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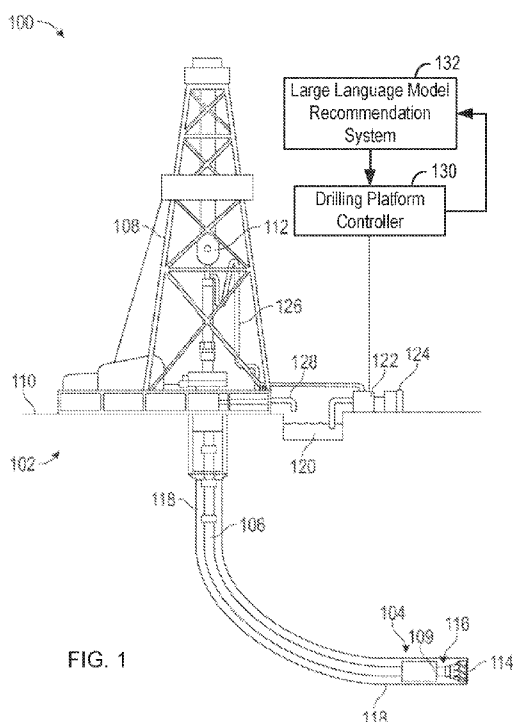
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(54) Title: METHOD OF GENERATING PROMPTS FOR AN INDUSTRY-SPECIFIC LARGE LANGUAGE MODEL RECOMMENDATION SYSTEM



(57) Abstract: A system and method for modifying operation of a drilling platform controller. A prompt generator receives drilling operations data relevant to drilling platform controller operation, wherein the drilling operations data includes current drilling parameters of a selected drilling platform controller. The prompt generator generates a prompt for recommended changes in operation of the selected drilling platform controller and applies the prompt to a large language model (LLM) trained with drilling operations domain knowledge. The LLM generates a recommendation for one or more changes in operation of the selected drilling platform controller. Feedback on efficacy of the recommendation is received from the selected drilling platform controller and is used to modify operation of the prompt generator.

FIG. 1

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METHOD OF GENERATING PROMPTS FOR AN INDUSTRY-SPECIFIC LARGE LANGUAGE MODEL RECOMMENDATION SYSTEM

BACKGROUND

[0001] As part of hydrocarbon recovery operations, a wellbore can be formed in a subterranean formation for extracting produced hydrocarbon material or other suitable material. The wellbore may experience or otherwise encounter one or more wellbore operations such as drilling the wellbore. Drilling, or otherwise forming, the wellbore can involve using a drilling system that can include a drill bit and other suitable tools or components for forming the wellbore. During drilling, the drilling system may change the course (e.g., speed, direction, etc.) of the drill bit to form a wellbore that may not be purely vertical. In some example approaches a drilling platform controller directs the drilling process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Embodiments of the disclosure may be better understood by referencing the accompanying drawings.

[0003] FIG. 1 is an elevation view in partial cross section of an example well system that supports directional drilling, according to aspects of the present disclosure.

[0004] FIG. 2 is a block diagram illustrating an example large language model (LLM) recommendation system.

[0005] FIG. 3 is a block diagram illustrating a data aggregation system which may be used with the example LLM recommendation system of FIG. 2.

[0006] FIG. 4 is a block diagram illustrating an example system for querying the example LLM recommendation system of FIG. 2.

[0007] FIG. 5 is a block diagram illustrating an example autonomous drilling controller which may be used with the example LLM recommendation system of FIG. 2.

[0008] FIG. 6 illustrates an example prompt format example which may be used with the LLM recommendation systems of FIGS. 2, 4 and 5.

[0009] FIG. 7 is a flowchart illustrating a method of applying the LLM recommendation systems of any of FIGS. 2, 4 and 5.

[0010] FIG. 8 is a flowchart illustrating a method of guiding a platform drilling controller with the LLM recommendation systems of any of FIGS. 2, 4 and 5.

[0011] Like reference numbers and designations in the various drawings indicate like elements.

DETAILED DESCRIPTION

[0012] The description that follows includes example systems, methods, techniques, and program flows that embody embodiments of the disclosure. Unless otherwise specified, use of the terms "connect," "engage," "couple," "attach," or any other like term describing an interaction between elements is not meant to limit the interaction to a direct interaction between the elements and may also include an indirect interaction between the elements described. Unless otherwise specified, use of the terms "up," "upper," "upward," "uphole," "upstream," or other like terms shall be construed as generally away from the bottom, terminal end of a well; likewise, use of the terms "down," "lower," "downward," "downhole," or other like terms shall be construed as generally toward the bottom, terminal end of the well, regardless of the wellbore orientation. Use of any one or more of the foregoing terms shall not be construed as denoting positions along a perfectly vertical axis. In some instances, a part near the end of the well can be horizontal or even slightly directed upwards. Unless otherwise specified, use of the term "subterranean formation" shall be construed as encompassing both areas below exposed earth and areas below earth covered by water such as ocean or fresh water.

[0013] As noted above, drilling operations may introduce a change in the operation (e.g., speed, direction, etc.) of the drill bit to change the trajectory of the drill string, forming a wellbore that may not be purely vertical. Doglegs, sections of a borehole where the trajectory changes rapidly, are an integral part of drilling. Thoughtfully planned and drilled, doglegs are part of an optimized borehole, avoiding problematic formations and maintaining the right drilling angle to reach a desired zone. Many factors, however, influence whether the dog leg location and curvature are appropriate or undesirable.

[0014] Operating parameters such as weight on bit (WOB), rotations per minute (RPM) of the bit, and flowrate may be adjusted in real time to steer a drill string. For example, the operating parameters may be adjusted to increase or decrease the dogleg capability of the drill string. At the same time, however, operating parameters (such as WOB, RPM, and flowrate) may be adjusted to maximize the rate of drilling, to manage a safe operating envelope and for telemetry and data transmission.

[0015] The mechanism by which parameters such as WOB, RPM, and flowrate individually impact the steering action is not understood. In addition, there is no comprehensive physics-based model that relates the influence of these controllable drilling parameters to dogleg severity (DLS). Instead, current practice often relies on the intuition and experience of the directional drillers to drive the change in these parameters for steering direction and efficiency. It can be very helpful to look at similar drilling operations when planning a new well and when addressing problems that arise in drilling the new well.

[0016] Certain aspects and features of the present disclosure relate to a bottom hole assembly (BHA) having a steering mechanism connected to a drill bit through a tool string, the drill bit for drilling into a subterranean formation to form a wellbore for extracting produced hydrocarbons. The steering mechanism may include a rotary steering system (RSS) including a steering collar and one or more pad actuators. In some examples, the steering collar may be a frame of the tool string, stiffening the tool string. In some examples, the pad actuators may be mounted on the steering collar to exert force on the side of a wellbore to change the direction of drilling while forming the wellbore.

[0017] Drilling companies accumulate information every time they drill a well. The information is recorded, for example, as a drilling report for each well, or is stored as data in a relational database. The data may include information from the drilling report or may be limited to copies or other representations of the drilling report. Older drilling reports may be limited to paper copies stored in a filing cabinet. It can, therefore, be difficult to access the accumulated information from drilling operations and to leverage the accumulated information to aid in making decisions while drilling new wells.

[0018] For automated drilling, the drilling controller may require the ability to identify the status and performance level of drilling, detect abnormalities, if any, to analyze contributing factors to

the abnormalities detected and to offer suggestions and decisions accordingly. A powerful and scalable large language model gathers domain knowledge as well as past drilling records. In some example approaches, the knowledge base is both human and machine readable, and, in some such example approaches, the knowledge base includes logic reasoning (i.e., can derive unknown information from known information via the logics).

[0019] Large Language Models (LLMs) can be effective tools for summarization of oil and gas records, but only when provided with a well-designed prompt. To date, the use of LLMs to help summarize oil and gas reports has had limited success due to the inability to create effective prompts from industry-specific source data. In the case of oil and gas operations, daily reports and documents created during well construction operations contain massive amounts of data in a variety of complex formats. These reports contain, for instance, key-value pairs, free-form text, images, and long form text fields. In addition, most reports are organized in unique formats making it difficult to quickly identify the information needed. Furthermore, consumers of daily reports would like feedback and recommendations from these reports rather than pure summary. LLMs can leverage existing data to provide recommendations from which may be used to improve ongoing operations.

[0020] A method of informing decision making by operators and automated controllers while planning and executing drilling operations is described below. In one example approach, the method receives data continuously or at short intervals from real-time telemetry sources and from summarized reports (e.g., daily drilling reports) to create industry specific LLM prompts formatted to improve LLM responses. Prompts are instructions that show an LLM in an LLM recommendation system exactly what the LLM recommendation system wants to accomplish. Prompts may include instructions, questions, examples, and contextual data, depending on the design of the large language model. In some cases, prompts may even include images.

[0021] In one example approach, the method enables users to score LLM summarizations and recommendations to provide feedback to the prompt generator. The feedback is then incorporated in the automated prompt generation process, enabling continuous improvement. Leveraging oil and gas jargon and industry specific formats ensures this process generates better prompts for standard LLMs.

