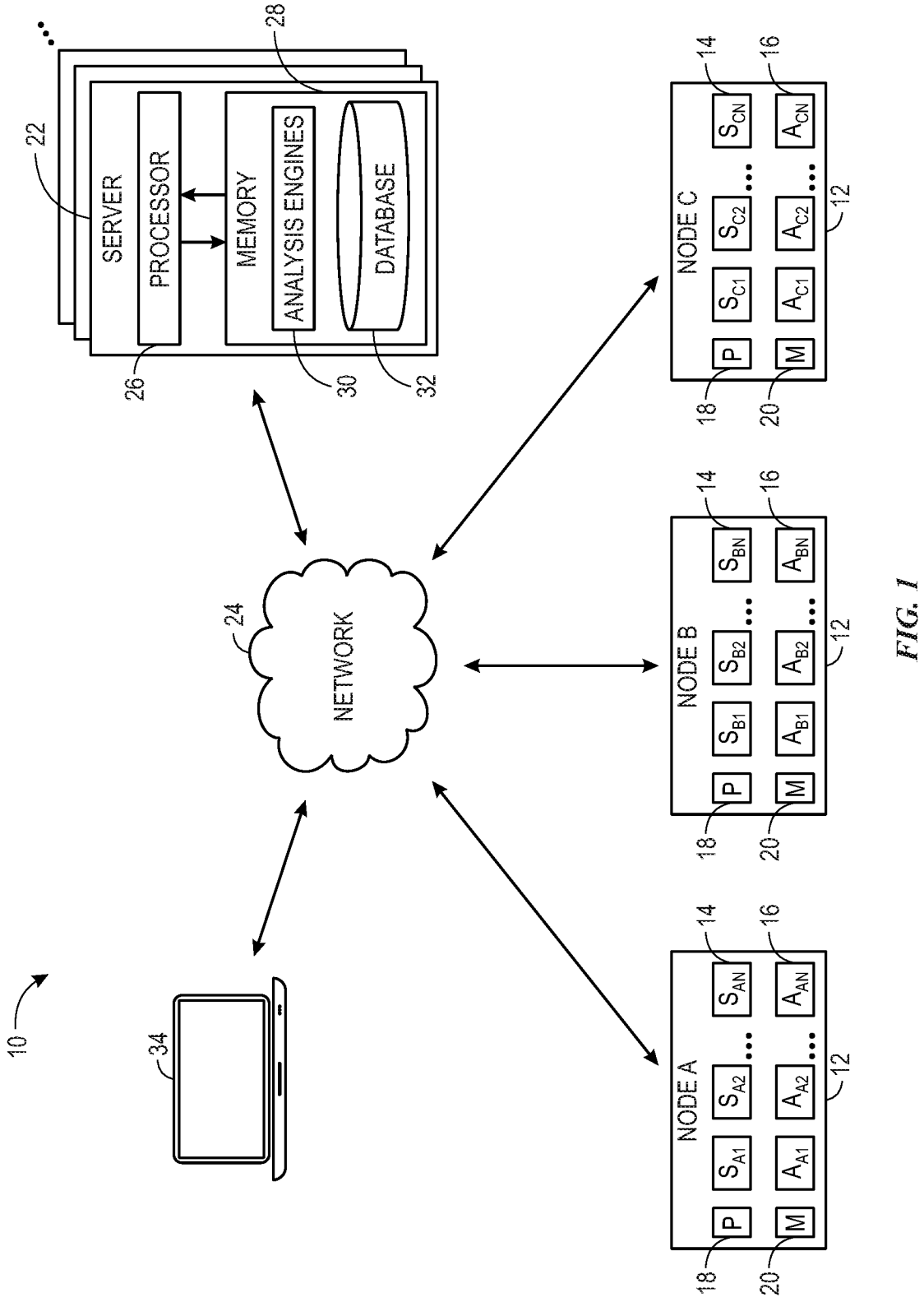

10
22
SERVER
PROCESSOR
MEMORY
ANALYSIS ENGINES
DATABASE
26
28
30
32
34
NETWORK
24
NODE A
NODE B
NODE C
12
14
16
18
20
P
M
S_{A1}
S_{A2}
S_{AN}
A_{A1}
A_{A2}
A_{AN}
S_{B1}
S_{B2}
S_{BN}
A_{B1}
A_{B2}
A_{BN}
S_{C1}
S_{C2}
S_{CN}
A_{C1}
A_{C2}
A_{CN}

FIG. 1

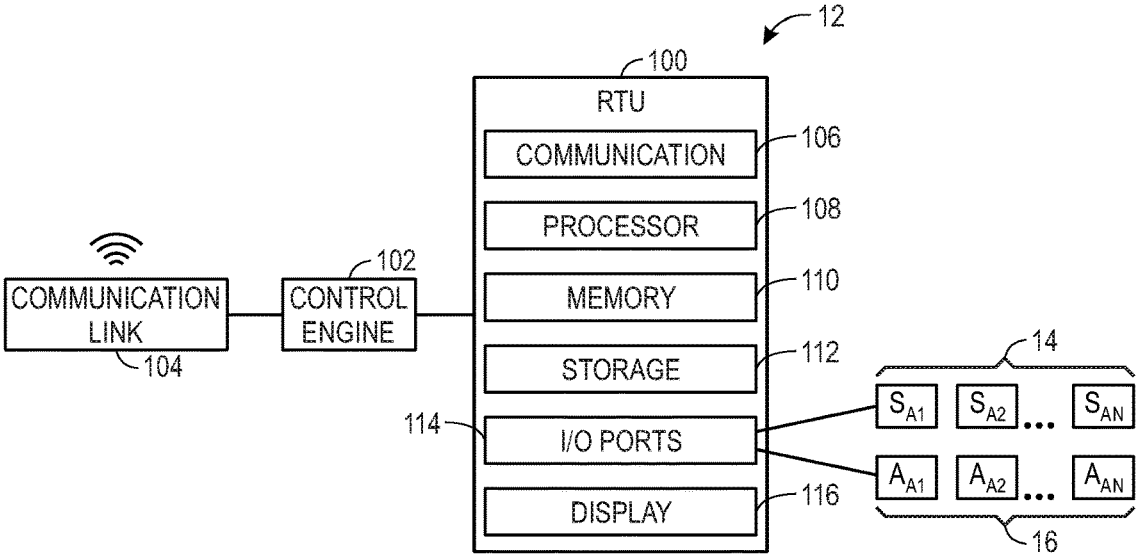

12
100
RTU
COMMUNICATION
106
PROCESSOR
108
MEMORY
110
STORAGE
112
I/O PORTS
114
DISPLAY
116
COMMUNICATION LINK
104
CONTROL ENGINE
102
14
S_{A1}
S_{A2}
S_{AN}
A_{A1}
A_{A2}
A_{AN}
16

FIG. 2

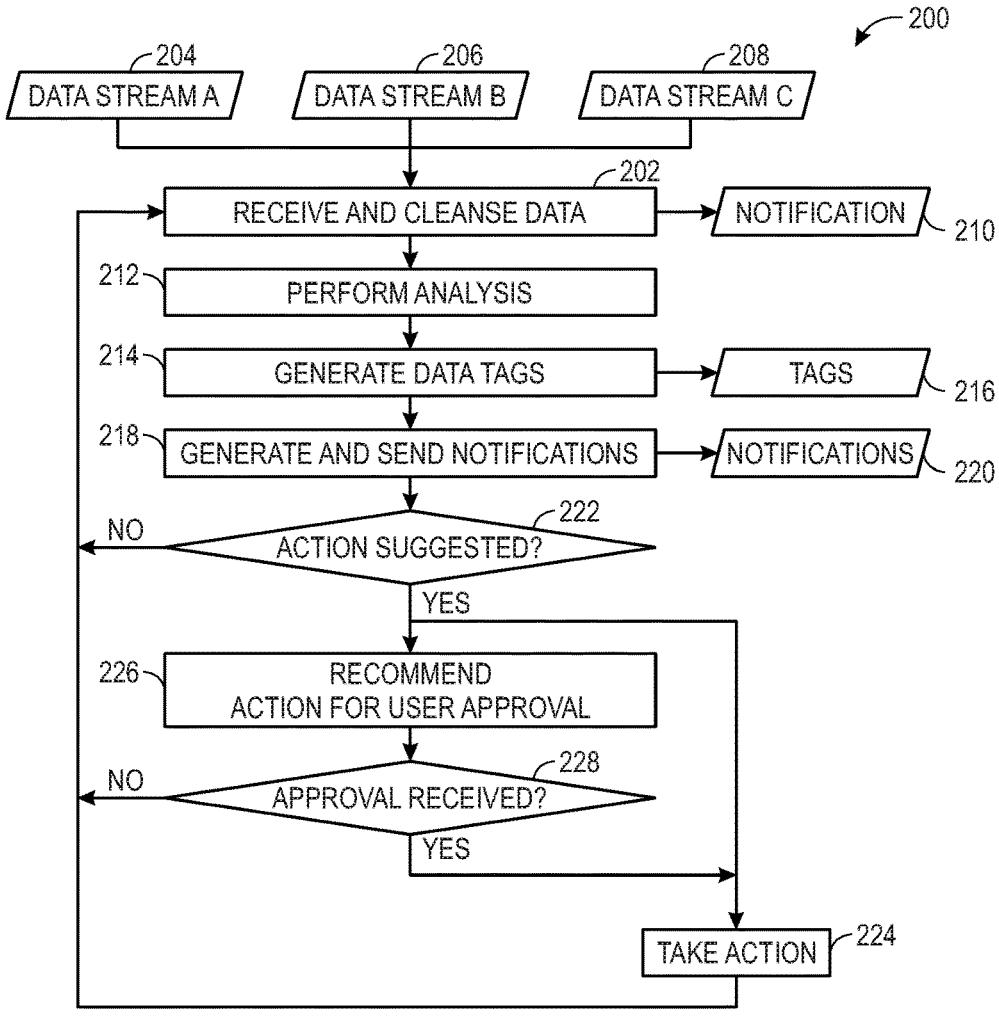

200
204
DATA STREAM A
206
DATA STREAM B
208
DATA STREAM C
202
RECEIVE AND CLEANSE DATA
NOTIFICATION
210
212
PERFORM ANALYSIS
214
GENERATE DATA TAGS
TAGS
216
218
GENERATE AND SEND NOTIFICATIONS
NOTIFICATIONS
220
222
NO
ACTION SUGGESTED?
YES
226
RECOMMEND ACTION FOR USER APPROVAL
228
NO
APPROVAL RECEIVED?
YES
TAKE ACTION
224

FIG. 3

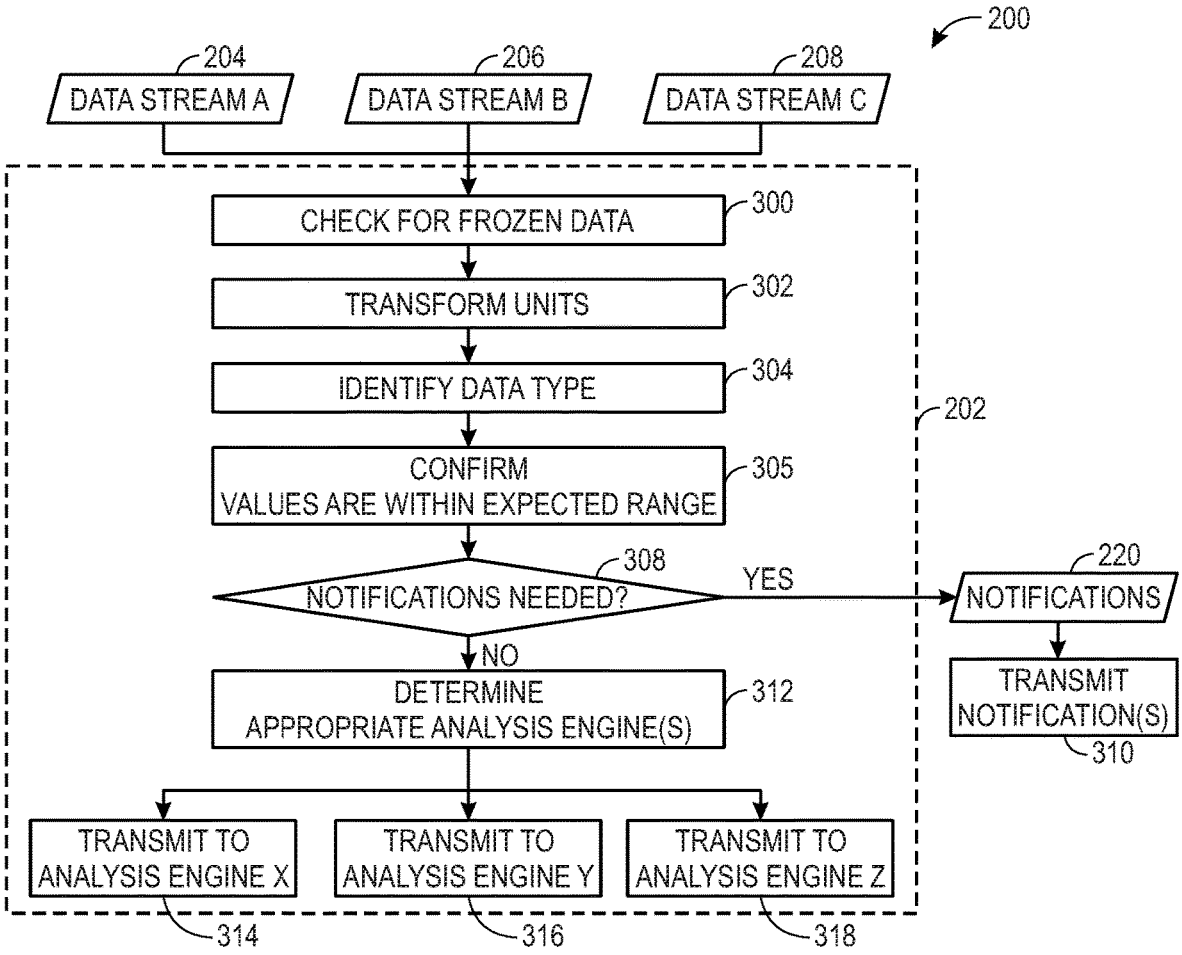

200
204
DATA STREAM A
206
DATA STREAM B
208
DATA STREAM C
CHECK FOR FROZEN DATA
300
TRANSFORM UNITS
302
IDENTIFY DATA TYPE
304
202
CONFIRM
VALUES ARE WITHIN EXPECTED RANGE
305
308
NOTIFICATIONS NEEDED?
YES
220
NOTIFICATIONS
TRANSMIT
NOTIFICATION(S)
310
NO
DETERMINE
APPROPRIATE ANALYSIS ENGINE(S)
312
TRANSMIT TO
ANALYSIS ENGINE X
TRANSMIT TO
ANALYSIS ENGINE Y
TRANSMIT TO
ANALYSIS ENGINE Z
314
316
318

FIG. 4

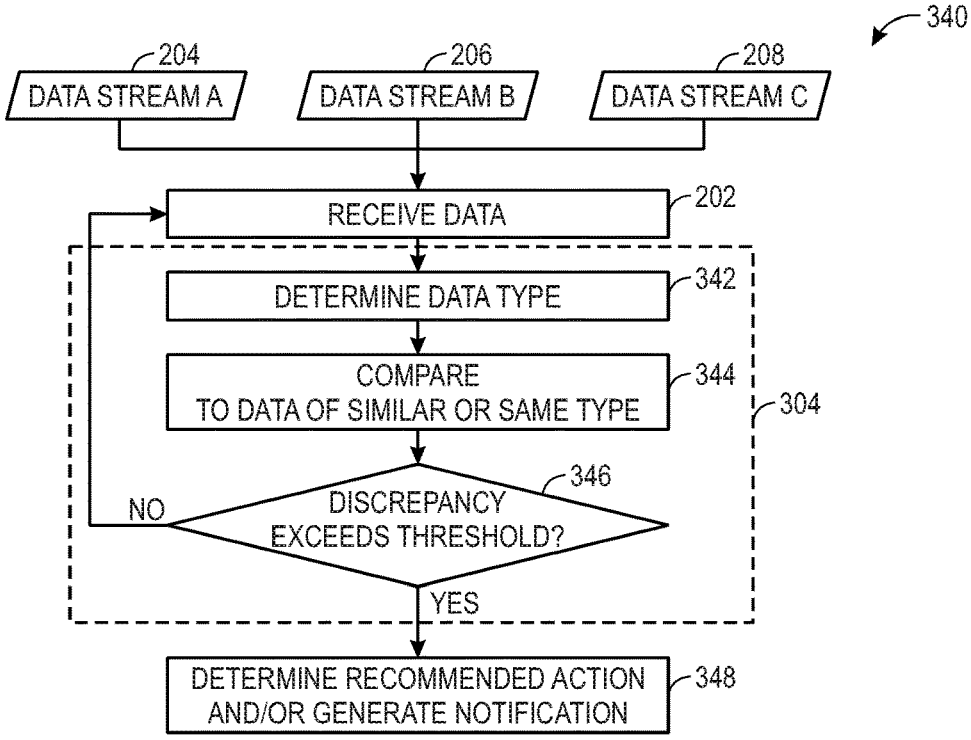

340
204
DATA STREAM A
206
DATA STREAM B
208
DATA STREAM C
RECEIVE DATA
202
DETERMINE DATA TYPE
342
COMPARE
TO DATA OF SIMILAR OR SAME TYPE
344
304
346
NO
DISCREPANCY
EXCEEDS THRESHOLD?
YES
DETERMINE RECOMMENDED ACTION
AND/OR GENERATE NOTIFICATION
348

FIG. 5

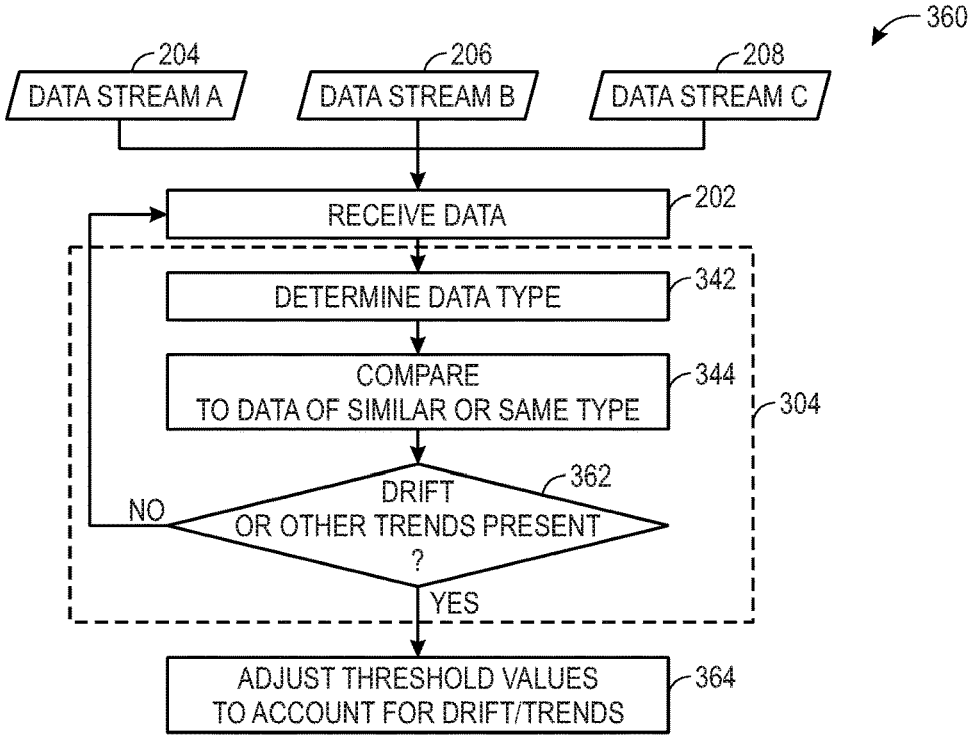

360
204
DATA STREAM A
206
DATA STREAM B
208
DATA STREAM C
RECEIVE DATA
202
DETERMINE DATA TYPE
342
COMPARE
TO DATA OF SIMILAR OR SAME TYPE
344
304
362
NO
DRIFT
OR OTHER TRENDS PRESENT
?
YES
ADJUST THRESHOLD VALUES
TO ACCOUNT FOR DRIFT/TRENDS
364

FIG. 6

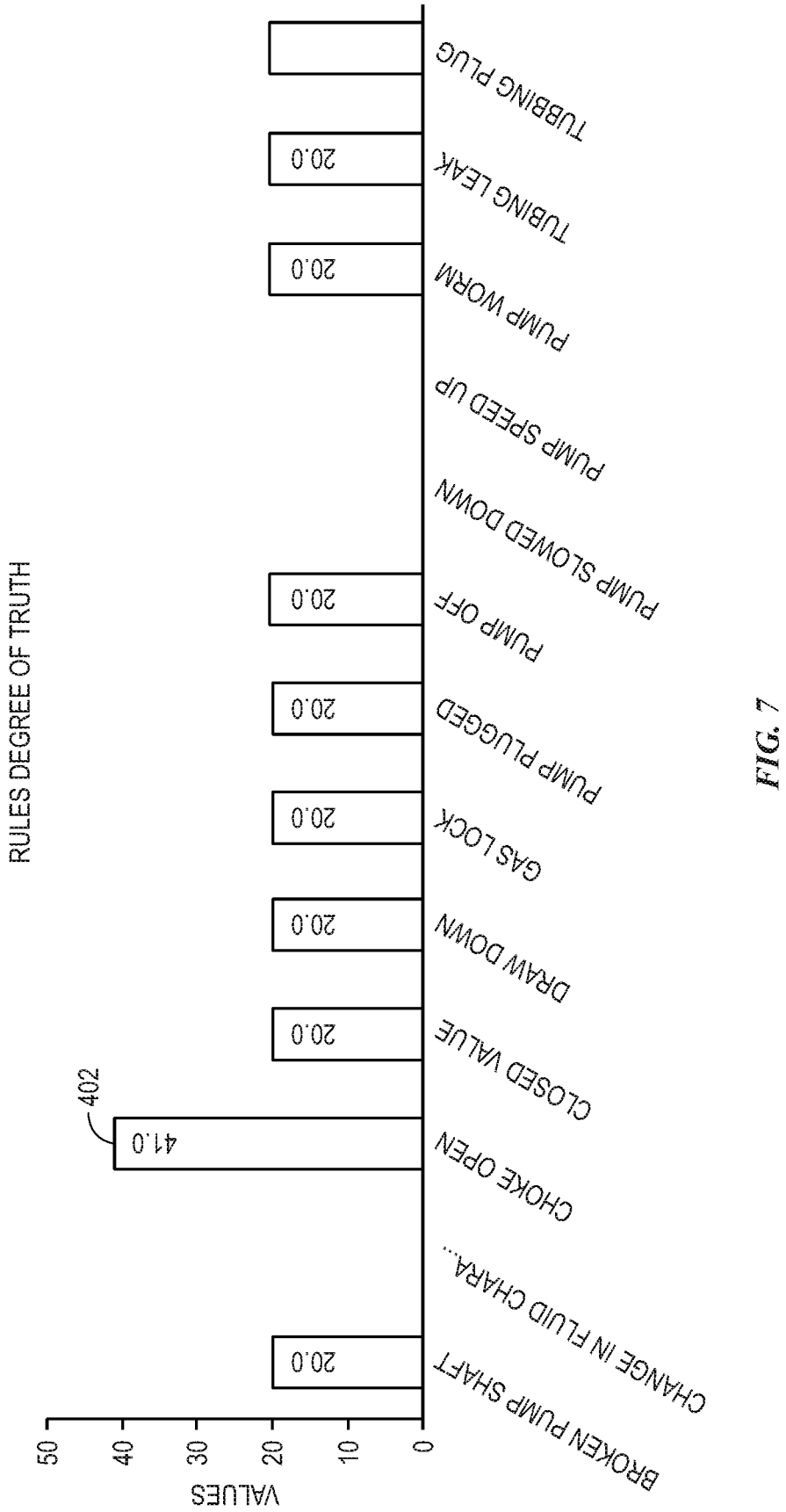

400
RULES DEGREE OF TRUTH
VALUES
0
10
20
30
40
50
402
41.0
20.0
BROKEN PUMP SHAFT
CHANGE IN FLUID CHARA...
CHOKE OPEN
CLOSED VALVE
DRAW DOWN
GAS LOCK
PUMP PLUGGED
PUMP OFF
PUMP SLOWED DOWN
PUMP SPEED UP
PUMP WORM
TUBING LEAK
TUBING PLUG

FIG. 7

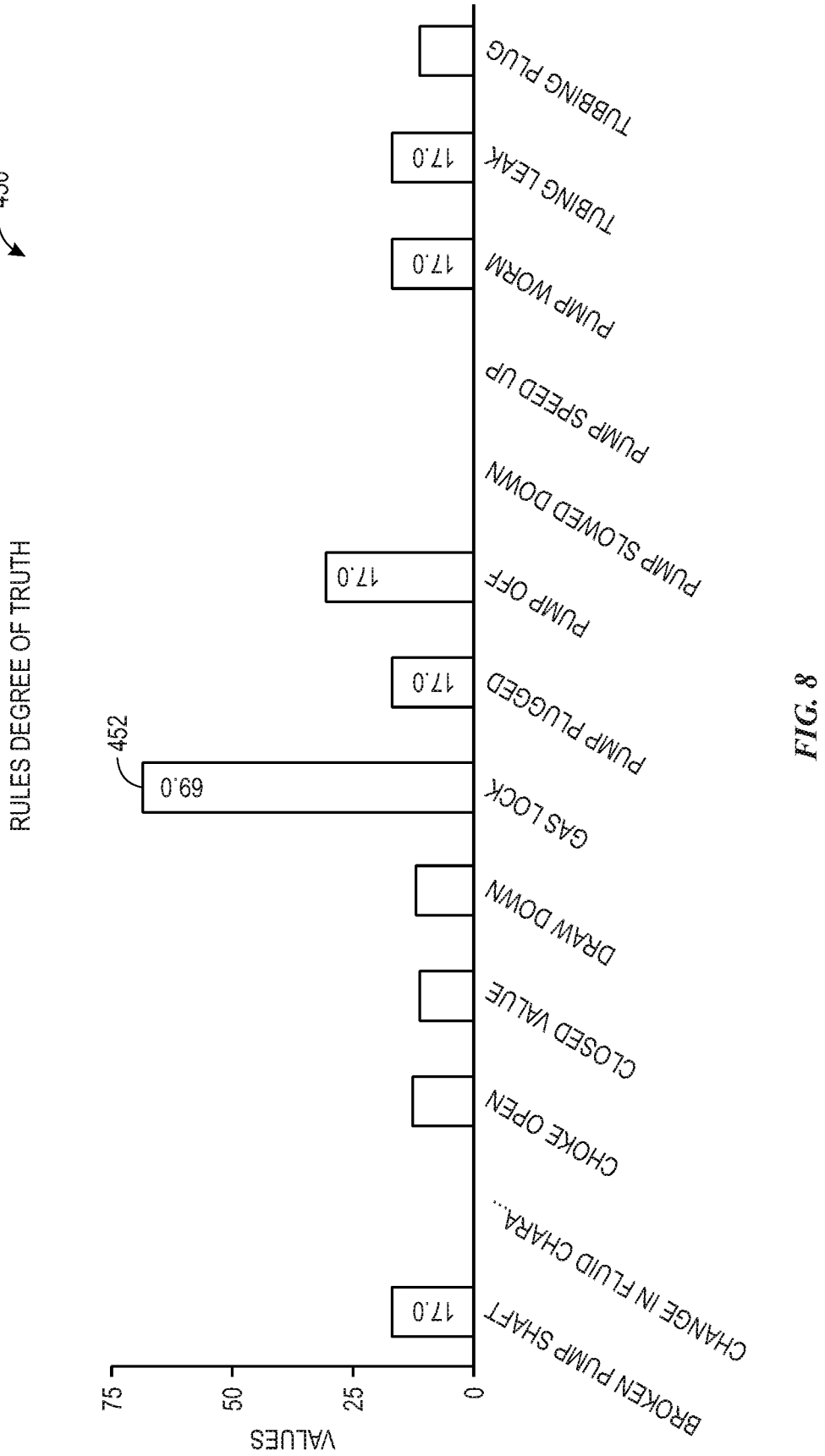

450
RULES DEGREE OF TRUTH
452
69.0
17.0
17.0
17.0
17.0
17.0
17.0
VALUES
75
50
25
0
BROKEN PUMP SHAFT
CHANGE IN FLUID CHARA...
CHOKE OPEN
CLOSED VALUE
DRAW DOWN
GAS LOCK
PUMP PLUGGED
PUMP OFF
PUMP SLOWED DOWN
PUMP SPEED UP
PUMP WORM
TUBING LEAK
TUBING PLUG

FIG. 8

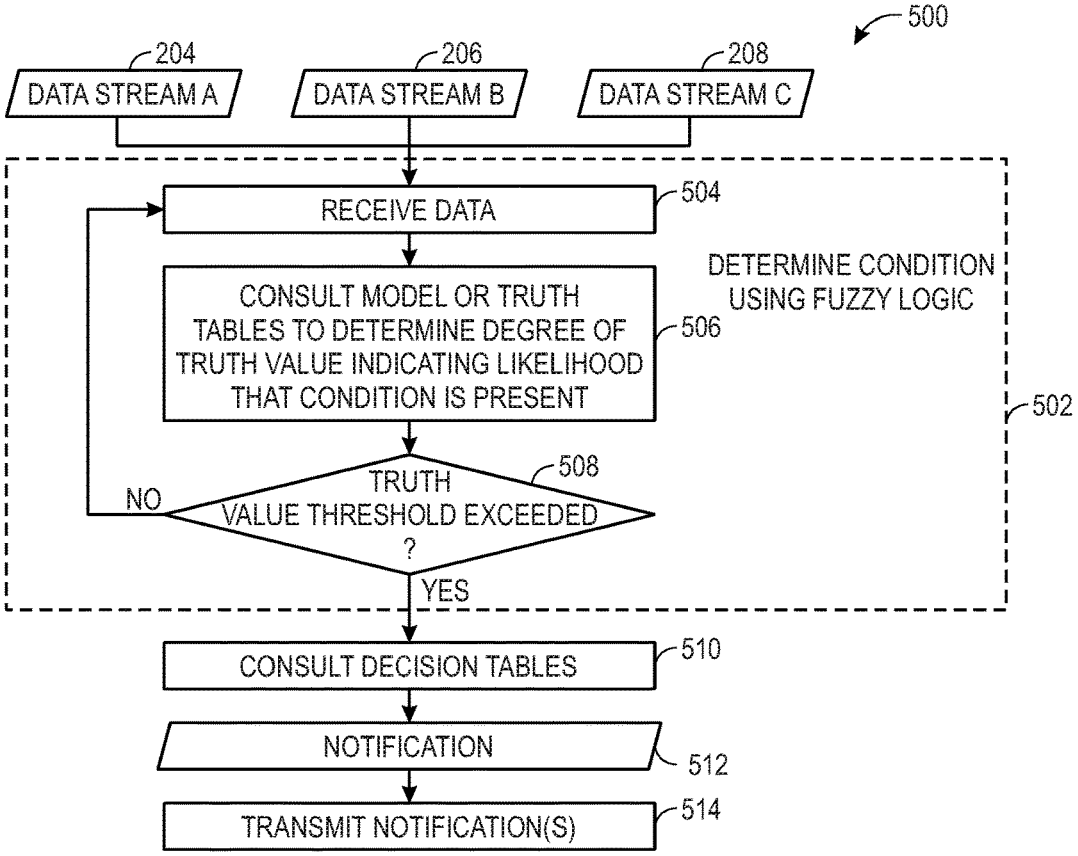

500
204
DATA STREAM A
206
DATA STREAM B
208
DATA STREAM C
RECEIVE DATA
504
CONSULT MODEL OR TRUTH TABLES TO DETERMINE DEGREE OF TRUTH VALUE INDICATING LIKELIHOOD THAT CONDITION IS PRESENT
506
DETERMINE CONDITION USING FUZZY LOGIC
502
TRUTH VALUE THRESHOLD EXCEEDED ?
508
NO
YES
CONSULT DECISION TABLES
510
NOTIFICATION
512
TRANSMIT NOTIFICATION(S)
514