[0022] In one example approach, the method applies prompt engineering and prompt feedback analysis to tune the prompt based on the information recorded from, for example, general drilling information and previous and current drilling operations. An LLM recommendation system is also described that operates in a feedback loop with operators, domain experts and autonomous drilling controllers to elevate the autonomous level of the drilling and to provide useful suggestions to the drillers to achieve better drilling performance and efficiency.

[0023] An autonomous drilling controller may, for instance, identify the status and performance level of the drilling and may detect abnormalities, if any. An LLM recommendation system may then analyze the contributing factors to the abnormality and make suggestions and decisions to address the abnormality accordingly. In one example approach, the LLM recommendation system may make such suggestions and decisions based on data received from a data aggregator.

[0024] In one example approach, past drilling records are stored in both human and machine-readable form. In one such example approach, the LLM recommendation system has an application programming interface (API) for machines, and a natural language interface for humans. The LLM recommendation system suggests optimal or near optimal operations and may respond to queries from both autonomous drilling controllers and site engineers and drillers.

[0025] In one example approach, the LLM recommendation system analyzes the current drilling operation and suggests changes to the current drilling operation. Outputs may include data sets to be ingested by the LLM, prompts that appropriately categorize the data sets, recommendations for next actions to adjust drilling operation for improved performance, and a ranking system for recommendations. In some such example approaches, the LLM recommendation system relies on logics reasoning to derive unknown information from known knowledge.

[0026] In one example approach, the LLM recommendation system operates with the drilling platform controller in near real time. Abnormalities such as drilling inefficiency may be spotted and responded to early in the drilling process. This helps with making more consistent, reliable and "data-supported" decisions. In one example approach, recommendations may lead directly to actions by a drilling platform controller once a certain model confidence threshold level is reached.

[0027] The same applies to autonomous drilling. By comparing the current drilling data with past drilling records and with other domain knowledge, the LLM recommendation system may detect

events such as vibrations or formation changes based on information received from the autonomous drilling controller and may advise the autonomous drilling controller to respond appropriately. In some example approaches, an autonomous drilling controller operates in a closed loop with sensors in a bottom hole assembly to determine and react to current drilling parameters.

[0028] The systems and methods described below may improve performance of drilling operations by using real-time data to identify more relevant variables needed to improve summarization prompts and may collect and process reports and real-time data to identify and extract critical information. The system and methods may also continuously collect and summarize live data to be used for the next prompt submission and may use user feedback to judge and record LLM summarization performance, and to retrain the LLM. The systems and method may further provide oil and gas industry specific prompt engineering by leveraging key variables and by placing the variables into an LLM prompt format that may be used to return useful responses.

[0029] The above approaches, therefore, elevate both drill operator decision making and autonomous drilling to a higher level, which makes drilling more cost-effective and at the same safer and the performance better and more consistent. The insights captured by the knowledge base, since it is both human and machine readable, can be used for further analysis or training. This scalable method for reviewing information increases productivity, reducing the number of people needed for well construction and reducing operational risk. What is described may be used to implement more automation on the jobsite, from simple routing control setpoint automation, to jobsite coordination and, even, material ordering automation.

[0030] This disclosure includes illustrative examples used to introduce the reader to the general subject matter discussed herein; the examples are not intended to limit the scope of the disclosed concepts. The following sections describe various additional features and examples with reference to the drawings in which like numerals indicate like elements, and directional descriptions are used to describe the illustrative aspects, but, like the illustrative aspects, should not be used to limit the present disclosure.

[0031] FIG. 1 is an elevation view in partial cross section of an example well system that supports directional drilling, according to aspects of the present disclosure. In the example shown in FIG. 1, the well system 100 directs a drill bit 114 in drilling a wellbore 118 through a subterranean formation 102, such as a subsea well or a land well. Example embodiments are not limited to only

drilling an oil well. Some implementations may also encompass natural gas wellbores, other hydrocarbon wellbores, or wellbores in general. Further, some implementations may be used for the exploration and formation of geothermal wellbores intended to provide a source of heat energy instead of hydrocarbons.

[0032] In the example shown in FIG. 1, well system 100 includes a drill string 106 attached to a derrick 108 and a bottom hole assembly (BHA) 104; the BHA 104 may be positioned or otherwise arranged at the bottom of the drill string 106. The derrick 108 may be located at the surface 110 and may, in some example approaches, include a kelly 112 connected to drill string 106; the kelly 112 may be used, for instance, to lower and raise the drill string 106.

[0033] The BHA 104 may include a drill bit 114, a rotary steerable system 109, other suitable components, or a combination thereof. The drill bit 114 may, in some examples, be operatively coupled to a tool string 116, with the tool string 116 attached to the drill string 106 such that the drill bit 114 may be moved axially within drilled wellbore 118. During operation, the drill bit 114 can penetrate the subterranean formation 102 to extend the wellbore 118.

[0034] The BHA 104 may control the drill bit 114 as the drill bit 114 advances into the subterranean formation 102. For example, the BHA 104 may use the rotary steerable system 109 to change the direction of drilling by applying a steering pressure or other suitable force to a wall of the wellbore 118.

[0035] In the example shown in FIG. 1, fluid such as a drilling mud may be pumped downhole from a mud tank 120 using a mud pump 122 that may be powered by an adjacent power source, such as a prime mover (or motor) 124. The mud may be pumped from the mud tank 120, through a standpipe 126, which feeds the mud through the drill string 106 to the rotary steerable system 109, or other suitable components of the well system 100, and on to the drill bit 114. The mud may, in some examples, exit one or more nozzles (not shown) arranged in the drill bit 114 and may thereby cool the drill bit 114. Additionally or alternatively, the mud may be directed (e.g., as pressurized mud) into the rotary steerable system 109 for adjusting a direction of the drill bit 114, as discussed in further detail below.

[0036] After exiting the drill bit 114 or other suitable components, the mud may circulate back to the surface 110 via an annulus defined between the wellbore 118 and the drill string 106. The

returning mud transports cuttings from the wellbore 118 into the mud tank 120 and aids in maintaining the integrity of the wellbore 118. For example, cuttings and mud mixture passed from the annulus through the flow line 128 may be processed such that a cleaned mud is returned down hole through the standpipe 126.

[0037] In some examples, the rotary steerable system 109 may include a steering collar, one or more actuation cylinders, and a radial seal for each cylinder. The steering collar may be designed to provide a rigid frame for the rotary steerable system 109. In one example approach, each actuation cylinder is mounted in a pocket of the steering collar, with a radial seal installed between each actuation cylinder and the steering collar; the radial seal forms a pressure seal or other suitable type of seal for each actuation cylinder in the rotary steerable system 109. In one such example approach, the radial seal allows the rotary steerable system 109 to receive pressure (e.g., via pressurized mud) used to apply the steering force without incurring damage, obstruction, excessive wear, or other related undesirable effects from the pressure. In one example approach, a piston positioned in each actuation cylinder may be used to apply the steering pressure or other suitable forces to the wall of the wellbore.

[0038] The tool string 116 may include one or more logging while drilling (LWD) or measurement-while-drilling (MWD) tools that collect data and measurements relating to various borehole and formation properties as well as the position of the drill bit 114 and various other drilling conditions as the drill bit 114 extends the wellbore 118 through the formations 102. The LWD/MWD tools may include a device for measuring formation resistivity, a gamma ray device for measuring formation gamma ray intensity, devices for measuring the inclination and azimuth of the tool string 116, pressure sensors for measuring drilling fluid pressure, temperature sensors for measuring borehole temperature, etc.

[0039] In one example approach, well system 100 includes a drilling platform controller 130 connected to mud pump 122 and to Large Language Model recommendation system 132. In one such example approach, drilling platform controller 130 receives drilling parameters from the drilling operation and receives or retrieves recommendations from LLM recommendation system 132. Drilling platform controller 130 then determines changes to be made to the drilling parameters based on the recommendations and on the current drilling parameters.

[0040] In some example approaches, drilling platform controller 130 is communicatively connected to LWD/MWD tools and receives one or more drilling parameters from the LWD/MWD tools. In some such example approaches, drilling platform controller 130 is communicatively connected to an RSS 109 and modifies a drilling direction via RSS 109. In some example approaches, drilling platform controller 130 includes an autonomous drilling controller, as detailed below.

[0041] In the example shown in FIG. 1, RSS 109 is configured to change the direction of the tool string 116 and/or the drill bit 114, such as based on information indicative of tool orientation and a desired drilling direction received from a drilling application. In one or more embodiments, the RSS 109 is coupled to the drill bit 114 and may drive rotation of the drill bit 114. Specifically, the RSS 109 may rotate in tandem with the drill bit 114 or may rotate at a fraction of the rate of drill bit 114. In some implementations, the rotary steerable tool 109 may be a point-the-bit system or a push-the-bit system.

[0042] FIG. 2 is a block diagram illustrating an example large language model (LLM) recommendation system. In the example of FIG. 2, LLM recommendation system 132 includes a large language model (LLM) system 200 connected through a data aggregator 240 to one or more data sources 242. The data sources may include, for example, real-time services, data in formats such as well-site information transfer standard markup language (WITSML) and daily reports.