FIG. 9

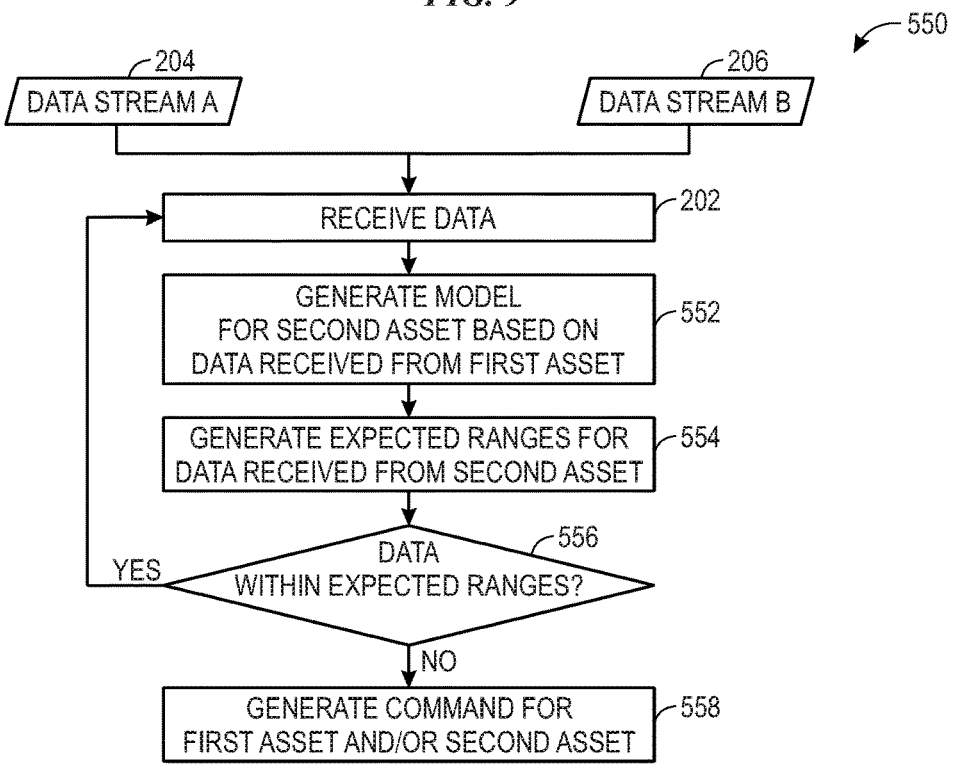

550
204
DATA STREAM A
206
DATA STREAM B
RECEIVE DATA
202
GENERATE MODEL FOR SECOND ASSET BASED ON DATA RECEIVED FROM FIRST ASSET
552
GENERATE EXPECTED RANGES FOR DATA RECEIVED FROM SECOND ASSET
554
DATA WITHIN EXPECTED RANGES?
556
YES
NO
GENERATE COMMAND FOR FIRST ASSET AND/OR SECOND ASSET
558

FIG. 10

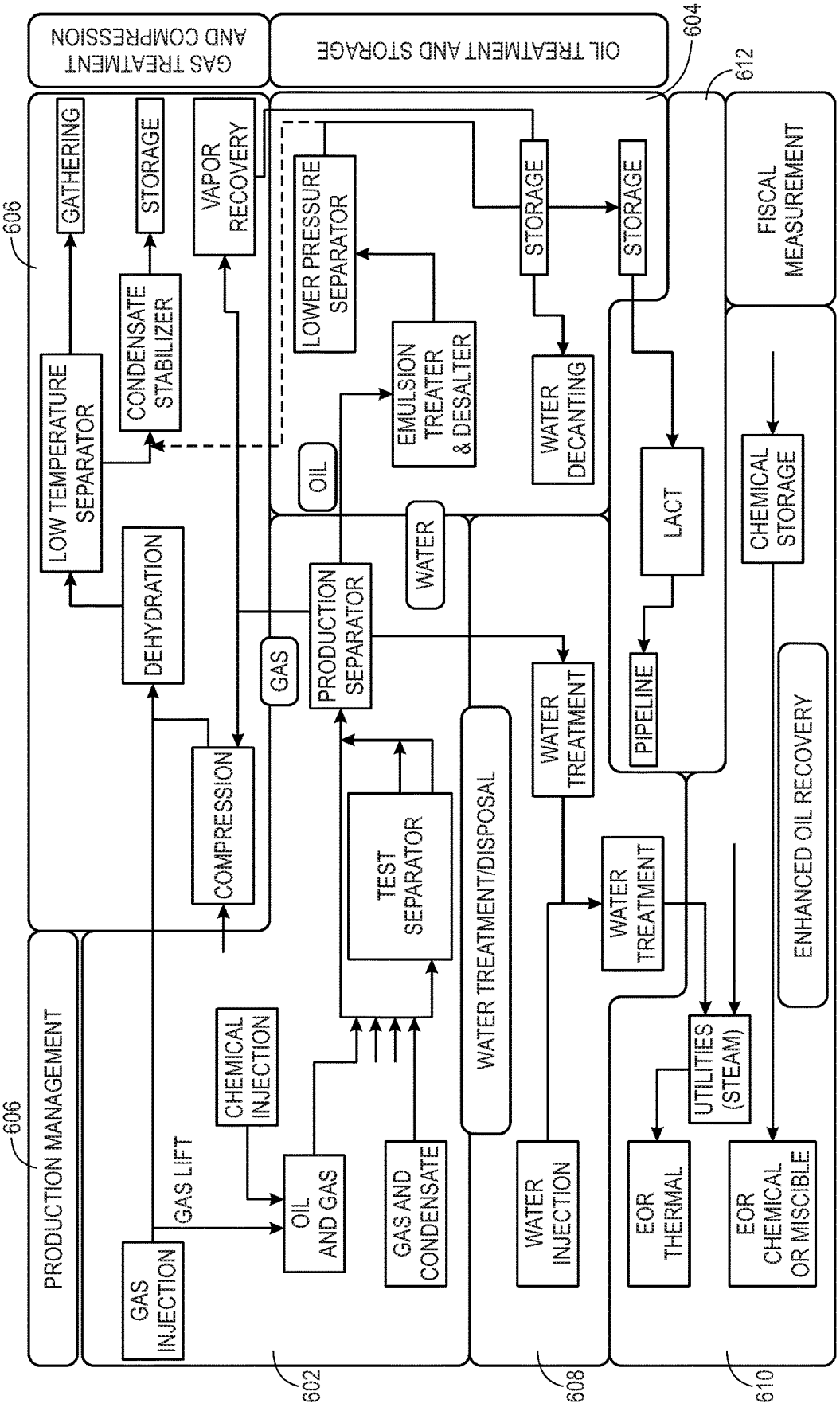

GAS TREATMENT AND COMPRESSION
OIL TREATMENT AND STORAGE
604
612
606
GATHERING
STORAGE
VAPOR RECOVERY
LOW TEMPERATURE SEPARATOR
CONDENSATE STABILIZER
LOWER PRESSURE SEPARATOR
EMULSION TREATER & DESALTER
OIL
STORAGE
STORAGE
WATER DECANTING
FISCAL MEASUREMENT
LACT
CHEMICAL STORAGE
DEHYDRATION
WATER
GAS
PRODUCTION SEPARATOR
COMPRESSION
WATER TREATMENT
PIPELINE
ENHANCED OIL RECOVERY
TEST SEPARATOR
WATER TREATMENT/DISPOSAL
WATER TREATMENT
606
PRODUCTION MANAGEMENT
CHEMICAL INJECTION
GAS LIFT
UTILITIES (STEAM)
OIL AND GAS
GAS AND CONDENSATE
WATER INJECTION
EOR THERMAL
EOR CHEMICAL OR MISCIBLE
GAS INJECTION
602
608
610

FIG. 11

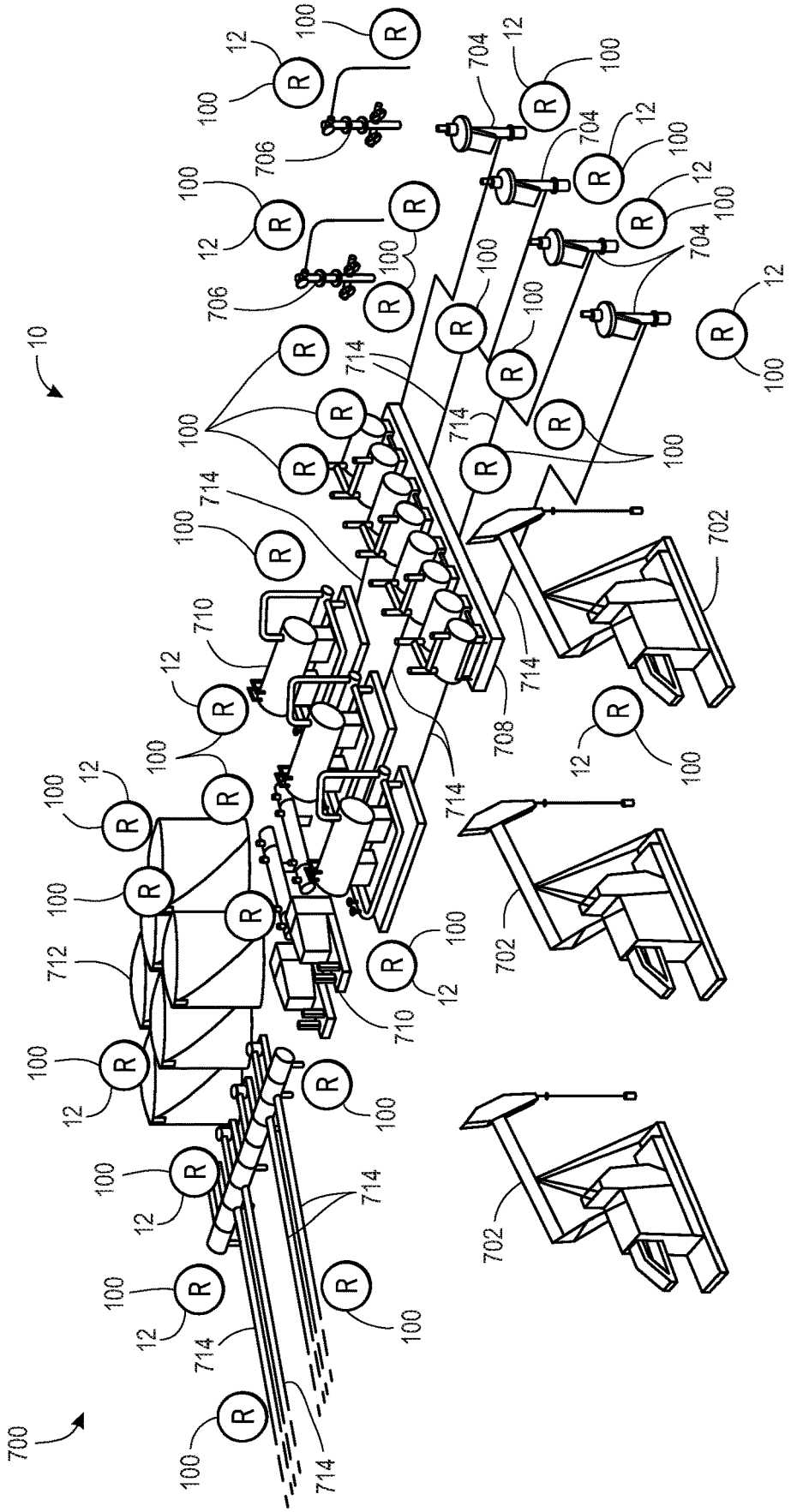


FIG. 12

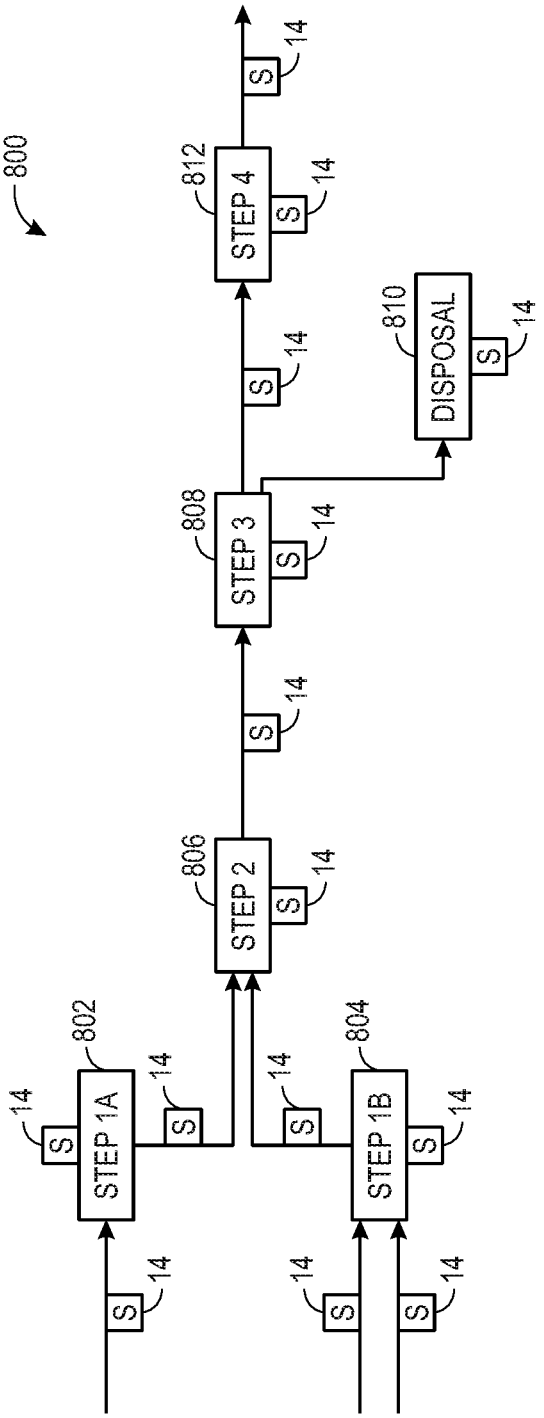

800
802
STEP 1A
804
STEP 1B
806
STEP 2
808
STEP 3
810
DISPOSAL
812
STEP 4
S
14

FIG. 13

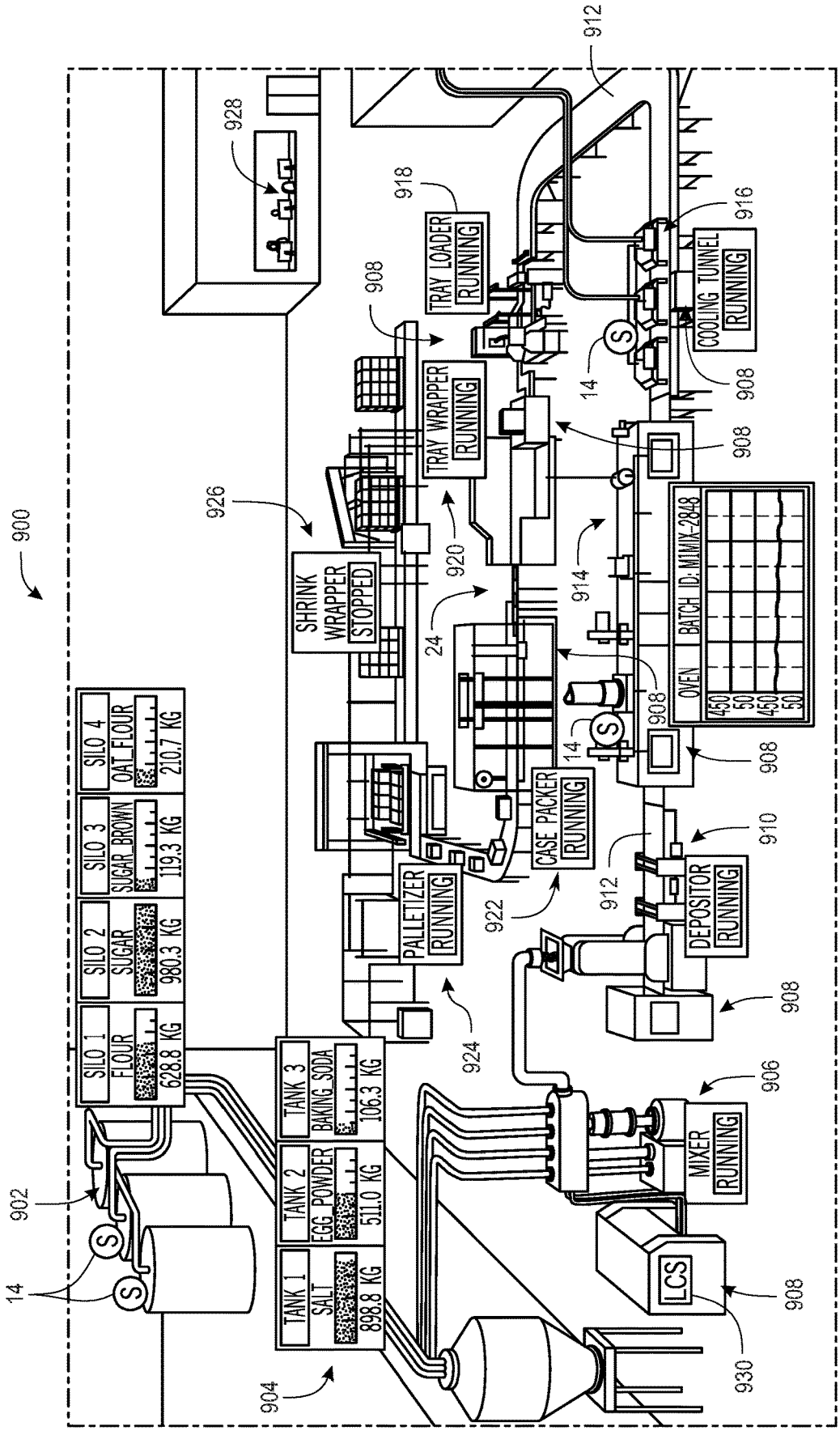

900
902
904
906
908
910
912
914
916
918
920
922
924
926
928
930
14
24
SILO 1 FLOUR 628.8 KG
SILO 2 SUGAR 980.3 KG
SILO 3 SUGAR_BROWN 119.3 KG
SILO 4 OAT_FLOUR 210.7 KG
TANK 1 SALT 898.8 KG
TANK 2 EGG_POWDER 511.0 KG
TANK 3 BAKING_SODA 106.3 KG
MIXER RUNNING
LCS
DEPOSITOR RUNNING
PALLETIZER RUNNING
CASE PACKER RUNNING
SHRINK WRAPPER STOPPED
TRAY WRAPPER RUNNING
TRAY LOADER RUNNING
COOLING TUNNEL RUNNING
OVEN BATCH ID: M1MIX-2848
450 50 450 50

FIG. 14

SYSTEMS AND METHODS FOR ANALYZING STREAM-BASED DATA FOR ASSET OPERATION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from and the benefit of U.S. Provisional Application No. 62/760,372, entitled "SYSTEMS AND METHODS FOR ANALYZING STREAM-BASED DATA FOR ASSET OPERATION", filed Nov. 13, 2018, which is incorporated by reference herein in their entirety for all purposes.

BACKGROUND

[0002] The present disclosure relates generally to improving operations of a control system that monitors and controls the operation of one or more components of an industrial process (e.g., oil and gas production, chemical processing, manufacturing, food and/or beverage processing, etc.). More specifically, the present disclosure relates to performing analysis on data collected from the industrial process in real time or near real time (e.g., in seconds or minutes).

[0003] An industrial process may include a series of steps performed by a collection of respective components or assets. Typically sensors disposed at each component may collect data, which a control system of the component may compare to preset threshold values or ranges and then take one or more predetermined actions based on whether or not the collected data exceed the threshold values and/or fall within the preset ranges. Accordingly, the control system of each component may not take into account the state of the other components working in concert to perform the industrial process when controlling the component in real time or near real time. Further, the control system of each component may not take into account an underlying condition of the industrial process or a holistic view of some or all of the other components working in concert to perform the industrial process when controlling the component. Accordingly, improved systems and methods for controlling various components of the industrial process while considering the operations of other components in the industrial process are desirable.

BRIEF DESCRIPTION

[0004] In one embodiment, a system includes a first asset disposed at a first location in an industrial system configured to perform one or more operations, a second asset disposed at a second location in the industrial system, and a server device communicatively coupled to the first asset and the second asset. The server device is configured to receive a first set of stream-based data from the first asset, receive a second set of stream-based data from the second asset, identify a first portion of the first set of stream-based data and a second portion of the second set of stream-based data, wherein the first portion and the second portion comprises a same type of data, determine whether the first portion of the first set of stream-based data corresponds to an expected range of values based on the second portion of the second set of stream-based data, and send a command to the first asset to adjust a first set of operations in response to the first portion of the first set of stream-based data not being within the expected range of values.

[0005] In another embodiment, a system includes a first asset disposed at an industrial automation system, a second asset disposed at the industrial automation system, and a server communicatively coupled to the first asset and the second asset. The server is configured to receive a first set of stream-based data from the first asset, generate a model for the second asset based on the first set of stream-based data, wherein the model is configured to output an expected set of stream-based data associated with the second asset, receive a second set of stream-based data from the second asset, and send a command to the first asset or the second asset in response to the second set of stream-based data being outside of a threshold from the expected set of stream-based data.

[0006] In yet another embodiment, a method includes receiving a first set of stream-based data from a first asset disposed at a first location in an industrial system configured to perform one or more operations, receiving a second set of stream-based data from a second asset disposed at a second location in the industrial system, identifying a first portion of the first set of stream-based data and a second portion of the second set of stream-based data, wherein the first portion and the second portion comprises a same type of data, determining whether the first portion of the first set of stream-based data corresponds to an expected range of values based on the second portion of the second set of stream-based data, and sending a command to the first asset to adjust a first set of operations in response to the first portion of the first set of stream-based data not being within the expected range of values.

DRAWINGS

[0007] These and other features, aspects, and advantages of the present embodiments will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0008] FIG. **1** illustrates a block diagram of a high-level overview of stream-based processing analysis system, in accordance with embodiments presented herein;

[0009] FIG. **2** illustrates a block diagram of a remote terminal unit (RTU) that may be employed in the stream-based processing analysis system of FIG. **1**, in accordance with embodiments presented herein;

[0010] FIG. **3** illustrates a flow chart of a process for stream-based processing analysis, in accordance with embodiments presented herein;

[0011] FIG. **4** illustrates a flow chart of a process for cleansing data within the stream-based processing analysis system of FIG. **1**, in accordance with embodiments presented herein;

[0012] FIG. **5** illustrates a flow chart of a process for identifying data type within the stream-based processing analysis system of FIG. **1**, in accordance with embodiments presented herein;

[0013] FIG. **6** illustrates a flow chart of a process for identifying drift and adjusting threshold values within the stream-based processing analysis system of FIG. **1**, in accordance with embodiments presented herein;

[0014] FIG. **7** illustrates a first bar graph visualization of degree of truth values for a number of conditions for an oil and gas well experiencing a problem, in accordance with embodiments presented herein;

[0015] FIG. **8** illustrates a second bar graph visualization of degree of truth values for the number of conditions for the oil and gas well experiencing a different problem than that of FIG. **7**, in accordance with embodiments presented herein;

[0016] FIG. **9** illustrates a flow chart of a process for using fuzzy logic in the stream-based processing analysis system of FIG. **1**, in accordance with embodiments presented herein;

[0017] FIG. **10** illustrates a flow chart of a process for comparing downstream data to a model generated based on upstream data within the stream-based processing analysis system of FIG. **1**, in accordance with embodiments presented herein;

[0018] FIG. **11** illustrates a schematic illustrating various operations involved in hydrocarbon production, in accordance with embodiments presented herein;

[0019] FIG. **12** illustrates a schematic of how stream-based processing may be applied at a hydrocarbon site, in accordance with embodiments presented herein;

[0020] FIG. **13** illustrates a schematic of a chemical process that may utilize the stream-based processing analysis system of FIG. **1**, in accordance with embodiments presented herein; and

[0021] FIG. **14** illustrates an example industrial automation system utilizing stream-based processing employed by a food manufacturer, in accordance with embodiments presented herein.

DETAILED DESCRIPTION

[0022] One or more specific embodiments will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0023] When introducing elements of various embodiments of the present invention, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0024] Embodiments of the present disclosure are generally directed towards systems and methods for providing improved control of one or more assets in a multi-node network using stream-based processing. An industrial process may include a series of steps performed by a collection of respective components or assets disposed at nodes. Sensors disposed at each node may collect data, which a control system of the asset may compare to preset threshold values or ranges. The control system may then take one or more predetermined actions based on whether or not the collected data exceed the threshold values and/or fall within the preset ranges. Accordingly, the control system of each asset may not take into account the state of the other assets within the network working in concert to perform the industrial process when controlling the component in real time or near real time. Further, the control system of each component may not take into account an underlying condition of the industrial process or a holistic view of some or all of the other components working in concert to perform the industrial process when controlling the component. This may result in the industrial process working in an inefficient or otherwise undesirable state.

[0025] To obtain a holistic view of the industrial process, an operator of the industrial process may hire a subject matter expert (SME) to perform an in-depth analysis of the industrial process. For example, the operator may collect data from the various nodes of the network for the industrial process over the course of a few weeks or months and then send the data to the SME for analysis. Based on the analysis of the SME, the operator may make adjustments to the industrial process. In the interim, the industrial process may run for weeks or months in an inefficient or undesirable state between collection of the data and the adjustments made upon receiving the results of the analysis provided by the SME.

[0026] With this is mind, the disclosed techniques include receiving streams of data from multiple nodes within the network, using the data received via the data streams to model one or more underlying conditions in real time or near real time (e.g., within seconds or minutes) using data received from the various streams as inputs, and then determine what, if anything, should be done to control one or more of the assets within the network to make the industrial process run more efficiently. The analysis may include, for example, using one or more analysis engines to maintain one or more models (e.g., state-based models) of various aspects of the industrial process, running scripts or routines on the received data, performing queries based on the data, updating an analysis function, applying fuzzy logic, consulting one or more truth tables, and so forth to analyze the received data in real time or near real time. In some embodiments, the received data may be cleansed or preprocessed to check for frozen data, transform units, identify data types, provide relevant data to the appropriate analysis engines, etc. Based on the underlying condition, decision tables may be referenced to determine what, if any, remedial action to recommend. In some embodiments, the recommended action may be automatically taken. In other embodiments, the recommended action may be recommended to a user for approval before the action is taken. In further embodiments, the recommended action may be recommended for the user to implement on his or her own. In yet further embodiments, the recommended action may be added to a workflow (e.g., a business workflow) and/or to a user's to do list. Accordingly, the disclosed techniques provide real time or near real time feedback for one or more assets within a multi-node network based on a holistic model of the network generated using streams of data provided by multiple nodes.

[0027] By way of introduction, FIG. **1** illustrates a high-level overview of a stream-based processing analysis system **10** for an enterprise. The analysis system **10** may include a plurality of nodes **12** disposed in the same or different industrial environments. The nodes **12** may be located geographically near one another (e.g., in the same industrial facility), located geographically remote from one another (e.g., located in different facilities, different cities, different

states, different regions, different countries, different continents, etc.), or some combination thereof (e.g., two nodes **12** in one industrial facility, and a third node **12** at a different location hundreds of miles away). Further, the nodes **12** may be distributed horizontally along some production process (e.g., the nodes **12** include or are coupled to machines performing the same or similar steps in a process in parallel), distributed vertically along some production process (e.g., the nodes **12** include or are coupled to machines performing different steps of a process in series), or some combination thereof. Accordingly, one or more of the nodes **12** may be situated upstream or downstream from one or more other nodes **12**. In other embodiments, the nodes **12** may be part of different, but in some cases, related processes. For example, in one embodiment related to oil and gas extraction, the nodes **12** may be various wells extracting hydrocarbons from the same reservoir or hydrocarbon deposit. In a second embodiment related to oil and gas, the nodes **12** may be correspond with steps along the process of extraction and processing (e.g., extraction, separation, transport, storage, decanting, refining, etc.).

[0028] As shown, each node **12** may include one or more sensors **14** and/or one or more actuators **16**. The sensors **14** may sense one or more parameters (e.g., temperature, pressure, flow rate, etc.) and provide a stream of measurements for the one or more parameters. The actuators **16** may be configured to move in response to a control signal to adjust one or more properties at one or more nodes **12** or to perform one or more tasks at one or more of the nodes **12**. In some embodiments, one or more of the nodes **12** may include a hardware processor **18** and a memory component **20**. The processor **18** and memory component **20** may represent a computing device coupled to the node **12**, a control system for the node **12**, a user interface for the node **12**, or some combination thereof. The memory component **20** may store data collected by the sensors **14**, code to be executed by the processor **18**, and so forth. The processor **18** may be configured to execute instructions stored on the memory component **20**. For example, the processor **18** may be configured to perform some analysis (e.g., pre-processing) on data collected by the sensors **14**. In other embodiments, the processor **18** may analyze the data collected by the sensors **14** and generate control signals for the actuators **16**. The processor **18** may also facilitate communication between the nodes **12** and various other components within the analysis system **10**.

[0029] The nodes **12** may include one or more industrial devices or assets that make up automation systems operating within respective facilities. Exemplary automation systems may include, but are not limited to, batch control systems (e.g., mixing systems), continuous control systems (e.g., proportional-integral-derivative (PID) control systems), or discrete control systems. In such embodiments, the nodes **12** may also include devices, such as industrial controllers (e.g., programmable logic controllers or other types of programmable automation controllers), field devices such as sensors and meters, motor drives, operator interfaces (e.g., human-machine interfaces, industrial monitors, graphic terminals, message displays, etc.), industrial robots, barcode markers and readers, vision system devices (e.g., vision cameras), smart welders, or other such industrial devices. Further, tit should be understood that the nodes **12** may be disposed within fixed-location industrial facilities, or the nodes **12** may be part of a mobile control application, such as a system contained in a truck or other service vehicle.