[0043] LLMs have become increasingly popular. They are known for the ability to learn from unstructured text and from domain knowledge, to support natural language (and to respond to a human query), and to enable code generation and plug-ins, making it possible for LLM to directly communicate with other software. In some example approaches, LLM 204 includes domain knowledge obtained from transfer learning of domain knowledge sources. In some example approaches, the LLM is a generic LLM trained with industry specific drilling operation domain knowledge and LLM recommendation system 132 is configured to enable replacement of one LLM 202 with another LLM trained with industry specific drilling operation domain knowledge. In one example approach LLM 204 includes two or more LLMs trained with different industry specific drilling operation domain knowledge; LLM 204 generates a recommendation from the output of the two LLMs.

[0044] In the example shown in FIG. 2, LLM system 200 includes a prompt generator 202, an LLM 204, a recommendation User Interface (UI) 206, recommendation feedback system 208, recommendation archives 210 and recommendation analysis and prompt engineering tool 212. In one example approach, agents collect specific data from pre-identified sources 242 then deposit the data into a centralized store. Data aggregator 240 then organizes the accumulated data to relate the variety of source information together for further analysis. Prompt generator 202 receives the organized data from the data aggregator 240, generates an engineered prompt and submits the engineered prompt to the LLM 204, which produces one or more recommendations based on the prompt. The recommendations are forwarded to recommendation UI 206 and to recommendation archives 210. In one example approach, recommendation UI 206 is a user facing application responsible for sharing the recommendations with the user or with autonomous drilling controller 230.

[0045] In one example approach, the LLM system 200 includes both an application programming interface (API) for machines, and a natural language interface for humans; it is, therefore, able to suggest modifications in operations and to respond to queries to both controller and site engineers and drillers. To further that goal, in some example approaches, as shown in FIG. 2, recommendation feedback system 208 receives feedback on efficacy of the recommendations received by users and by autonomous drilling controller 230 and associates the feedback with the recommendation that was stored in recommendation archives 210. The feedback may be, for instance, a grade for the usefulness of the recommendation, a snapshot of the resulting drilling parameters or other such criteria. In some example approaches, the feedback is stored with its associated recommendation in recommendation archives 210. Such an approach serves as the historical record of all interactions.

[0046] In one example approach, recommendation analysis and prompt engineering tool 212 receives the recommendation and its associated feedback and performs prompt engineering so that subsequent prompts avoid or limit the issues raised in the feedback. For instance, tool 212 may determine that subsequent prompts should reduce the length of a data window, reduce the weight on certain variables or increase the weight on other variables in the data received from data aggregator 240. In some example approaches, tool 212 may also provide information used to train LLM 204 to avoid the situation in the future.

[0047] In some example approaches, prompt engineering includes modifying the prompt in the future to include one or more examples of a successful recommendation that addresses the feedback. In some example approaches, prompt engineering includes modifying the prompt in the future to include a chain-of-thought prompt to encourage critical thinking by LLM 204 when responding to the prompts like the prompt that led to the recommendation. In some example approaches, as shown in FIG. 2, domain experts retrieve recommendations with feedback and provide feedback to prompt generator 202 to guide prompt generator 202 to better recommendations when faced with similar data patterns. For instance, the original prompt may be modified to include chain-of-thought prompting sequences or self-criticism prompting. The prompt generator may also be trained to use, for instance, leading words, to provide further context or to structure the data received from data aggregator 240 in a way that avoids the issues raised in the feedback.

[0048] FIG. 3 is a block diagram illustrating a data aggregation system which may be used with the example LLM recommendation system of FIG. 2. In the data aggregation system 300 of FIG. 3, Real-Time (RT) Data Agent 310 is a long-running service which understands the Real-Time drilling stream source APIs and subscribes to and consumes variables from Real-Time Drilling Stream 300 deemed relevant to generating LLM prompts. WITSML Agent 312 is a long-running service which queries WITSML server 302 for specific data objects predetermined to be relevant to generating LLM prompts. Document parser 314 parses reports such as daily or morning reports received from one or more report sources 304 into key-value pairs and tabular datasets to extract relevant data from the reports. In some example approaches, parser 314 supports multiple parser models to support a wide variety of custom formatted documents. In one example approach, document indexer 316 receives the parsed documents and places them in the document indexer, which includes pre-defined terms to be used in prompt generation.

[0049] In some example approaches, data aggregator 240 receives the data collected by Real-Time (RT) Data Agent 310, by WITSML Agent 312 and by document indexer 316 and formats the data with information relevant to generating LLM prompts from offset logs 306 and from end of well reports 308 before sending the aggregated data to prompt generator 202 as shown in FIG. 2.

[0050] FIG. 4 is a block diagram illustrating an example system for querying the example LLM recommendation system of FIG. 2. In the example shown in FIG. 4, LLM recommendation system

132 includes the data aggregator 240, the prompt generator 202 and the LLM 204 shown in FIG. 2. Drilling platform controller 130 includes a processor 402 connected to a memory 404. In one example approach, processor 502 receives current drilling parameters associated with the current drilling operation and executes instructions stored in memory 504 to forward the current drilling parameters to LLM recommendation system 132.

[0051] Processor 402 then executes instructions stored in memory 404 query LLM recommendation system 132 using the methods described above for FIGS. 2 and 3. In some example approaches, the query is a machine language query that results in a machine language response. In some example approaches, the LLM recommendation system 132 provides the recommended changes in drilling parameters to the drilling operator or to automated drilling controllers 230 in real time and without the need for a query. The recommended changes may include changes to the current drilling parameters. The recommended changes are issued in the new drilling parameters.

[0052] In some example approaches, processor 402 executes instructions stored in memory 404 to provide feedback from the drilling operator or other domain expert to the recommendation. In some example approaches, the feedback is stored with its associated recommendation in recommendation archives 210 as discussed in the context of FIG. 2 above. The feedback is then used for prompt engineering or LLM training as necessary.

[0053] FIG. 5 is a block diagram illustrating an example system for querying the example LLM recommendation system of FIG. 2. In the example shown in FIG. 5, LLM recommendation system 132 includes the data aggregator 240, the prompt generator 202 and the LLM 204 shown in FIG. 2. Automated drilling platform controller 230 includes a processor 502 connected to a memory 504. In one example approach, processor 502 receives current drilling parameters associated with the current drilling operation and executes instructions stored in memory 504 to forward the current drilling parameters to LLM recommendation system 132. In one such example approach, the current drilling parameters include Weight on Bit (WOB), Rate of Penetration (ROP), Rotations per Minute (RPM), flowrate, and inclination while the new drilling parameters include WOB, RPM and flowrate.

[0054] Processor 502 then executes instructions stored in memory 504 to query LLM recommendation system 132 using the methods described above for FIGS. 2 and 3. In some

example approaches, the query is a machine language query that results in a machine language response. In some example approaches, the LLM recommendation system 132 provides the recommended changes in drilling parameters to the drilling operator or to automated drilling controllers 230 in real time and without the need for a query. The recommended changes may include changes to the current drilling parameters. The recommended changes are issued in the new drilling parameters, such as one or more of a new WOB, a new RPM or a new flowrate.

[0055] In some example approaches, processor 502 executes instructions stored in memory 504 to provide feedback from the drilling operator or other domain expert to the recommendation. In some example approaches, the feedback is stored with its associated recommendation in recommendation archives 210 as discussed in the context of FIG. 2 above. The feedback is then used for prompt engineering or LLM training as necessary.

[0056] FIG. 6 illustrates an example prompt format example which may be used with the LLM recommendation systems of FIGS. 2, 4 and 5. The example shown in FIG. 6 is a simplified demonstrative example that describes some properties of BHAs and drilling records. In practice, the prompt format may be a more complex representation. In the example shown in FIG. 6, a basic prompt has the format of:

Assume the role of a <persona> who would like to <current_objective>. Within the last 24 hours, the following activities occurred <24_hour_summary>. The current state of operations is <Current_Activity>. The current downhole equipment is <BHA_Info>. The latest information regarding the <Current_Activity> is <Latest_Telemetry>. Using this information, what can be done to achieve <current_objective>?

[0057] In this example, based on the data received from data aggregator 240, the persona is selected from drilling engineer, company man, well-site geologist, directional driller, and mud engineer. The current objective is selected from 1) increase ROP, 2) minimize vibration, 3) drill to target, 4) reduce stick slip, and 5) avoid wash-out. The 24-hour summary may include bottom hole depth, footage drilled, current hole section, and events. The current activity may include drilling, tripping in, tripping out, making connection, circulating, running casing, cementing, and drilling through the shoe. The BHA Information may include drill bit model, drill bit size, motor,

and MWD / LWD tool strings and locations. The latest telemetry may include Avg ROP, Azimuth, Inclination, Vibration (x,y,z), Standpipe Pressure (SPP), Depth, True Vertical Depth (TVD), Pressure While Drilling (PWD), Equivalent Circulating Density (ECD), Formation, ROP Trend, Vibration Trend, PWD Trend and ECD Trend.

[0058] In some example approaches, a domain expert uses prompt engineering to modify the basic prompt based on the feedback. This may take the form of adding further context, providing examples, or adding further instructions. In one such example approach, the basic prompt would be modified to include chain-of-thought prompting as follows:

Assume the role of a <persona> who would like to <current_objective>. Within the last 24 hours, the following activities occurred <24_hour_summary>. The current state of operations is <Current_Activity>. The current downhole equipment is <BHA_Info>. The latest information regarding the <Current_Activity> is <Latest_Telemetry>. Using this information, what can be done to achieve <current_objective>? Let's think step by step.