[0030] As shown, the nodes **12** may be in communication with one or more servers **22** via a network **24** (e.g., the internet). A communication link between the nodes **12** and the network **24** may be a wired or a wireless connection, such as Wi-Fi®, Bluetooth®, and the like. Each of the servers **22** may include a hardware processor **26** and a memory component **28** accessible by the processor **26**. The memory component **28** may store, for example, instructions to be executed by the processor **26**, one or more analysis engines **30**, scripts, or routines to be applied by the processor **26**, and a database **32**. The database **32** may store historical data, training data, results of analysis, etc. As shown, the server **22** may receive streams of data from multiple nodes **12** and analyze sets of stream-based data received from the data streams in real time or near real time (e.g., within seconds or minutes). The processor **26** may run scripts or models stored in the memory **28** to analyze incoming data. In some embodiments, historical data, training data, or other data stored in the database **32** may be used to provide context to analysis of incoming data or may be used as training data for training a machine learning model. The processor **26** may determine recommended actions, generate control signals for implementing recommended actions, generate notifications, generate visualizations, etc. Although various processes described herein are detailed as being performed by the server **22**, it should be noted that any suitable computing device (e.g., node **12**, processor **18**) may also be used to perform the techniques described herein.

[0031] FIG. **1** shows a plurality of servers **22**. In some embodiments data received from the nodes **12** may be sent to one or more specific servers **22** for analysis based on the type of the data, the source of the data (e.g., the model number and/or manufacturer of the device or asset), or some other characteristic of the data. In other embodiments, the data analysis may be cloud-based. That is, data analysis functions may be distributed over a plurality of servers **22**.

[0032] As discussed in more detail below, the nodes **12** may collect data and then provide streams of data (e.g., data sent in real time or near real time) to the one or more servers **22** via the network **24**. The one or more servers **22** may then then clean, preprocess, or filter noise from the data in the data stream (e.g., perform some preprocessing functions, such as identify the data type, filter data, check for frozen data, confirm that values are in expected ranges, transform units, send to a specific analysis engine, etc.). The analysis engines **30** on the server **22** may then perform analysis (e.g., run a model, run a script, perform fuzzy logic calculations, etc.) in real time or near real time (e.g., analysis is completed in seconds or minutes), and then either automatically take action or propose a recommended action to be provided to a user for approval.

[0033] In some embodiments, the stream-based analysis system **10** may also include a computing device **34** connected to the nodes **12** and/or the one or more servers **22** via the network **24** or directly (not shown). The computing device **34** may review the analysis, review and/or approve recommended actions, set or modify parameters for analysis, view data from the nodes **12**, control various aspects of the nodes **12**, etc. Generally, the computing device **34** may be any type of processing device that may include communication abilities, processing abilities, and the like. For example, the computing device **34** may be a controller, such

as a programmable logic controller (PLC), a programmable automation controller (PAC), or any other controller that may monitor, control, and operate the industrial device. The computing device **34** may be incorporated into any physical device (e.g., the industrial device) or may be implemented as a stand-alone computing device (e.g., general purpose computer), such as a desktop computer, a laptop computer, a tablet computer, a mobile computing device, or the like. The computing device **34** may provide a graphical user interface (e.g., a browser, an application, etc.) by which a user may monitor and control various aspects of the analysis system **10**.

[0034] FIG. **2** is a schematic view of an embodiment of one of the nodes **12** of FIG. **1**. As shown, in the illustrated embodiment, the node **12** includes a remote terminal unit (RTU) **100**, a control engine **102**, and a communication link **104**. The RTU **100** may include sensors **14** or may be coupled to various sensors **14** that may monitor various properties associated with a component at an industrial site. The RTU **100** may then analyze the various properties associated with the component and may control various operational parameters of the component. For example, the RTU **100** may measure a pressure or a differential pressure of a well or a component at the industrial site. The RTU **100** may also measure temperatures of contents stored inside a component at the industrial site, an amount of hydrocarbons being processed or extracted by components at the industrial site, and the like. The RTU **100** may also measure a level or amount of hydrocarbons stored in a component, such as a storage tank. In certain embodiments, the RTU **100** may be iSens-GP Pressure Transmitter, iSens-DP Differential Pressure Transmitter, iSens-MV Multivariable Transmitter, iSens-T2 Temperature Transmitter, iSens-L Level Transmitter, or Isens-IO Flexible I/O Transmitter manufactured by Rockwell Automation.

[0035] In one embodiment, the RTU **100** may include a sensor **14** that may measure pressure, temperature, fill level, flow rates, and the like. The RTU **100** may also include communication component **106** or a transmitter, such as a radio wave transmitter, that may transmit data acquired by the sensor **14** via an antenna or the like. The sensor **14** in the RTU **100** may be a wireless sensor that may be capable of receiving and sending data signals between RTUs **100**. To power the sensors **14** and the transmitters, the RTU **100** may include a battery or may be coupled to a continuous power supply. Since the RTU **100** may be installed in harsh outdoor and/or explosion-hazardous environments, the RTU **100** may be enclosed in an explosion-proof container that may meet certain standards established by the National Electrical Manufacturer Association (NEMA) and the like, such as a NEMA 4× container, a NEMA 7× container, and the like.

[0036] The RTU **100** may transmit data acquired by the sensor **14** or data processed by a processor **108** to other monitoring systems, a router device, a supervisory control and data acquisition (SCADA) device, or the like. As such, the RTU **100** may enable users to monitor various properties of various components in the industrial site without being physically located near the corresponding components.

[0037] In operation, the RTU **100** may receive real-time or near real-time data associated with the associated component case head pressure, flowline pressure, wellhead pressure, wellhead temperature, and the like. In any case, the RTU **100** may analyze the real-time data with respect to static data that may be stored in a memory **110** of the RTU **100**. The static data may include a well depth, a tubing length, a tubing size, a choke size, a reservoir pressure, a bottom hole temperature, well test data, fluid properties of the hydrocarbons being extracted, and the like. The RTU **100** may also analyze the real-time data with respect to other data acquired by various types of instruments (e.g., water cut meter, multiphase meter) to determine an inflow performance relationship (IPR) curve, a desired operating point for a wellhead, key performance indicators (KPIs) associated with the wellhead, wellhead performance summary reports, and the like. Although the RTU **100** may be capable of performing the above-referenced analyses, the RTU **100** may not be capable of performing the analyses in a timely manner. Moreover, by just relying on the processor capabilities of the RTU **100**, the RTU **100** may be limited in the amount and types of analyses that it may perform. Moreover, since the RTU **100** may be limited in size, the data storage abilities may also be limited.

[0038] Keeping the foregoing in mind, in certain embodiments, the RTU **100** may establish a communication link **104** with the stream-based processing analysis system **10** shown in FIG. **1**. As such, the stream-based processing analysis system **10** may use its larger processing capabilities to analyze data acquired by multiple RTUs **100**. Moreover, the stream-based processing analysis system **10** may access historical data associated with the respective RTU **100**, data associated with well devices associated with the respective RTU **100**, data associated with the industrial site associated with the respective RTU **100** and the like to further analyze the data acquired by the RTU **100**.

[0039] Accordingly, in one embodiment, the RTU **100** may communicatively couple to the stream-based processing analysis system **10** via the communication link **104** shown in FIG. **2**. The RTU **100** may communicatively couple to the control engine **102** such as ControlLogix® or the like. The control engine **102** may, in turn, communicatively couple to the communication link **104** that may provide a protocol or specifications such as OPC Data Access that may enable the control engine **102** and the RTU **100** to continuously communicate its data to the stream-based processing analysis system. The communication link **104** may be communicatively coupled to the stream-based processing analysis system **10**. Although the RTU **100** is described as communicating with the stream-based processing analysis system **10** via the control engine **102** and the communication link **104**, it should be noted that in some embodiments, the RTU **100** may communicate directly with the stream-based processing analysis system **10**.

[0040] In some embodiments, the RTU **100** may communicatively couple to the control engine **102** or the communication link **104** via an Ethernet IP/Modbus network. As such, a polling engine may connect to the RTU **100** via the Ethernet IP/Modbus network to poll the data acquired by the RTU **100**. The polling engine may then use an Ethernet network to connect to the stream-based processing analysis system.

[0041] As mentioned above, the RTU **100** may monitor and control various types of industrial components (e.g., oil and gas well devices) and may send the data acquired by the respective components to the stream-based processing analysis system **10** according to the architecture described above. For example, the RTU **100** may monitor and control an electrical submersible pump (ESP), a gas lift (GL), a rod pump controller (RPC), a progressive cavity pump (PCP),

and the like. In the ESP, the RTU **100** may sense and control the wellhead and other operating variables of the ESP system. In the GL, the RTU **100** may adjust a gas lift injection flow to operator flow rate, compute real-time estimated gas-oil-water production, and the like. In the RPC, the RTU **100** may provide advance rod pump controlling operations for beam pump applications and the like. The RTU **100** may also monitor both polish rod load and continuous walking beam position to develop dynamometer cards. In the PCP, the RTU **100** may provide local and remote monitoring of the wellhead and other PCP variable. Here, the RTU **100** may also perform basic analysis and adjust the pumping conditions of the PCP based on the received data from the PCP.

[0042] As shown in FIG. **2**, the RTU **46** may include the communication component **106**, the processor **108**, the memory **110**, a storage **112**, input/output (I/O) ports **114**, a display **116**, and the like. The communication component **106** may be a wireless or wired communication component that may facilitate communication between different RTUs **100**, gateway communication devices, various control systems, and the like. The processor **108** may be any type of computer processor or microprocessor capable of executing computer-executable code. The memory **110** and the storage **112** may be any suitable articles of manufacture that can serve as media to store processor-executable code, data, or the like. These articles of manufacture may represent computer-readable media (i.e., any suitable form of memory or storage) that may store the processor-executable code used by the processor **108** to perform the presently disclosed techniques. The memory **110** and the storage **112** may also be used to store data received via the I/O ports **114**, data analyzed by the processor **108**, or the like.

[0043] The I/O ports **114** may be interfaces that may couple to various types of I/O modules such as sensors **14**, actuators **16**, programmable logic controllers (PLC), and other types of equipment. For example, the I/O ports **114** may serve as an interface to pressure sensors, flow sensors, temperature sensors, and the like. As such, the RTU **100** may receive data associated with a well via the I/O ports **114**. The I/O ports **114** may also serve as an interface to enable the RTU **100** to connect and communicate with surface instrumentation, flow meters, water cut meters, multiphase meters, and the like.

[0044] In addition to receiving data via the I/O ports **114**, the RTU **100** may control various devices via the I/O ports **114**. For example, the RTU **100** may be communicatively coupled to the actuator **16** or motor that may modify the size of a choke that may be part of the well. The choke may control a fluid flow rate of the hydrocarbons being extracted at the well or a downstream system pressure within the network of pipelines or the like. In one embodiment, the choke may be an adjustable choke that may receive commands from the RTU **100** to change the fluid flow and pressure parameters at the well.

[0045] The display **116** may include any type of electronic display such as a liquid crystal display, a light-emitting-diode display, and the like. As such, data acquired via the I/O ports and/or data analyzed by the processor **108** may be presented on the display **116**, such that operators having access to the RTU **100** may view the acquired data or analyzed data at the hydrocarbon well site. In certain embodiments, the display **116** may be a touch screen display or any other type of display capable of receiving inputs from the operator.

[0046] In addition to employing the RTU **100** to analyze data associated with a component at an industrial site (e.g., a well, a well device, etc.), the RTU **46** may also, as discussed above, receive analyzed data from the stream-based processing analysis system **10**. Moreover, the computing device **34** shown in FIG. **1** may also receive the same analyzed data from the stream-based processing analysis system, thereby providing the operator the opportunity to interpret the analyzed data and modify the operating parameters of the associated industrial equipment. Moreover, since the stream-based processing analysis system **10** may have access to additional data sources and may have more processing power as compared to the RTU **100**, the operator may have access to more accurate analysis to further increase the efficiency of the operations of the industrial equipment.

[0047] FIG. **3** is a flow chart of a process **200** for controlling an asset (e.g., an industrial component) using the stream-based processing analysis system **10** shown in FIG. **1**. In the instant embodiment, the process **200** is performed by one of the servers **22** shown in FIG. **1**. However, it should be understood that performance of the process **200** may be distributed over multiple servers **22** within the stream-based processing analysis system **10**. Further, in some embodiments, the process **200** may be performed by any computing device (e.g., the computing device **34** shown in FIG. **1**, or a computing device associated with one or more of the nodes **12**, such as the RTU **100** or the control engine **102** shown in FIG. **2**) or other suitable component within the stream-based processing analysis system **10**. At block **202**, data streams **204**, **206**, **208** are received by the server from various respective nodes **12** and cleansed or otherwise pre-processed. As previous described, rather than being received in batches, data is transmitted in real time or near-real time as it is sensed at the node, resulting in streams of data **204**, **206**, **208** from the nodes to the one or more servers **22**. Cleansing the data, which is described in more detail with regard to FIG. **4**, may include, preprocessing the data streams **204**, **206**, **208** and providing data from the data streams **204**, **206**, **208** to the appropriate analysis engines. Preprocessing may include, for example, checking for frozen data, transforming the units of the data, identifying the type of data (e.g., temperature, pressure, flow rate, etc.), confirming that data values are within an expected range, generating and transmitting notifications **210** if there are any issues with the data, and determining the appropriate analysis engine. If all of the data streams **204**, **206**, **208** were provided to each analysis engine, each analysis engine would then have to sift through a large amount of irrelevant data and isolate the relevant data for performing its assigned task (e.g., modeling the pressure dynamics of a hydrocarbon reservoir or deposit), thus hindering the analysis engine's ability to perform analysis in real time or near real time. Accordingly, the efficiency of the stream-based processing analysis system **10** may be improved by identifying data received via the data streams **204**, **206**, **208** providing the data to the appropriate analysis engines for analysis.

[0048] At block **212**, the one or more analysis engines may perform analysis based on the data received via the data streams **204**, **206**, **208** in real time or near real time (e.g., in seconds or minutes). Rather than comparing a single value

to some pre-set threshold value and then generating alerts or implementing some kind of control based on whether or not the value in question exceeds the threshold value, the instant techniques utilize data from multiple sources to gain a more complete understanding of the underlying state or condition and then determine what, if any, adjustments should be made. In some embodiments, the analysis may include comparing data of the same type received from different data streams **204**, **206**, **208**, updating a model (e.g., a state-based model) with multiple inputs, running scripts on the data, performing queries based on the data, updating an analysis function, applying fuzzy logic, consulting one or more truth tables, and so forth. The analysis engines may be set up to model a broad aspect of an industrial system (e.g., output of a manufacturing system) based on a large number of inputs, a specific aspect of an industrial system (e.g., pressure of a reservoir or a temperature at a location of a manufacturing process), or anywhere in between. As previously discussed, the nodes that provide the data streams **204**, **206**, **208** may be located geographically near one another (e.g., in the same industrial facility), located geographically remote from one another (e.g., located in different facilities), or some combination thereof. Further, the nodes may be distributed horizontally along some production process (e.g., the nodes include or are coupled to machines performing the same or similar steps in a process in parallel), distributed vertically along some production process (e.g., the nodes include or are coupled to machines performing different steps of a process in series), or some combination thereof. Accordingly, one or more of the nodes may be situated upstream or downstream from one or more other nodes. In such an embodiment, the data provided by the upstream node or nodes may be used as inputs to a model to generate expected values for the downstream node or nodes, to which the data received from the downstream nodes may be compared. In other embodiments, the nodes may be part of different, but in some cases, related processes. For example, in one embodiment related to oil and gas extraction, the nodes may be various wells extracting hydrocarbons from the same reservoir or hydrocarbon deposit. In such an embodiment, the data provided from one node may be compared to data provided by one or more other nodes. In a second embodiment related to oil and gas, the nodes **12** may be correspond with steps along the process of extraction and processing (e.g., extraction, separation, transport, storage, decanting, refining, etc.).