[0059] In some example approaches, feedback is used to weight variables to influence the prompt. In one such example approach, the basic prompt would be modified to include parameter weighting as follows:

Assume the role of a <persona> who would like to <current_objective>. Within the last 24 hours, the following activities occurred <24_hour_summary>. The current state of operations is <Current_Activity>. The current downhole equipment is <BHA_Info>. The latest information regarding the <Current_Activity> is <Weighted_Latest_Telemetry>. Using this information, what can be done to achieve <current_objective>?

[0060] In some example approaches, <Weighted_Latest_Telemetry> is determined from <Latest_Telemetry> based on weights defined, for instance, via prompt engineering. In one such example approach, the feedback for a recommendation is used to weight variables to influence future recommendations from the LLM 204. Other prompt engineering techniques may be used as well as discussed in more detail above.

[0061] FIG. 7 is a flowchart illustrating a method of applying the LLM recommendation systems of any of FIGS. 2, 4 and 5. In the example approach of FIG. 7, LLM recommendation system 132 receives oil and gas drilling data relevant to generating a prompt from data aggregator 240 (700). Prompt generator 202 generates a prompt based on the received data (702) and applies the prompt to LLM 204 (704). The LLM 202 generates a recommendation for one or more changes in operation of the drilling platform controller 130 based on the prompt (706) and transmits the recommendation to the drilling platform controller 130 (708). The drilling platform controller may provide feedback for the recommendation and, if so (710), the feedback is associated with the recommendation and used to modify the operation of the prompt generator 202 based on the feedback (712). In some example approaches, the feedback may be used to further train LLM 202 in addition to or instead of modifying the operation of prompt generator 202.

[0062] FIG. 8 is a flowchart illustrating a method of guiding a platform drilling controller with the LLM recommendation systems of any of FIGS. 2, 4 and 5. In the example shown in FIG. 8, an autonomous drilling controller 230 receives (800) current drilling parameters and submits a query to the LLM recommendation system 132 for a recommendation based on the current drilling parameters (802). The LLM recommendation system 132 returns (804) a response including an indication of a recommended change in one or more of the current drilling parameters. The autonomous drilling controller 230 modifies (806) one or more of the current drilling parameters based on the recommendation (806). The autonomous drilling controller 230 then generates feedback for the recommendation if necessary and transmits the feedback to the LLM recommendation system 132 (808).

[0063] Examples of using an LLM recommendation system 132 are described next. Consider a performance issue where the rate of penetration suddenly drops during the drilling. There are a variety of factors that may contribute to this situation, such as a worn-out bit, a hard formation, or required bit cleaning. Conventionally, an experienced directional driller (DD) must be involved to identify the main factors and to make decisions to address the problem, such as to pull out the drill string and replace the bit, to increase weight on bit, or to increase flow rate. In contrast, in a system in which an autonomous drilling controller 230 is paired with an LLM recommendation system 132, the controller 230 may query past drilling records that used similar BHA and bit design, and that were drilled in nearby regions, which helps to determine the main factors to the problem. an LLM recommendation system 132 submits a prompt to LLM 204 based on the relevant

information and receives recommendations tailored for the current operation and drilling conditions. The system requires no human interaction, and the decision making may be done quickly and accurately with the recommendations provided by LLM recommendation system 132.

[0064] In another example, consider a geosteering application where the BHA 104 measures the surrounding geophysical and petrophysical data, and uses that logging data to identify and control the position of BHA 104, keeping the wellbore 118 within a hydrocarbon pay zone. In addition to the measurements, geophysical information obtained from nearby past drillings may be useful for the BHA 104 to identify its position more accurately. With the LLM recommendation system 132 described above, the autonomous drilling controller 230 receives recommendations for geosteering based on geophysical and petrophysical data from nearby drilling sites and on formation and hydrocarbon characteristics. LLM 202 matches the retrieved formation and hydrocarbon characteristics with the petrophysical measurements of the current drilling based on the appropriate prompt, identifying the relative location of the hydrocarbon pay zone from the wellbore 118 more accurately. With better position identification, elevated levels of autonomous control may be implemented.

[0065] Various modifications to the implementations described in this disclosure may be readily apparent to persons having ordinary skill in the art, and the generic principles defined herein may be applied to other implementations without departing from the spirit or scope of this disclosure. Thus, the claims are not intended to be limited to the implementations shown herein but are to be accorded the widest scope consistent with this disclosure, the principles and the novel features disclosed herein.

[0066] Additionally, various features that are described in this specification in the context of separate implementations also can be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation also can be implemented in multiple implementations separately or in any suitable subcombination. As such, although features may be described above as acting in particular combinations, and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination.

[0067] Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in a particular order or in sequential order, or that all illustrated operations be performed, to achieve desirable results. Further, the drawings may schematically depict one or more example processes in the form of a flowchart or flow diagram. However, other operations that are not depicted can be incorporated in the example processes that are schematically illustrated. For example, one or more additional operations can be performed before, after, simultaneously, or between any of the illustrated operations. In some circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the implementations described above should not be understood as requiring such separation in all implementations; the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products. Additionally, other implementations are within the scope of the following claims. In some cases, the actions recited in the claims can be performed in a different order and still achieve desirable results.

Example Implementations:

[0068] Example implementations include the following:

[0069] Implementation #1: A large language model (LLM) recommendation system, comprising an LLM trained with drilling operations domain knowledge; an LLM prompt generator connected to the LLM, the LLM prompt generator configured to receive drilling operations data, including current drilling parameters associated with a selected drilling platform controller, and to generate LLM prompts, the LLM prompts configured to request a recommendation from the LLM for changes to operation of the selected drilling platform controller based on the received data; and a feedback system connected to the LLM prompt generator and the LLM, the feedback system configured to receive feedback on efficacy of the recommendation, from the selected drilling platform controller, for each recommendation received by the selected drilling platform controller; and to modify operation of the LLM prompt generator based on the feedback.

[0070] Implementation #2: The LLM recommendation system of Implementation #1, wherein the feedback system includes a recommendation archive and a recommendation feedback system, wherein the LLM stores each recommendation in the recommendation archive, and wherein the recommendation feedback system receives feedback, from the selected drilling platform, for each

recommendation received by the selected drilling platform controller and associates the feedback with the respective stored recommendation.

[0071] Implementation #3: The LLM recommendation system of Implementation #1, wherein the feedback system includes a recommendation archive and a recommendation feedback system, wherein the LLM stores each recommendation in the recommendation archive, and wherein the recommendation feedback system receives feedback, from the selected drilling platform, for each recommendation received by the selected drilling platform controller and stores the feedback with the respective stored recommendation.

[0072] Implementation #4: The LLM recommendation system of Implementation #3, wherein the feedback system further includes a prompt engineering tool, the prompt engineering tool configured to receive a stored recommendation with its associated feedback and to modify operation of the LLM prompt generator based on the feedback.

[0073] Implementation #5: The LLM recommendation system of Implementation #1, the LLM recommendation system further includes a data aggregator connected to one or more data sources and to the LLM prompt generator, the data aggregator configured to receive drilling operations data relevant to the LLM prompt generator.

[0074] Implementation #6: The LLM recommendation system of Implementation #5, the data sources include one or more of real-time drilling stream data, well-site information transfer standard markup language (WITSML) data, or daily reports.

[0075] Implementation #7: The LLM recommendation system of Implementation #6, wherein the data aggregator includes one or more agents, the agents configured to query the data sources for drilling operations data relevant to the LLM prompt generator.

[0076] Implementation #8: The LLM recommendation system of Implementation #1, wherein the LLM includes domain knowledge obtained from transfer learning of domain knowledge sources.

[0077] Implementation #9: A method comprising receiving drilling operations data relevant to drilling platform controller operation, wherein the drilling operations data includes current drilling parameters of a selected drilling platform controller; generating, at a prompt generator, a prompt for recommended changes in operation of the selected drilling platform controller; applying the

prompt to a large language model (LLM) trained with drilling operations domain knowledge; receiving, from the LLM, a recommendation for one or more changes in operation of the selected drilling platform controller; receiving, from the selected drilling platform controller, feedback on efficacy of the recommendation; and modifying operation of the prompt generator based on the feedback.

[0078] Implementation #10: The method of Implementation #9, wherein receiving a recommendation includes storing the recommendation into a recommendation archive.

[0079] Implementation #11: The method of Implementation #10, wherein receiving feedback includes associating the feedback with the respective stored recommendation.

[0080] Implementation #12: The method of Implementation #10, wherein receiving feedback includes storing the feedback in the recommendation archive with the respective stored recommendation.

[0081] Implementation #13: The method of Implementation #9, wherein the feedback includes one or more of a grade or a snapshot of one or more of the drilling parameters for the selected drilling platform controller after implementing the recommended changes.

[0082] Implementation #14: The method of Implementation #9, wherein modifying operation of the prompt generator based on the feedback includes receiving a selected stored recommendation and the feedback associated with the selected stored recommendation and modifying operation of the prompt generator based on the selected stored recommendation and the feedback associated with the selected stored recommendation.