[0049] Data from the data streams **204**, **206**, **208** may be used to generate a model of the underlying condition of a system or update an existing model of the underlying condition of the system or systems in question and then make determinations as to what, if anything, should be done to make adjustments to the system or systems in question. Accordingly, as data is collected over time and the behavior of the underlying system is monitored as the system undergoes a wider range of conditions, the model of the system may adapt and become more robust and sophisticated.

[0050] Along these lines, in some embodiments, as data is collected, some or all of the data may be added to a database of historical data and used to fine tune the model. If only some of the data is stored in the database as historical data, decisions as to what data should be stored in the database may be made automatically or by a human expert. For example, when the system undergoes conditions that are unusual or otherwise noteworthy, a decision may be made to store data from before, during, and/or after that condition in the database. In some embodiments, the historical data in the database may be used to train a machine learning algorithm. The machine learning algorithm may then be used to develop a model used to analyze the data streams **204**, **206**, **208**, or the machine learning algorithm may analyze the data streams **204**, **206**, **208** itself to determine the underlying condition.

[0051] In some embodiments, the data received via the data streams **204**, **206**, **208** may be accompanied by metadata (e.g., tags) or have metadata embedded in the data that may identify one or more characteristics of the data (e.g., the type of data, the measured parameter, the source of the data, the location of the data, offset values, calibration data, etc.) that may provide some context for the data and/or help sort the data upon receipt. If data is added the database of historical data, tags may also be used include information about the conditions when the data was collected. In some embodiments, received data may not include tags, or may include tags that are incomplete or incorrect. In such an embodiment, at block **214**, new tags **216** may be generated and added to the data as though the tags **216** had been generated at the node. The new tags **216** may be added to data that was received without tags, may supplement incomplete tags that were received with the data, or may replace incorrect tags received with the data.

[0052] At block **218**, notifications **220** may be generated based on the analysis performed at block **212** and transmitted for review. In some embodiments, the notifications may include reports and/or visualizations as to the underlying condition of the system or systems in question, as determined during the analysis performed at block **212**. The notifications **220** may also include alerts or alarms configured to inform a user that one or more specific conditions are present. For example, a notification **220** may inform a user that a part of component is malfunctioning, at risk of failure, or has broken. In other embodiments, the notification **220** may inform a user that a pressure, temperature, flow rate, etc. is too low or too high, etc.

[0053] At decision block **222**, the server determines whether or not to suggest an action. In most cases, analysis performed at block **212** will determine that the system or systems are performing as expected and that no action is recommended. In such a case, the server may return to block **202** and cleanse new data received from the data streams **204**, **206**, **208**. However, in some cases, the analysis performed at block **212** may determine that the underlying system or systems are not running according to some threshold (e.g., output efficiency, power efficiency) and that some adjustment may improve operation. In such a case, server may apply the underlying condition determined during the analysis performed at block **212** to one or more decision tables in order to determine what action, if any, should be taken to improve operation. For example, the recommended action may include adjusting a valve, adjusting the speed of a rotating motor, adjusting a heater, adjusting a pump pressure etc.

[0054] In some embodiments, the server may be pre-approved to automatically take any recommended action, or to automatically take a recommended action from an approved list of actions. For example, in some embodiments, the server may be pre-approved to adjust the temperature of a heater, a pump pressure, a position of a valve, or a speed of a rotating motor within some pre-set range of

values. Accordingly, at block **224**, the server may automatically take the recommended action without requesting user approval. For example, the server may generate a control signal or a command adjusting one or more properties for one or more assets disposed at respective nodes. The server may then return to **202** and cleanse new data received from the data streams **204**, **206**, **208**.

[0055] However, certain actions may request user approval before implementing. In such embodiments, at block **226**, the server may recommend an action to be taken. For example, a notification recommending the action may be provided to a user via a graphical user interface of a computing device. The user may then acknowledge the recommendation and implement the recommended action or decline to implement the recommended action. In some embodiments, the server may execute the recommended action (block **224**) upon determining that approval for the recommended action has been received (block **228**). In some embodiments, the action may include sending a command or signal to an actuator or other component to adjust its operation (e.g., speed, temperature). In other embodiments, the user may take action to implement the recommended action. The server may then return to **202** and cleanse new data received from the data streams **204**, **206**, **208**.

[0056] FIG. **4** is a flow chart expanding the receive and cleanse data block (block **202**) into a sub-process **202**. At block **300**, the server performs a frozen data check for the data received from the data streams **204**, **206**, **208**. For example, the server may monitor data received via the data streams **204**, **206**, **208** and determine if a data field remains constant at a value for more than some threshold amount of time. For example, if a measured pressure or flow rate stays at the same value for more than 10 minutes, it may be indicative of a problem with the sensor. In other embodiments, the server may compare data of the same type pulled from multiple data streams **204**, **206**, **208**. If the data from one stream does not move as expected with the other data streams **204**, **206**, **208**, there may be a problem with the sensor, the asset, or the communication connection.

[0057] At block **302**, the server may transform the data received via the data streams **204**, **206**, **208** into a desired unit value. In some embodiments, raw data may be received from the data streams **204**, **206**, **208** as it is received from the sensor (e.g., as an analog voltage or a digital signal). For example, temperature data collected by a thermocouple may arrive via one of the data streams **204**, **206**, **208** as an analog voltage signal. The server may then convert that signal into a desired unit value (e.g., degrees Fahrenheit, Centigrade, or Kelvin). In other embodiments, the node **12** may perform some processing of the signal output by the sensor **14** before providing it via one of the data streams **204**, **206**, **208**. In such an embodiment, the server may convert the received data into a desired unit.

[0058] At block **304**, the server identifies the data type of data received via the data streams **204**, **206**, **208**. This may be referred to as type system analysis. As previously discussed, in some embodiments, the data received via the data streams **204**, **206**, **208** may include tags or other metadata that identify the type of data. If the data includes tags, the server may assume the data is of the type identified by the tags unless server has reason to believe the data is of a different type. In other embodiments, the server may analyze the values of the data, movement of the values over time, and other context to determine or infer the data type. Similarly, if the received data lacks tags, the server may analyze the values of the data, movement of the values over time, and other context to determine or infer the data type.

[0059] At block **306**, the server may determine whether the values of the received data are within an expected range. For example, ranges for various values may be set and stored that indicate expected values for various data types. It should be understood, however, that these ranges are not defined based on particular operating conditions of the underlying system or systems, but based on expected readings by the sensors **14**. That is, at this stage of the process **200**, the server is attempting to determine if there is a problem with the sensor **14** and not whether there is a problem with the underlying system or systems. Accordingly, the expected value ranges applied at block **306** may be much wider than the expected ranges when the system or systems are running for certain operations. For example, data may be received from a temperature sensor coupled to a component intended to heat a liquid to 95 degrees Centigrade. Though the range of measured temperature values during one operation may range from 90 to 95 degrees Centigrade, the expected range of values associated with the health of the sensor for block **306** may be much wider, for example −250 to 500 Centigrade.

[0060] At decision block **308**, the server may determine whether any notifications **220** are needed. If there is a problem with any of steps **300**, **302**, **304**, and **306**, the server may generate notifications **220** and transmit them to a user **310**. That is, if the server determines that there is some problem with data received from the data streams **204**, **206**, **208**, the server may generate a notification to let the user know of the problem before sending the data to one or more analysis engines for analysis. For example, if the server determines that the received data includes frozen data, the server is unable to transform the units of the data, the server is unable to identify the data type **304**, or the some of the values of the received data fall outside of expected sensor ranges, the server may alert the use to a possible problem with the received data.

[0061] At block **312**, the server determines the appropriate analysis engine or engines to which the received data should be sent. The appropriate analysis engine or engines may be determined based on data type, data source, time of collection, some other factor, or a combination thereof. As previously described, for a given system or systems, multiple analysis engines may be running in parallel to model different aspects of the system or systems. As such, in order to provide real time or near real time analysis, the analysis engines should only be provided with data that will be used to perform the analysis. Put another way, if all of the data received via the data streams **204**, **206**, **208** was provided to every analysis engine and each analysis engine was tasked with filtering out irrelevant data for the analysis the analysis engine is tasked with performing, for even somewhat complex systems, the analysis engines could become overloaded with data and unable to perform analysis in real time or near real time. The received data may then be separated and duplicated as needed and then transmitted to the appropriate analysis engine or engines (blocks **314**, **316**, **318**).

[0062] It should be understood that though various steps of data cleansing are shown in FIG. **4** in a particular order, the order of steps, such as blocks **300**, **302**, **304**, and **306** may be changed in some embodiments. Further, some embodiments of data cleansing may omit one or more of the blocks

shown, or may add one or more additional steps. Further, in some embodiments, one or more of the actions in blocks **300**, **302**, **304**, and **306** may be performed by the analysis engine rather than being performed before being provided to an analysis engine, as shown in FIG. **4**.

[0063] FIG. **5** is a flow chart of a process **340** that expands the identify data block **304** of FIG. **4** into a subprocess **304**. As shown, data is received (block **202**) from multiple data streams **204**, **206**, **208**. At block **342**, the server parses the data received from the various data streams **204**, **206**, **208** to group portions of data by type and identify the type of each portion of data. In some embodiments, the data streams **204**, **206**, **208** may include metadata that identifies the data type or some other characteristic that may be used as context to identify the data type (e.g., units, location where data was generated, source of the data, manufacturer, model, serial number of the asset that generated the data, protocol of transmission, etc.). In some embodiments, the server may be able to identify or infer the data type based on the values of the data and how the values change over time. For example, the server know based on the range of value received via a data stream and the rate of change in the values that the data likely corresponds to well pressure for an ESP well. In other embodiments, the server may compare data received via a data stream to data received via a different data stream of a known type or historical data of a known type to determine the type of data.

[0064] At block **344**, once the data types for the various data streams **204**, **206**, **208** are known, the server may compare data received from the various data streams **204**, **206**, **208** that is determined to be of the same data type. Comparing data of the same type received from different data streams **204**, **206**, **208** allows the server to quickly and easily identify one or more nodes in a system that are experiencing a different condition from the other nodes in the system. For example, if one artificial lift device of a collection of artificial lift devices has a surface card that does not match the surface cards of the other artificial lift devices pumping from the same reservoir, the server may recognize this discrepancy more quickly by performing stream-based processing based on type. In some embodiments, when data is compared, the server may synchronize the data such that data of the same type from different data streams **204**, **206**, **208** may be compared at the same time, or at approximately the same time. In instances in which some event occurs that causes data values to change, synchronizing data from different data streams **204**, **206**, **208** may be useful in gaining a more complete understanding of what is taking place before, during, and/or after the event. In some embodiments, synchronizing the data may be done using timestamps that accompany the data, metadata, or based on known sampling rates. In other embodiments, changes in values associated with events that appear in multiple data streams **204**, **206**, **208** may be used to synchronize the data.

[0065] Comparing data of the same type from various data streams **204**, **206**, **208** may include comparing differences to raw threshold numbers, threshold percentages, standard deviations, and so forth. The thresholds may be manually set by a person, set algorithmically based on historical data, set by a machine learning algorithm, etc. At decision block **346**, the server determines whether the difference in the data exceeds the threshold value or is outside of some acceptable range. If not, the server returns to block **202** and continues to receive data from the data streams **204**, **206**, **208**. If yes, the server proceeds to block **348** and generates a notification and/or determines a recommended action to be taken at one or more of the nodes to return the industrial system to a more desirable operating condition. In some embodiments, the server may proceed to modify operation of one or more of the assets disposed at one or more of the nodes. In other embodiments, the server may recommend an action for approval by a user. In a further embodiment, the notification may be provided to the user informing the user that the data may not be correct, that an action is recommended, or that operation should be stopped.

[0066] FIG. **6** is a flow chart of a process **360** for identifying drift and adjusting threshold values. Data is received (block **202**) from multiple data streams **204**, **206**, **208**. At block **342**, as previously described, the server parses data received from the various data streams **204**, **206**, **208** to group portions of data by type and identify the type of each portion of data. As previously described, identifying the type of a portion of data may include extracting and analyzing metadata, or using some other characteristic of the data as context to identify the data type (e.g., location where data was generated, source of the data, manufacturer, model, serial number of the asset that generated the data, etc.). If data type is not identified by metadata or other identifying characteristics, the server may be able to identify or infer the data type based on the values of the data and how the values change over time. In other embodiments, the server may compare data received via a data stream to data received via a different data stream of a known type or historical data of a known type to determine the type of data.

[0067] At block **344**, once the data types for the various data streams **204**, **206**, **208** are known, the server may compare data received from the various data streams **204**, **206**, **208** that is determined to be of the same data type. Comparing data of the same type from various data streams **204**, **206**, **208** may include comparing differences to raw threshold numbers, threshold percentages, standard deviations, and so forth. The thresholds may be manually set by a person, set algorithmically based on historical data, set by a machine learning algorithm, etc. At decision block **362**, the server determines of the data is drifting upward or downward, or if there are other notable data trends. In some embodiments, this determination may be made by comparing data from one or more data streams **204**, **206**, **208** to data from the other data streams **204**, **206**, **208** over time. In other embodiments, data from the data streams **204**, **206**, **208** may be compared to historical data (e.g., stored in a database) from the same or similar sources to identify drift or other trends. If drift or other trends are not present, the server returns to block **202** and receives data from the data streams **204**, **206**, **208**. If drift or other trends are present, the server may adjust the threshold values (block **364**) to account for the drift and/or data trends. In some embodiments, the server may run an analysis to confirm that the drift is not the result of a condition that should be addressed (e.g., a slow leak causing pressure to drift downward). If the drift is determined to not be indicative of a condition to be addressed, the server may model the drift over the sampled period and/or analyze historical data stored in a database to model the drift and determine where the new threshold values should be set. In some embodiments, fuzzy logic may be used in conjunction with one or more truth tables and one or more decision tables to determine the new threshold values. In other

embodiments, historical data stored in a database may be used (e.g., by a machine learning algorithm) to set the new threshold values.

[0068] Returning to FIG. **3**, in some embodiments, fuzzy logic may be used at block **212** in place of or in addition to quantitative data analysis. Fuzzy logic provides a nonanalytic alternative to traditional control theory. Specifically, based on a collection of states, an underlying condition may be determined. For example, rather than using one or more quantitative values (e.g., the temperature is 45 degrees Centigrade), a collection of states or qualitative observations (e.g., high/low, hot/cold, on/off, fast/slow, etc.) are used to determine an underlying condition. However, it should be understood that fuzzy logic may be used to analyze quantitative data received from sensors via the data streams **204**, **206**, **208**. Indeed, use of fuzzy logic to analyze data received from sensors via the data streams **204**, **206**, **208** may be significantly less computationally resource intensive such that using fuzzy logic may be more efficient than quantitative data analysis. For example, for each data point received via the data streams **204**, **206**, **208**, the value may be compared to a threshold value for that type of data to determine a state of each data point (e.g., high or low based whether the value is above or below the threshold value). The various states may then be plugged into one or more models and/or one or more truth tables to determine a degree of truth value for a plurality of different possible conditions, each indicating the likelihood that the condition is present.

[0069] For example, FIG. **7** is an embodiment of a first bar graph visualization **400** of degree of truth values for a number of conditions for an oil and gas well experiencing a problem. As previously described, sensor data may be collected from multiple sensors **14** disposed throughout the well. The sensor data may have been received in states or converted into states after being received. The states may then be input to one or more truth tables to determine degree of truth values to a range of possible conditions. As shown, the condition **402** with the highest degree of truth is "choke open" at a degree of truth value of 41.0. If the degree of truth value exceeds a set threshold, the analysis system may determine that the choke is likely open and consult a decision table to determine a recommended action. However, if the degree of truth value for each condition is below the set threshold, the analysis system may determine that the condition of the well cannot be determined at the time.