[0083] Implementation #15: The method of Implementation #9, wherein receiving drilling operations data includes querying data sources for drilling operations data relevant to the LLM prompt generator.

[0084] Implementation #16: The method of Implementation #9, the method further comprising receiving a query from the selected drilling platform controller and transmitting the recommendation to the selected drilling platform controller in response to the query, wherein the received query is a machine language query, and the response is a machine language response.

[0085] Implementation #17: The method of Implementation #9, the method further comprising receiving a query from the selected drilling platform controller and transmitting the recommendation to the selected drilling platform controller in response to the query, wherein the received query is a natural language query, and the response is a natural language response.

[0086] Implementation #18: A drilling platform controller comprising a processor; and a memory connected to the processor, the memory including instructions that, when executed by the processor, cause the processor to transmit current drilling parameters to a large language model (LLM) recommendation system; receive, from the LLM recommendation system, a recommendation, the recommendation including recommended changes to one or more drilling parameters; change one or more of the drilling parameters based on the recommended changes; and transmit feedback on efficacy of the recommendation to the LLM recommendation system.

[0087] Implementation #19: The drilling platform controller of Implementation #18, wherein changing one or more of the current drilling parameters based on the recommendation includes changing one or more of Weight on Bit (WOB), Rotations per Minute (RPM) or flowrate.

[0088] Implementation #20: The drilling platform controller of Implementation #18, wherein the current drilling parameters include one or more of WOB, Rate of Penetration (ROP), RPM, flowrate, or inclination.

WHAT IS CLAIMED IS:

1. A large language model (LLM) recommendation system, comprising:
 - an LLM trained with drilling operations domain knowledge;
 - an LLM prompt generator connected to the LLM, the LLM prompt generator configured to receive drilling operations data, including current drilling parameters associated with a selected drilling platform controller, and to generate LLM prompts, the LLM prompts configured to request a recommendation from the LLM for changes to operation of the selected drilling platform controller based on the received data; and
 - a feedback system connected to the LLM prompt generator and the LLM, the feedback system configured:
 - to receive feedback on efficacy of the recommendation, from the selected drilling platform controller, for each recommendation received by the selected drilling platform controller; and
 - to modify operation of the LLM prompt generator based on the feedback.
2. The LLM recommendation system of claim 1, wherein the feedback system includes a recommendation archive and a recommendation feedback system, wherein the LLM stores each recommendation in the recommendation archive, and
 - wherein the recommendation feedback system receives feedback, from the selected drilling platform, for each recommendation received by the selected drilling platform controller and associates the feedback with the respective stored recommendation.
3. The LLM recommendation system of claim 1, wherein the feedback system includes a recommendation archive and a recommendation feedback system, wherein the LLM stores each recommendation in the recommendation archive, and
 - wherein the recommendation feedback system receives feedback, from the selected drilling platform, for each recommendation received by the selected drilling platform controller and stores the feedback with the respective stored recommendation.
4. The LLM recommendation system of claim 3, wherein the feedback system further includes a prompt engineering tool, the prompt engineering tool configured to receive a stored

recommendation with its associated feedback and to modify operation of the LLM prompt generator based on the feedback.

5. The LLM recommendation system of claim 1, wherein the LLM recommendation system further includes a data aggregator connected to one or more data sources and to the LLM prompt generator, the data aggregator configured to receive drilling operations data relevant to the LLM prompt generator.

6. The LLM recommendation system of claim 5, wherein the data sources include one or more of real-time drilling stream data, well-site information transfer standard markup language (WITSML) data, or daily reports.

7. The LLM recommendation system of claim 6, wherein the data aggregator includes one or more agents, the agents configured to query the data sources for drilling operations data relevant to the LLM prompt generator.

8. The LLM recommendation system of claim 1, wherein the LLM includes domain knowledge obtained from transfer learning of domain knowledge sources.

9. A method, comprising:

receiving drilling operations data relevant to drilling platform controller operation, wherein the drilling operations data includes current drilling parameters of a selected drilling platform controller;

generating, at a prompt generator, a prompt for recommended changes in operation of the selected drilling platform controller;

applying the prompt to a large language model (LLM) trained with drilling operations domain knowledge;

receiving, from the LLM, a recommendation for one or more changes in operation of the selected drilling platform controller;

receiving, from the selected drilling platform controller, feedback on efficacy of the recommendation; and

modifying operation of the prompt generator based on the feedback.

10. The method of claim 9, wherein receiving a recommendation includes storing the recommendation into a recommendation archive.
11. The method of claim 10, wherein receiving feedback includes associating the feedback with the respective stored recommendation.
12. The method of claim 10, wherein receiving feedback includes storing the feedback in the recommendation archive with the respective stored recommendation.
13. The method of claim 9, wherein the feedback includes one or more of a grade or a snapshot of one or more of the drilling parameters for the selected drilling platform controller after implementing the recommended changes.
14. The method of claim 9, wherein modifying operation of the prompt generator based on the feedback includes receiving a selected stored recommendation and the feedback associated with the selected stored recommendation and modifying operation of the prompt generator based on the selected stored recommendation and the feedback associated with the selected stored recommendation.
15. The method of claim 9, wherein receiving drilling operations data includes querying data sources for drilling operations data relevant to the LLM prompt generator.
16. The method of claim 9, the method further comprising receiving a query from the selected drilling platform controller and transmitting the recommendation to the selected drilling platform controller in response to the query, wherein the received query is a machine language query, and the response is a machine language response.
17. The method of claim 9, the method further comprising receiving a query from the selected drilling platform controller and transmitting the recommendation to the selected drilling platform controller in response to the query, wherein the received query is a natural language query, and the response is a natural language response.
18. A drilling platform controller, comprising:

a processor; and

a memory connected to the processor, the memory including instructions that, when executed by the processor, cause the processor to:

- transmit current drilling parameters to a large language model (LLM) recommendation system;
- receive, from the LLM recommendation system, a recommendation, the recommendation including recommended changes to one or more drilling parameters;
- change one or more of the drilling parameters based on the recommended changes;
- and
- transmit feedback on efficacy of the recommendation to the LLM recommendation system.

19. The drilling platform controller of claim 18, wherein changing one or more of the current drilling parameters based on the recommendation includes changing one or more of Weight on Bit (WOB), Rotations per Minute (RPM) or flowrate.

20. The drilling platform controller of claim 18, wherein the current drilling parameters include one or more of WOB, Rate of Penetration (ROP), RPM, flowrate, or inclination.

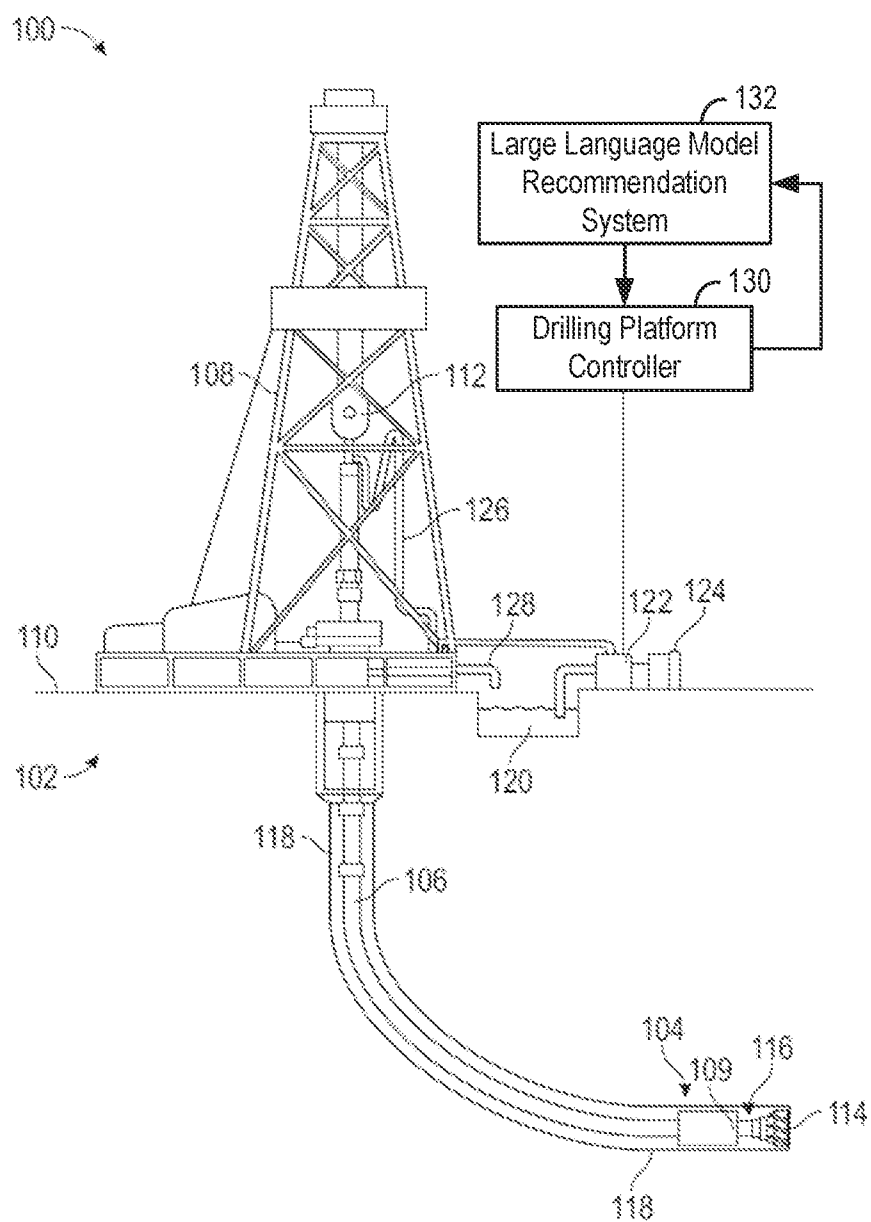


FIG. 1

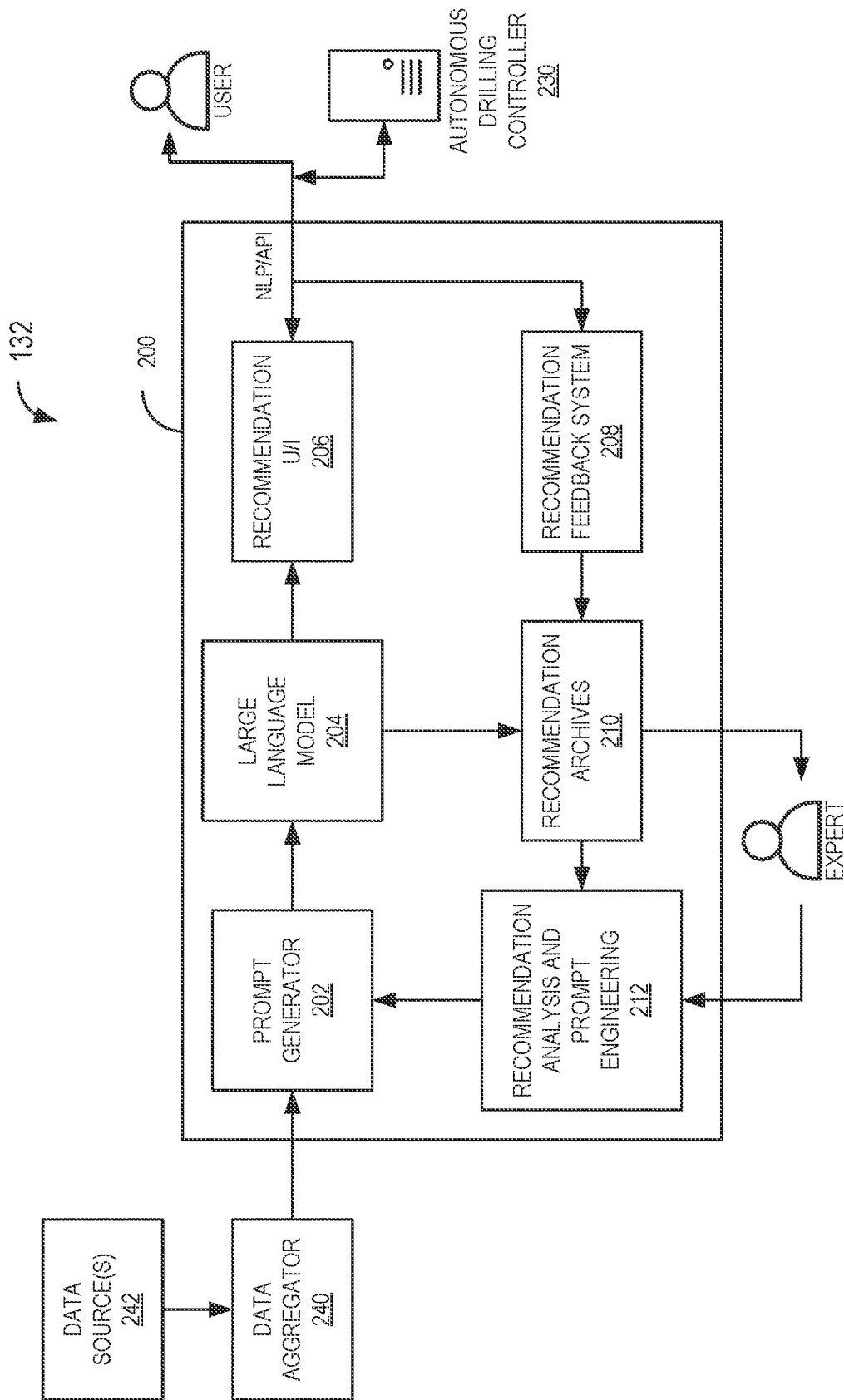


FIG. 2

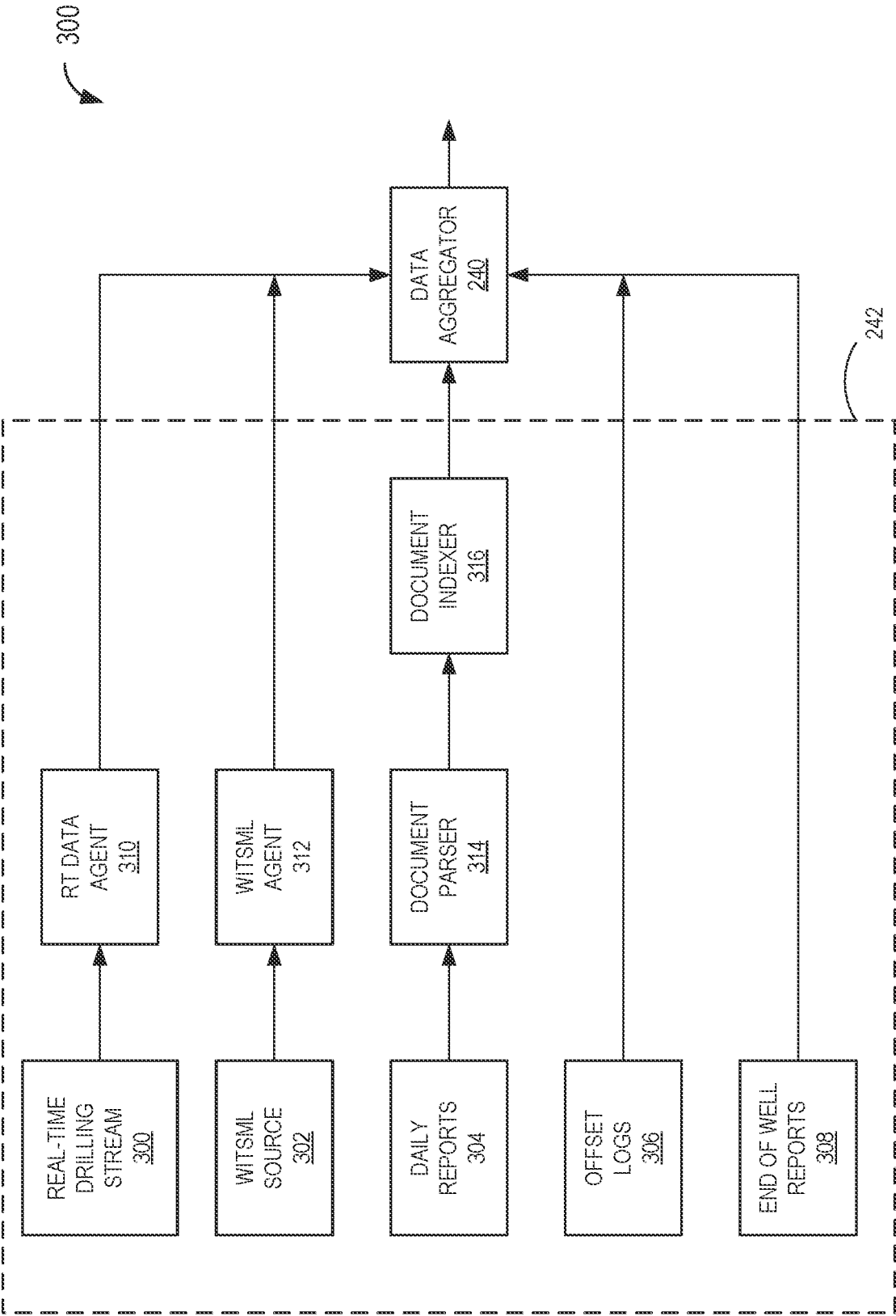


FIG. 3

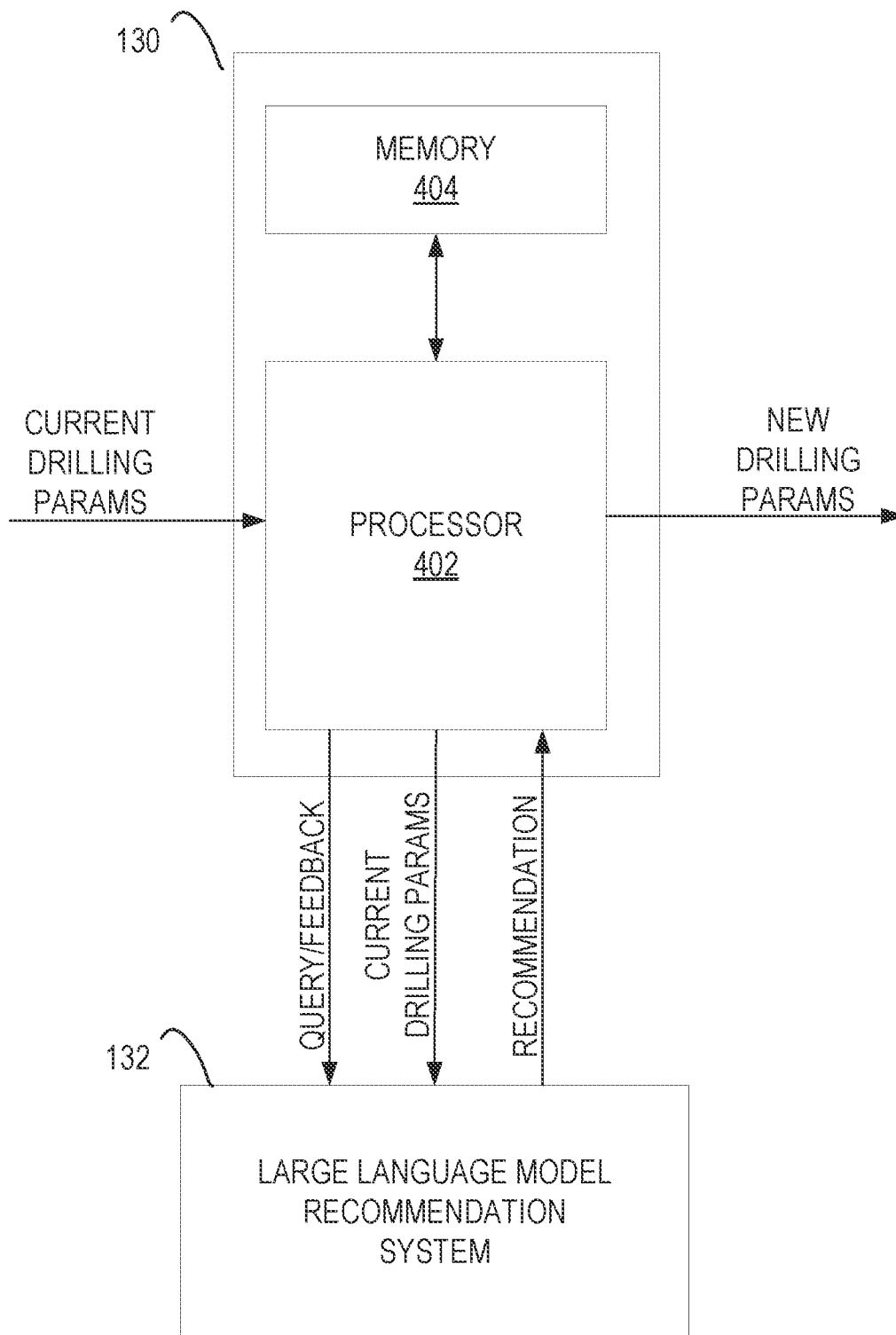


FIG. 4

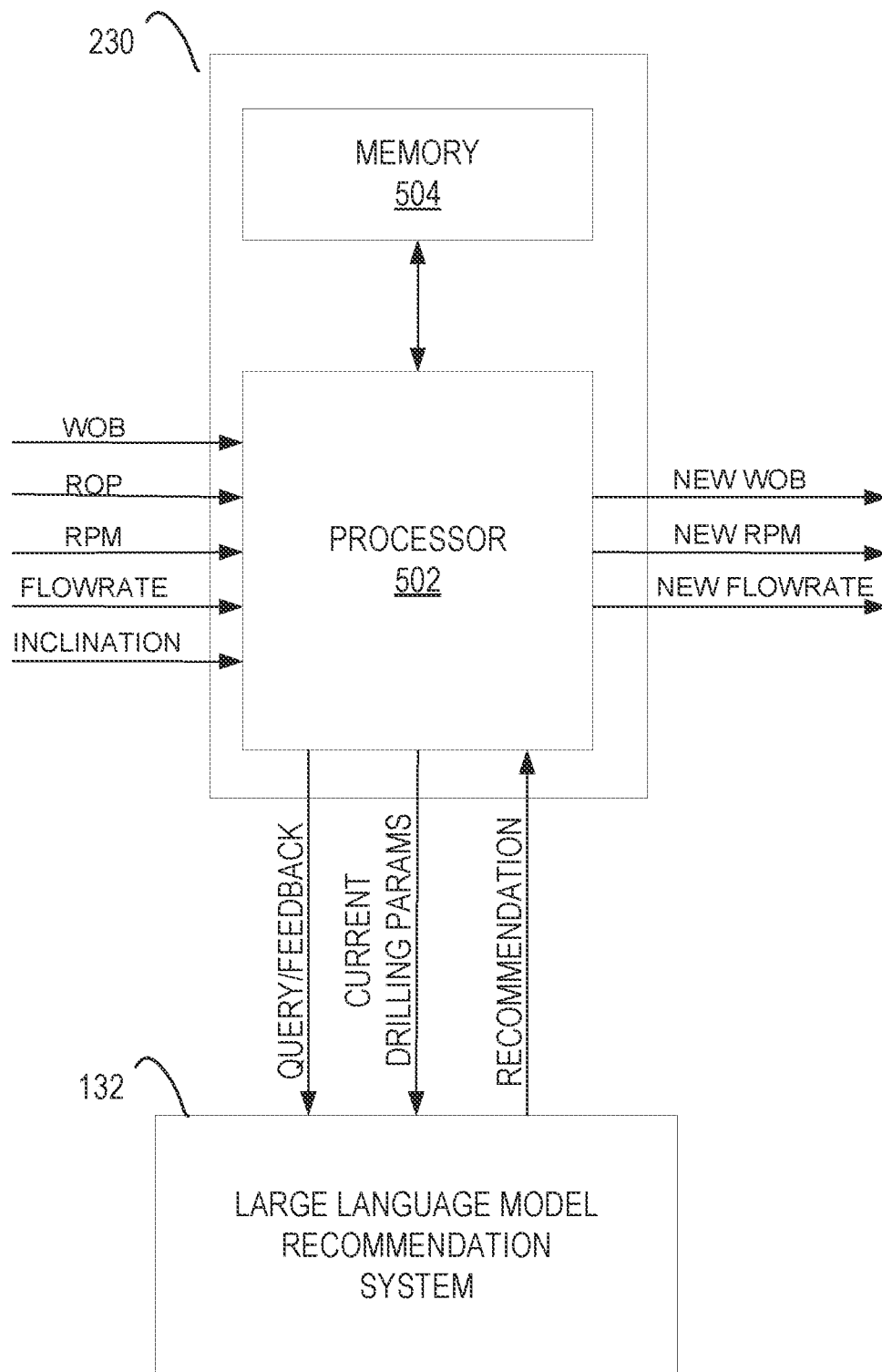


FIG. 5

Example Prompt Format

Assume the role of a <persona> who would like to <current_objective>. Within the last 24 hours, the following activities occurred <24_hour_summary>. The current state of operations is <Current_Activity>. The current downhole equipment is <BHA_Info>. The latest information regarding the <Current_Activity> is <Latest_Telemetry>. *add weight factor for key variables* Using this information, what can be done to achieve <current_objective>?

Variables

- Persona (select one)
 - Drilling Engineer
 - Company man
 - Well-site geologist
 - Directional driller
 - Mud engineer
- Current_objective (select one)
 - Increase ROP
 - Minimize vibration
 - Drill to target
 - Reduce stick slip
 - Avoid wash-out
- 24_hour_summary
 - Bottom hole depth
 - Footage drilled
 - Current hole section
 - Events
- Current_Activity
 - Drilling
 - Tripping In
 - Tripping out
 - Making Connection
 - Circulating
 - Running Casing
 - Cementing
 - Drilling through the shoe
- BHA_Info
 - Drill Bit Model
 - Drill Bit Size
 - Motor
 - MWD / LWD tool strings and locations
- Example Info:
- Latest_Telemetry
 - Avg ROP
 - Azimuth
 - Inclination
 - Vibration (x,y,z)
 - SPP
 - Depth
 - TVD
 - PWD
 - ECD
 - Formation
 - ROP Trend
 - Vibration Trend
 - PWD Trend
 - ECD Trend