[0070] FIG. **8** is an embodiment of a second bar graph visualization **450** of degree of truth values for the number of conditions for the oil and gas well experiencing a different problem. As shown, the condition **452** with the highest degree of truth is "gas lock" at a degree of truth value of 69.0. If the degree of truth value exceeds a set threshold, as is likely the case here, the analysis system may determine that a gas lock has likely occurred and consult a decision table to determine a recommended action.

[0071] FIG. **9** is a flow chart of a process **500** for using fuzzy logic in a stream-based processing analysis system **10**. At block **504**, states are received by the server via the data streams **204**, **206**, **208**. As previously discussed, in some embodiments, quantitative data may be received via the data streams **204**, **206**, **208** and converted to states by comparing the quantitative data to one or more thresholds. At block **506**, the states of multiple nodes are provided as inputs to one or more models and/or one or more truth tables to determine a degree of truth value for each of a plurality of possible conditions indicating the likelihood that the condition is present. Each of the truth tables may correspond to a component, a collection of components, a subsystem, a system, etc. of the industrial environment. The server may use fuzzy logic to analyze data from multiple data sources to understand the underlying condition of the system. For example, if a first asset provides a data stream indicating that pressure is high and a second asset, downstream from the first asset, provides a data stream indicating that the pressure is low, the server may use fuzzy logic to determine that there is a leak between the first asset and the second asset. In some embodiments, one or more of the truth tables may be multi-factor truth tables. That is, the server may recognize that the conditions of multiple operationally related assets may correlate to one another. Accordingly, the server may understand the correlation and recommend actions at, or send commands to, multiple assets when certain conditions are fond to be present. Similarly, the server may use fuzzy logic, machine learning, or other disclosed techniques to understand how different variables at the same or related assets correlate with one another or are otherwise related to one another. At decision block **508**, the degree of truth values (e.g., probability that the condition is present) for each condition are compared to a threshold value. If none of the degree of truth values exceeds the threshold value, the server returns to block **504** and receives additional data from the data streams **204**, **206**, **208**. However, if one of the degree of truth values exceeds the threshold value, the server proceeds to block **510** and consults one or more decision tables to determine what, if anything, should be done to address the condition. Accordingly, fuzzy logic operations may be used on the data received via the data streams **204**, **206**, **208** to make truth determinations based on whether the data received from the data streams **204**, **206**, **208** confirms one or more truth models. Thus, a collection of states may be used to determine an underlying condition in an industrial environment. Each of the decision tables may correspond to one or more components within the system. Based on the one or more conditions input to one or more decision tables, the decision tables may help to identify what actions should be taken at respective assets to address the condition. In some embodiments, the server may generate a notification **512** to be transmitted (block **514**) to the user for review (e.g., via the computing device) to notify the user of the condition.

[0072] FIG. **10** is a flow chart of a process **550** for analyzing data from a downstream node by comparing it to a model based on data from an upstream node. At block **202**, data is received from an upstream node via the first data stream **204** and from a downstream node via the second data stream **206**. For simplicity, only two data streams are shown in FIG. **10**, however, it should be understood that the same techniques may be used with data streams from more than two nodes. At block **552**, data received from a first asset at a first node via the first data stream **204** is used to model a condition for a second asset disposed at a second node, downstream of the first node. The model may be based on raw measurements taken at the first node (e.g., temperature, pressure, flow rate, etc.), based on an underlying condition at the first node, based on a state of the first asset of the first node, etc. At block **554**, the server uses the model of the second asset disposed at the second node to generate a set of expected ranges that the server would expect to receive from the second asset disposed at the second node via the second data stream **206**. At decision block **556**, the server compares

the data received from the second data stream **206** to the expected ranges. If the data received from the second asset at the second node via the second data stream **206** is within the expected values, the server may return to block **202** and receive more data from the data streams **204**, **206**. However, if the data received from the second asset at the second node via the second data stream **206** is not within the expected ranges, the server may generate a notification or recommend an action to adjust operation of the first or second asset (block **558**) to bring data output by the second asset at the second node within the expected ranges. Though the instant embodiment includes assets disposed at upstream and downstream nodes, it should be understood that similar techniques may be used to use data from one or more nodes within an industrial environment to generate expected data ranges at one or more other nodes within the industrial environment and then compare measured data from those other nodes to the expected ranges as a way to analyze one or more assets operating within an industrial environment.

Example Implementations of Stream-Based Processing

[0073] As previously discussed, the stream-based processing analysis system **10** may be implemented with nodes **12** distributed horizontally and/or vertically at various locations throughout the hydrocarbon production chain. FIG. **11** is a schematic **600** illustrating various operations involved in hydrocarbon production. Box **602** represents oil and gas extraction. The extracted fluid is then separated into oil, gas, and water. The separated oil goes through an oil treatment and storage **604** process and then through a fiscal measurement process **612**. The gas goes through a gas treatment and compression process **606**. The water goes through a water treatment and disposal process **608**. In some embodiments, the water may be used for an enhanced oil recovery process **610**. For oil and gas applications, the nodes **12** of the stream-based processing analysis system **10** may be distributed horizontally along the hydrocarbon production chain, distributed vertically along some production process (e.g., the nodes include or are coupled to machines performing different steps of a process in series, or some combination thereof. In other embodiments, the nodes **12** may be part of different, but in some cases, related processes. For example, in one embodiment related to oil and gas extraction, the nodes **12** may be various wells extracting hydrocarbons from the same reservoir or deposit. In a second embodiment related to oil and case, the nodes **12** may correspond with steps along the process of extraction and processing (e.g., extraction, separation, transport, storage, decanting, refining, etc.

Hydrocarbon Production

[0074] FIG. **12** is a schematic illustrating how stream-based processing may be applied at a hydrocarbon site **700** of a hydrocarbon extraction system. The hydrocarbon site **700** may be an area in which hydrocarbons, such as crude oil and natural gas, may be extracted from the ground, processed, and stored. As such, the hydrocarbon site **700** may include a number of wells and a number of well devices that may control the flow of hydrocarbons being extracted from the wells. In one embodiment, the well devices at the hydrocarbon site **700** may include any device equipped to monitor and/or control production of hydrocarbons at a well site. As such, the well devices may include pumpjacks **702**, submersible pumps **704**, well trees **706**, and the like. After the hydrocarbons are extracted from the surface via the well devices, the extracted hydrocarbons may be distributed to other devices such as wellhead distribution manifolds **708**, separators **710**, storage tanks **712**, and the like. At the hydrocarbon site **700**, the pumpjacks **702**, submersible pumps **704**, well trees **706**, wellhead distribution manifolds **708**, separators **710**, and storage tanks **712** may be connected together via a network of pipelines **714**. As such, hydrocarbons extracted from a reservoir may be transported to various locations at the hydrocarbon site **700** via the network of pipelines **714**.

[0075] The pumpjack **702** may mechanically lift hydrocarbons (e.g., oil) out of a well when a bottom hole pressure of the well is not sufficient to extract the hydrocarbons to the surface. The submersible pump **704** may be an assembly that may be submerged in a hydrocarbon liquid that may be pumped. As such, the submersible pump **704** may include a hermetically sealed motor, such that liquids may not penetrate the seal into the motor. Further, the hermetically sealed motor may push hydrocarbons from underground areas or the reservoir to the surface.

[0076] The well trees **706** or Christmas trees may be an assembly of valves, spools, and fittings used for natural flowing wells. As such, the well trees **706** may be used for an oil well, gas well, water injection well, water disposal well, gas injection well, condensate well, and the like. The wellhead distribution manifolds **708** may collect the hydrocarbons that may have been extracted by the pumpjacks **702**, the submersible pumps **704**, and the well trees **706**, such that the collected hydrocarbons may be routed to various hydrocarbon processing or storage areas in the hydrocarbon site **700**.

[0077] The separator **710** may include a pressure vessel that may separate well fluids produced from oil and gas wells into separate gas and liquid components. For example, the separator **710** may separate hydrocarbons extracted by the pumpjacks **702**, the submersible pumps **704**, or the well trees **706** into oil components, gas components, and water components. After the hydrocarbons have been separated, each separated component may be stored in a particular storage tank **712**. The hydrocarbons stored in the storage tanks **712** may be transported via the pipelines **714** to transport vehicles, refineries, and the like.

[0078] The hydrocarbon site **700** may also include or be a part of the stream-based processing analysis system **10**. As previously discussed, the stream-based processing analysis system **10** may include a plurality of nodes **12** placed at various locations in the hydrocarbon site **700** to monitor or provide information related to certain aspects of the hydrocarbon site **700**. For example, each node **12** may include the RTU, or any computing device that may include communication abilities, processing abilities, and the like. For discussion purposes, the nodes **12** will be embodied as the RTUs **100**, or groups of RTUs **100** throughout the hydrocarbon site **700**. However, it should be understood that the node **12** may be any component capable of monitoring and/or controlling various components at the hydrocarbon site **700**.

[0079] As previously discussed, each RTU **100** may include sensors or may be coupled to various sensors that may monitor various properties associated with a component at the hydrocarbon site **700**. The RTU **100** may then analyze the various properties associated with the component and

may control various operational parameters of the component. For example, the RTU **100** may measure a pressure or a differential pressure of a well or a component (e.g., storage tank **712**) in the hydrocarbon site **700**. The RTU **100** may also measure a temperature of contents stored inside a component in the hydrocarbon site **700**, an amount of hydrocarbons being processed or extracted by components in the hydrocarbon site **700**, and the like. The RTU **100** may also measure a level or amount of hydrocarbons stored in a component, such as the storage tank **712**.

[0080] In one embodiment, the RTU **100** may include a sensor that may measure pressure, temperature, fill level, flow rates, and the like. The RTU **100** may also include a transmitter, such as a radio wave transmitter, that may transmit data acquired by the sensor via an antenna or the like. The sensor in the RTU **100** may be wireless sensors that may be capable of receive and sending data signals between RTUs **100**. The RTU **100** may transmit data acquired by the sensor or data processed by a processor to other monitoring systems, a router device, a supervisory control and data acquisition (SCADA) device, or the like. As such, the RTU **100** may enable users to monitor various properties of various components in the hydrocarbon site **700** without being physically located near the corresponding components.

[0081] In operation, the RTU **100** may receive real-time or near real-time data associated with a well device. The data may include, for example, tubing head pressure, tubing head temperature, case head pressure, flowline pressure, wellhead pressure, wellhead temperature, and the like. In any case, the RTU **100** may analyze the real-time data with respect to static data that may be stored in a memory of the RTU **100**. The static data may include a well depth, a tubing length, a tubing size, a choke size, a reservoir pressure, a bottom hole temperature, well test data, fluid properties of the hydrocarbons being extracted, and the like. The RTU **100** may also analyze the real-time data with respect to other data acquired by various types of instruments (e.g., water cut meter, multiphase meter) to determine an inflow performance relationship (IPR) curve, a desired operating point for the wellhead, key performance indicators (KPIs) associated with the wellhead, wellhead performance summary reports, and the like. Although the RTU **100** may be capable of performing the above-referenced analyses, the RTU **100** may not be capable of performing the analyses in a timely manner. Moreover, by just relying on the processor capabilities of the RTU **100**, the RTU **100** is limited in the amount and types of analyses that it may perform. Moreover, since the RTU **100** may be limited in size, the data storage abilities may also be limited.

[0082] Keeping the foregoing in mind, in certain embodiments, the RTU **100** may establish a communication link with the stream-based processing analysis system **10** described above. As such, the stream-based processing analysis system **10** may use its larger processing capabilities to analyze data acquired by multiple RTUs **100** in real time or near real time to determine a condition at the hydrocarbon site **700** based on data collected from the various RTUs **100** or nodes **12**. Moreover, the stream-based processing analysis system may access historical data associated with the respective RTU **100**, data associated with well devices associated with the respective RTU **100**, data associated with the hydrocarbon site **700** associated with the respective RTU **100** and the like to further analyze the data acquired by the multiple RTUs **100** and determine a condition at the hydrocarbon site **700** based on the collected data.

[0083] For example, in one embodiment, a plurality of RTUs **100** may collect data from multiple submersible pump wells **704** extracting hydrocarbons from the same reservoir and provide streams of data to the stream-based processing analysis system **10**. The stream-based processing analysis system **10** may examine a plurality of parameters (e.g., 5-8 parameters) for each well and determine that one or more of the wells is experiencing a problem. For example, the server **22** may receive similar stream-based operational data from all but one submersible pump well **704**. Since each of the stream-based datasets from the submersible pump wells **704** are related to the same reservoir, the server **22** may determine that the single submersible pump well **704** is experiencing a problem due to the fact that the other similar type of submersible pump wells **704** operating in the same reservoir do not have data that matches the single submersible pump well **704**. In some embodiments, the analysis for identifying the problem may also include, for example, applying a model, performing fuzzy logic, etc. to determine a condition of the wells, and in some cases, a degree of confidence in that condition. After identifying the problem or the problematic dataset, the server **22** may then consult one or more decision tables to determine a recommended action. The decision table may be prepopulated with certain actions for various circumstances. However, it should be noted that the server **22** may also employ artificial intelligence modules or schemes to determine an action to perform to address the identified problem. For example, the server **22** may analyze the other streaming data received from components within a proximity of the one submersible pump well **704**. The server **22** may then determine whether the streaming data acquired by adjacent components of the one submersible pump well **704** matches expected values or matches the values received from adjacent components of the other submersible pump wells **704**. If the values of the adjacent component does not match an expected value, the server **22** may determine that a problem may exist in the one submersible pump well **704** that may involve a technician to repair. As such, the server **22** may send a command to the one submersible pump well **704** to shut down or stop operations. If the decision tables result in multiple possible recommended actions, the stream-based processing analysis system **10** may perform some additional analysis (e.g., risk/reward, calculating cost, probability of success, etc.) to determine a preferred action.

[0084] In another oil and gas example, multiple wells (e.g., submersible pump wells **704**) may provide fluid to a single separator **710**. The separator may be outfitted with an RTU **100** that acts as a node **12** and includes a water cut sensor to determine the ratio of water in the fluid. Each of the wells **704** may also include an RTU **100** that acts as a node **12**, however, each of the wells may not be outfitted with a water cut sensor in order to reduce costs. The stream-based processing analysis system **10** may collect data from the various nodes **12** and/or wells **704**. The stream-based processing analysis system **10** may recognize that the incoming data is of the same type and compare data from each of multiple data streams to determine that the ratio of water in the fluid being provided to the separator **710** by the wells **704** has a higher ratio of water than desired. This determination may be made, for example, by using the received data to update a model, using fuzzy logic to

determine a state for each of the incoming data streams and infer an underlying condition based on the collection of states, by directly comparing the data from multiple data streams, etc. The stream-based processing analysis system **10** may then determine based on the other measured values (pressures, flow rates, etc.) which of the wells **704** is responsible to the high ratio of water. The condition or conditions may then act as inputs for one or more decision tables, a machine learning algorithm, a script, etc. to determine an action to bring the water cut back into a desirable range. For example, the stream-based processing analysis system **10** may choke down or shut down the well in question to bring the water cut back to the desired range.

[0085] In a third embodiment, the well tress **706** may be used for gas injection wells and outfitted with RTUs **100** that act as a nodes **12**. The stream-based processing analysis system **10** may determine based on data collected from the various nodes that back pressure is building up in one or more of the wells. For example, data of the same type from the various nodes may be compared to identify outlier nodes. In some embodiments, once an outlier node has been identified, one or more models, one or more truth tables, machine learning algorithms, fuzzy logic algorithms, scripts, or some combination thereof, may be used to perform additional analysis to determine why backpressure is building and then determine what action should be taken to relieve the back pressure (e.g., via one or more decision tables, machine learning, a historical database, etc.). In other embodiments, data collected from the RTUs **100** may be used to model the underlying condition. In some cases, data from each of the RTUs may be compared to the model to determine if data from any of the RTUs **100** deviate from the expected values. The stream-based processing analysis system **10** may then determine what, if anything should be done to bring the asset associated with the RTU **100** back into a more desirable operating condition. For example, the stream-based processing analysis system **10** may then use data collected at the nodes to determine what actions should be taken to relieve the backpressure. Further, the stream-based processing analysis system **10** may then flag data leading up to the back pressure build up, combine the data with data from other instances of backpressure build up, and use machine learning to identify the conditions correlated with the back pressure buildup such that future instances of back pressure build up can be caught earlier or avoided all together.