FIG. 6

7/8

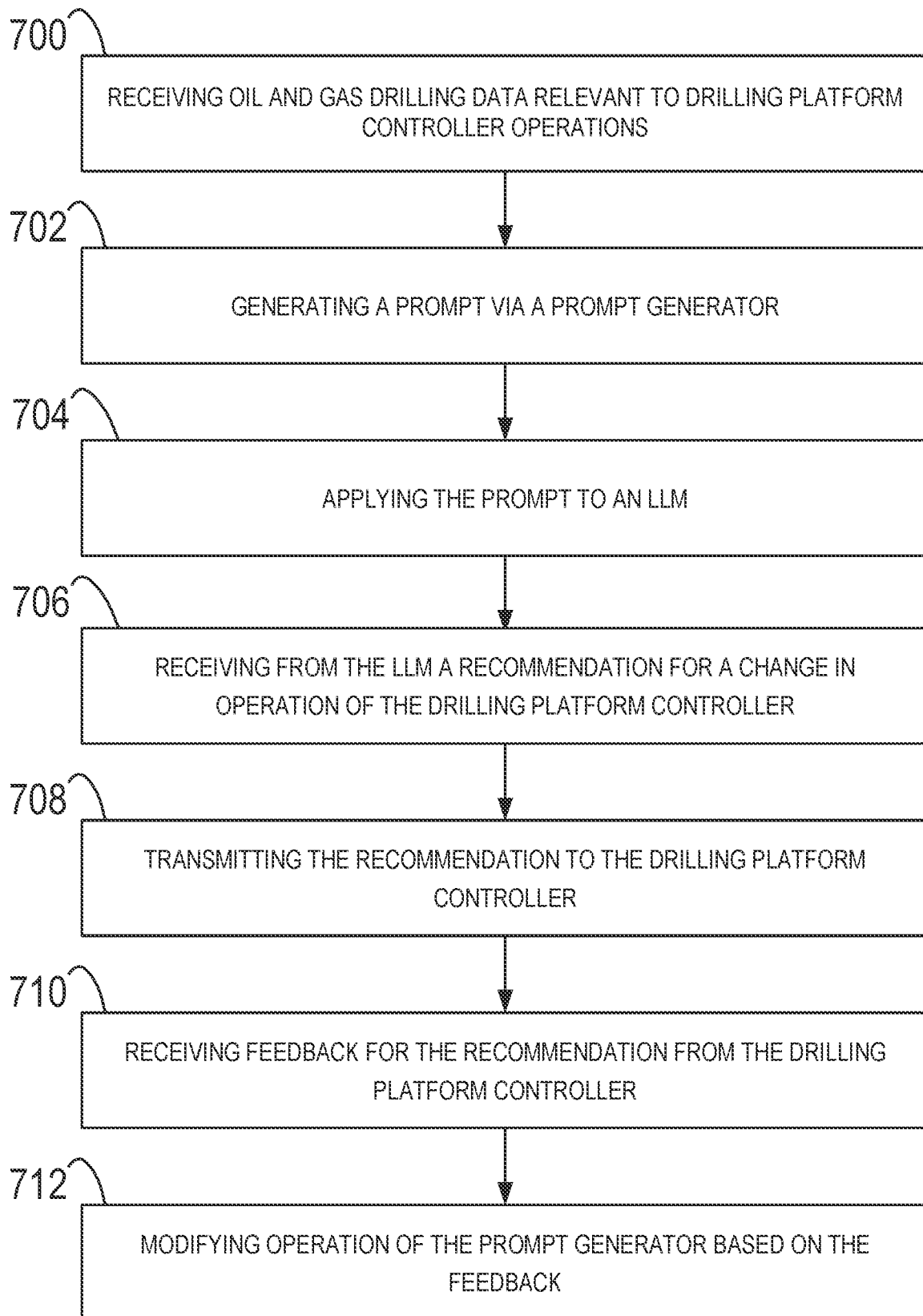


FIG. 7

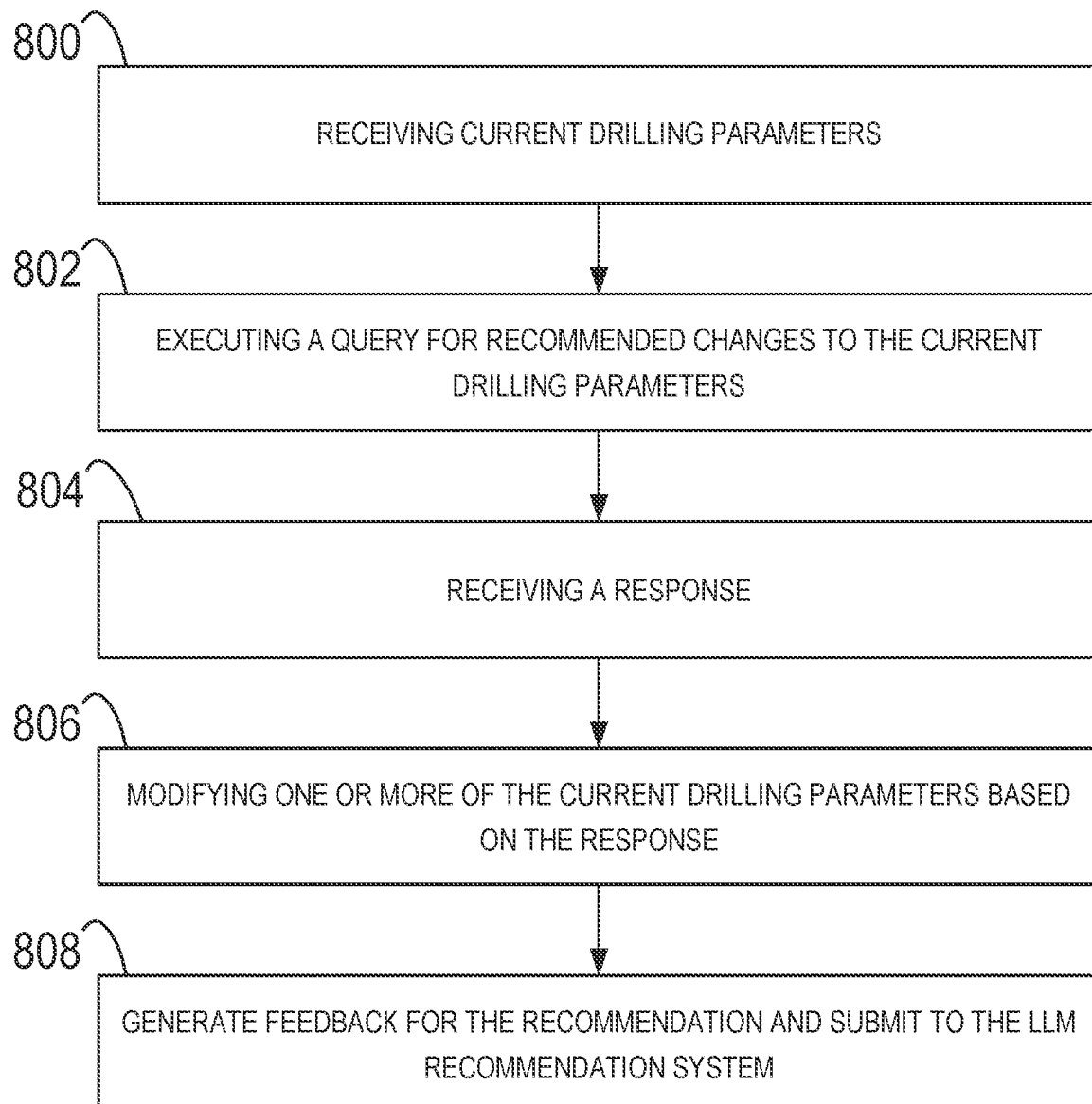


FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/084977

A. CLASSIFICATION OF SUBJECT MATTER**E21B 44/00**(2006.01)i; **G06N 20/00**(2019.01)i; **G06N 5/04**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 44/00(2006.01); E21B 21/08(2006.01); E21B 44/02(2006.01); E21B 47/12(2006.01); G06F 40/30(2020.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: large language model, prompt generator, drilling platform controller, recommendation, feedback, daily reports

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2019-0345809 A1 (BAKER HUGHES, A GE COMPANY, LLC) 14 November 2019 (2019-11-14) paragraphs [0006], [0007], [0031], [0032], [0035]-[0039], claims 1-3 and figures 1, 2	1-20
A	US 2022-0372866 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 24 November 2022 (2022-11-24) paragraphs [0013], [0024], [0026], [0054]-[0068] and figure 3	1-20
A	ANTONIAK et al. Natural Language Processing Techniques on Oil and Gas Drilling Data. In: SPE Intelligent Energy International Conference and Exhibition. Society of Petroleum Engineers, 6-8 September 2016, pp.1-6.	1-20
A	KOWALCHUK, P. Implementing a Drilling Reporting Data Mining Tool Using Natural Language Processing Sentiment Analysis Techniques. In: SPE Middle East Oil and Gas Show and Conference. Society of Petroleum Engineers, 18-21 March 2019, pp.1-14.	1-20

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

“A” document defining the general state of the art which is not considered to be of particular relevance

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

10 September 2024

Date of mailing of the international search report

10 September 2024

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/084977

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CINELLI et al. Automatic event identification and extraction from daily drilling reports using an expert system and artificial intelligence. Journal of Petroleum Science and Engineering, 20 May 2021, Vol. 205, pp. 1-9. pages 1-8	1-20

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US2023/084977

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	2019-0345809	A1	14 November 2019	BR	112020022959	A2	02 February 2021
				EP	3791042	A1	17 March 2021
				US	11066917	B2	20 July 2021
				WO	2019-217813	A1	14 November 2019
US	2022-0372866	A1	24 November 2022	AU	2020-346985	A1	07 April 2022
				CA	3154704	A1	18 March 2021
				EP	4028639	A1	20 July 2022
				EP	4028639	A4	06 September 2023
				WO	2021-051141	A1	18 March 2021