Chemical Processing

[0086] Though FIGS. **10** and **11** describe specific applications of the stream-based processing analysis system to various aspects of oil and gas production, it should be understood that the application of the stream-based processing analysis system is not limited to oil and gas production. For example, FIG. **13** is a schematic of a chemical process **800** that may utilize the stream-based processing analysis system. Step **1**A **802** has a single input and Step **1**B **804** has two inputs and a single output. The outputs of Step **1**A **802** and Step **1**B **804** are combined in Step **2 806**, which has a single output. Step **3 808** has a single input and two outputs. One of the outputs is directed to a disposal **810** and the other output is directed to Step **4 812**, which has a single input and a single output. As shown, the sensors **14** may be disposed throughout the process to measure various parameters (e.g., pressure, temperature, flow rate, etc.) during the process. The sensors **14** may then provide data to the stream-based processing analysis system for analysis. In some embodiments, each sensor **14** may be considered a node. In other embodiments, two or more of the sensors **14** may be grouped to form a node. The stream-based processing analysis system **10** may analyze data collected from the various nodes in real time or near real time and determine what, if anything should be done to improve the process **800**. In some embodiments, sensor data of the same type from different nodes may be compared to determine when data from a node is outside of an expected range. In other embodiments, data from a cluster of nodes may be compared to determine if any outlier nodes are experiencing a condition that should be addressed. In further embodiments, data from upstream nodes may be used to model a condition at one or more downstream nodes. The data provided by the one or more downstream nodes may then be compared to the expected values produced by the model to evaluate if the asset associated with the downstream node is operating as desired. For example, the stream-based processing analysis system may determine that a flow rate between Step **3 808** and Step **4 812** is less than desired, determine that opening a valve that controls the one of the inputs to Step **1**B **804** is likely to solve the problem, and then either automatically take that action or recommend that a user take that action.

Food and Beverage Processing

[0087] Additionally, the stream-based processing analysis system may be used in the food and beverage industry (e.g., with a food and/or beverage processing system). For example, FIG. **14** illustrates an example industrial automation system **900** utilizing stream-based processing employed by a food manufacturer. The example industrial automation system **900** for a food manufacturer may include silos **902** and tanks **904**. The silos **902** and the tanks **904** may store different types of raw material, such as grains, salt, yeast, sweeteners, flavoring agents, coloring agents, vitamins, minerals, and preservatives. In some embodiments, sensors **14** may be positioned within or around the silos **902**, the tanks **904**, or other suitable locations within the industrial automation system **900** to measure certain properties, such as temperature, mass, volume, pressure, humidity, and the like.

[0088] The raw materials may be provided to a mixer **906**, which may mix the raw materials together according to a specified ratio. The mixer **906** and other machines in the industrial automation system **900** may employ certain industrial automation devices **908** to control the operations of the mixer **906** and other machines. The industrial automation devices **908** may include controllers, input/output (I/O) modules, motor control centers, motors, human machine interfaces (HMIs), operator interfaces, contactors, starters, sensors **14**, actuators, conveyors, drives, relays, protection devices, switchgear, compressors, sensor, actuator, firewall, network switches (e.g., Ethernet switches, modular-managed, fixed-managed, service-router, industrial, unmanaged, etc.) and the like.

[0089] The mixer **906** may provide a mixed compound to a depositor **910**, which may deposit a certain amount of the mixed compound onto conveyor **912**. The depositor **910** may deposit the mixed compound on the conveyor **912** according to a shape and amount that may be specified to a control system for the depositor **910**. The conveyor **912** may be any suitable conveyor system that transports items to various types of machinery across the industrial automation system **900**. For example, the conveyor **912** may transport

deposited material from the depositor **910** to an oven **914**, which may bake the deposited material. The baked material may be transported to a cooling tunnel **916** to cool the baked material, such that the cooled material may be transported to a tray loader **918** via the conveyor **912**. The tray loader **918** may include machinery that receives a certain amount of the cooled material for packaging. By way of example, the tray loader **918** may receive 25 ounces of the cooled material, which may correspond to an amount of cereal provided in a cereal box.

[0090] A tray wrapper **920** may receive a collected amount of cooled material from the tray loader **918** into a bag, which may be sealed. The tray wrapper **920** may receive the collected amount of cooled material in a bag and seal the bag using appropriate machinery. The conveyor **912** may transport the bagged material to case packer **922**, which may package the bagged material into a box. The boxes may be transported to a palletizer **924**, which may stack a certain number of boxes on a pallet that may be lifted using a forklift or the like. The stacked boxes may then be transported to a shrink wrapper **926**, which may wrap the stacked boxes with shrink-wrap to keep the stacked boxes together while on the pallet. The shrink-wrapped boxes may then be transported to storage or the like via a forklift or other suitable transport vehicle.

[0091] To perform the operations of each of the devices in the example industrial automation system **900**, the industrial automation devices **908** may be used to provide power to the machinery used to perform certain tasks, provide protection to the machinery from electrical surges, prevent injuries from occurring with human operators in the industrial automation system **900**, monitor the operations of the respective device, communicate data regarding the respective device to a supervisory control system **928**, and the like. In some embodiments, each industrial automation device **908** or a group of industrial automation devices **908** may be controlled using a local control system **930**. The local control system **932** may include receive data regarding the operation of the respective industrial automation device **908**, other industrial automation devices **908**, user inputs, and other suitable inputs to and use stream-base processing to control the operations of the respective industrial automation device (s) **908**.

[0092] The stream-based processing analysis system **10** may analyze data collected from the various nodes in real time or near real time and determine what, if anything should be done to improve the industrial automation system **900**. In some embodiments, sensor data of the same type from different nodes may be compared to determine when data from a node is outside of an expected range. In other embodiments, data from a cluster of nodes may be compared to determine if any outlier nodes are experiencing a condition that should be addressed. In further embodiments, data from upstream nodes may be used to model a condition at one or more downstream nodes. The data provided by the one or more downstream nodes may then be compared to the expected values produced by the model to evaluate if the asset associated with the downstream node is operating as desired. In some embodiments, the analysis for identifying the problem may also include, for example, applying a model, performing fuzzy logic, etc. to determine a condition of the one or more assets within the industrial automation system **900**, and in some cases, a degree of confidence in that condition. After identifying the problem or the problematic dataset, the server may consult one or more decision tables to determine a recommended action. The decision table may be prepopulated with certain actions for various circumstances. However, the server may also employ artificial intelligence techniques to determine an action to perform to address the identified problem. For example, the server may analyze the other streaming data received from components within a proximity of an asset of the industrial automation system **900**. The server may then determine whether the streaming data acquired by adjacent components of the asset matches expected values or matches the values received from adjacent components. If the values of the adjacent component does not match an expected value, the server may determine that a problem may exist in the asset that may involve a technician to repair. As such, the server may send a command to the asset or the larger industrial automation system **900** to shut down or stop operations.

Mining

[0093] As with previously discussed embodiments in which stream-based processing is used to monitor and control multiple wells extracting hydrocarbons from a single reservoir, embodiments are also envisaged for monitoring and controlling multiple mining assemblies mining a single formation. For example, returning to FIG. **1**, in one embodiment, a plurality of nodes **12** may collect data from multiple mining assemblies extracting materials from the same formation. The stream-based processing analysis system **10** may examine one or more parameter for each node **12** and determine that one or more of the nodes **12** is experiencing a problem. For example, the server **22** may receive similar stream-based operational data from all but one node **12**. Since each of the stream-based datasets from the nodes **12** are related to the same formation, the server **22** may determine that the single mining assembly is experiencing a problem due to the fact that the other mining assemblies operating on the same formation do not have data that matches the single mining assembly. In some embodiments, the analysis for identifying the problem may also include, for example, applying a model, performing fuzzy logic, etc. to determine a condition of the mining assemblies, and in some cases, a degree of confidence in that condition. After identifying the problem or the problematic dataset, the server **22** may then consult one or more decision tables to determine a recommended action. The decision table may be prepopulated with certain actions for various circumstances. However, it should be noted that the server **22** may also employ artificial intelligence modules or schemes to determine an action to perform to address the identified problem. For example, the server **22** may analyze the other streaming data received from components within a proximity of the one mining assembly. The server **22** may then determine whether the streaming data acquired by adjacent components of the one mining assembly matches expected values or matches the values received from adjacent components of the other mining assemblies. If the values of the adjacent mining assembly does not match an expected value, the server **22** may determine that a problem may exist in the one mining assembly that may involve a technician to repair. As such, the server **22** may send a command to the one mining assembly to shut down or stop operations. If the decision tables result in multiple possible recommended actions, the stream-based processing analysis system **10** may perform

some additional analysis (e.g., risk/reward, calculating cost, probability of success, etc.) to determine a preferred action.

[0094] The disclosed techniques include receiving streams of data from multiple nodes within the network, using the data received via the data streams to model one or more underlying conditions in real time or near real time (e.g., within seconds or minutes), and then determine what, if anything, should be done to control one or more of the assets within the network to make the industrial process run more efficiently. The analysis may include, for example, using one or more analysis engines to maintain one or more models (e.g., state based models) of various aspects of the industrial process, run scripts or routines on the received data, performing queries based on the data, updating an analysis function, applying fuzzy logic, consulting one or more truth tables, and so forth to analyze the received data in real time or near real time. In some embodiments, the received data may be cleansed or preprocessed to check for frozen data, transform units, identify data types, provide relevant data to the appropriate analysis engines, etc. Based on the underlying condition, decision tables may be referenced to determine what, if any, action to recommend. In some embodiments, the recommended action may be automatically taken. In other embodiments, the recommended action may be recommended to a user for approval before the action is taken. In further embodiments, the recommended may be recommended for the user to complete on her or her own. Accordingly, the disclosed techniques provide real time or near real time feedback for one or more assets within a multi-node network based on a holistic model of the network generated using streams of data provided by multiple nodes.

[0095] While only certain features of the present disclosure have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the embodiments described herein.

1. A system, comprising:

a first asset disposed at a first location in an industrial system configured to perform one or more operations;

a second asset disposed at a second location in the industrial system; and

a server device communicatively coupled to the first asset and the second asset, wherein the server device is configured to:

receive a first set of stream-based data from the first asset;

receive a second set of stream-based data from the second asset;

identify a first portion of the first set of stream-based data and a second portion of the second set of stream-based data, wherein the first portion and the second portion comprises a same type of data;

determine whether the first portion of the first set of stream-based data corresponds to an expected range of values based on the second portion of the second set of stream-based data; and

send a command to the first asset to adjust a first set of operations in response to the first portion of the first set of stream-based data not being within the expected range of values.

2. The system if claim **1**, wherein the first portion and the second portion are associated with a type of device coupled to a common hydrocarbon deposit.

3. The system if claim **2**, wherein the type of device comprises a separator device, an electric submersible pump, a valve, or a remote terminal unit.

4. The system of claim **2**, wherein the type of device is determined based on a manufacturer of the first asset and the second asset.

5. The system if claim **1**, wherein the server device is configured to:

monitor a first alarm limit drift with respect to the first portion of the first set of stream-based data; and

adjust a second alarm limit for the second portion of the second set of data based on the first alarm drift.

6. The system if claim **1**, wherein the industrial system comprises a chemical processing system, a food and beverage processing system, a hydrocarbon extraction system, or a mining system.

7. The system if claim **1**, wherein the server device is configured to:

receive sensor data representative of the one or more operations;

determine a state of the industrial system by applying a fuzzy logic algorithm comprising a relationship between the first portion, the second portion, and the sensor data; and

send an additional command to the first asset or the second asset based on the state.

8. The system of claim **1**, wherein the server device is configured to determine a state associated with the first asset based on fuzzy logic, a first plurality of datasets from the first set of stream-based data, and a second plurality of datasets from the second set of stream-based data.

9. The system of claim **1**, wherein the server device is configured to:

recognize that the first portion of the first set of stream-based data does not include metadata;

determine a data type of the first portion;

generate new metadata for the first portion; and

add the new metadata to the first portion.

10. The system of claim **1**, wherein the server device is configured to:

determine a first state of the first portion;

determine a second state of the second portion;

determine a degree of truth value for each of a plurality of conditions by applying the first state and the second state to one or more fuzzy logic truth tables; and

determine whether each of the degree of truth values for each of the plurality of conditions exceeds a respective condition threshold value.

11. The system of claim **10**, wherein the server device is configured to:

determine that a first condition of the plurality of conditions is correlated with a second condition of the plurality of conditions; and

send a second command to the second asset to adjust a second set of operations.

12. The system of claim **10**, comprising utilizing the one or more fuzzy logic truth tables to recognize drift in the first set of stream-based data or the second set of stream-based data and adjusting a first alarm limit for the first portion of the first set of data or a second alarm limit for the second portion of the second set of data based on the drift.

13. A system, comprising:
a first asset disposed at an industrial automation system;
a second asset disposed at the industrial automation system; and
a server communicatively coupled to the first asset and the second asset, wherein the server is configured to:
receive a first set of stream-based data from the first asset;
generate a model for the second asset based on the first set of stream-based data, wherein the model is configured to output an expected set of stream-based data associated with the second asset;
receive a second set of stream-based data from the second asset; and
send a command to the first asset or the second asset in response to the second set of stream-based data being outside of a threshold from the expected set of stream-based data.

14. The system if claim **13**, wherein the industrial automation system comprises a chemical processing system, a food and beverage processing system, a hydrocarbon extraction system, or a mining system.

15. The system of claim **13**, wherein the server is configured to:
monitor a first alarm limit drift with respect to a first portion of the first set of stream-based data; and
adjust a second alarm limit for a second portion of the second set of data based on the first alarm drift.

16. A method, comprising:
receiving a first set of stream-based data from a first asset disposed at a first location in an industrial system configured to perform one or more operations;
receiving a second set of stream-based data from a second asset disposed at a second location in the industrial system;
identifying a first portion of the first set of stream-based data and a second portion of the second set of stream-based data, wherein the first portion and the second portion comprises a same type of data;
determining whether the first portion of the first set of stream-based data corresponds to an expected range of values based on the second portion of the second set of stream-based data; and
sending a command to the first asset to adjust a first set of operations in response to the first portion of the first set of stream-based data not being within the expected range of values.

17. The method of claim **16**, comprising:
monitoring a first alarm limit drift with respect to the first portion of the first set of stream-based data; and
adjusting a second alarm limit for the second portion of the second set of data based on the first alarm drift.

18. The method of claim **16**, comprising:
receiving sensor data representative of the one or more operations;
determining a state of the industrial system by applying a fuzzy logic algorithm comprising a relationship between the first portion, the second portion, and the sensor data; and
sending an additional command to the first asset or the second asset based on the state.

19. The method of claim **16**, comprising
recognizing that the first portion of the first set of stream-based data does not include metadata;
determining a data type of the first portion;
generating new metadata for the first portion; and
adding the new metadata to the first portion.

20. The method of claim **16**, comprising:
determining a first state of the first portion;
determining a second state of the second portion;
determining a degree of truth value for each of a plurality of conditions by applying the first state and the second state to one or more fuzzy logic truth tables; and
determining whether each of the degree of truth values for each of the plurality of conditions exceeds a respective condition threshold value.

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