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(54) **AUTOMATED AGENT CHAIN-OF-THOUGHT RESPONSE GENERATION USING STRUCTURE-BASED CONSTRAINTS**

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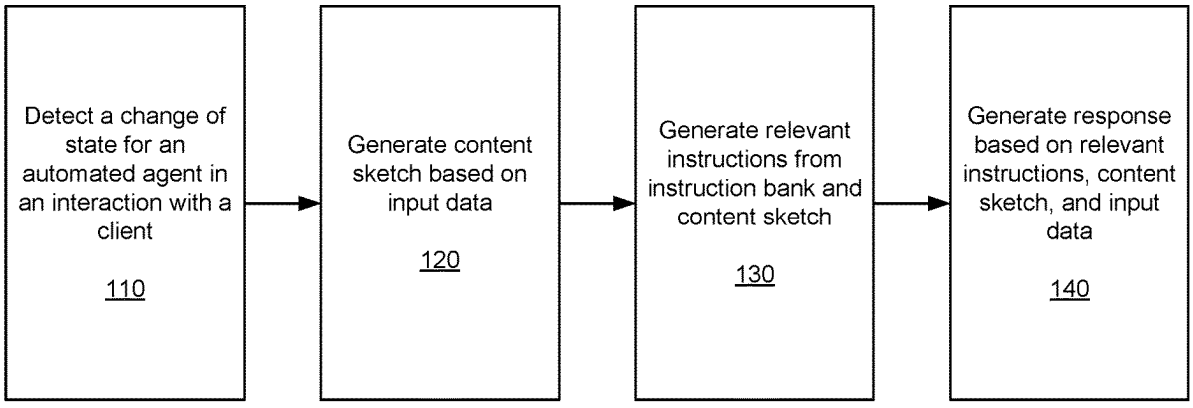
CPC ***G06N 5/046*** (2013.01)

(57) **ABSTRACT**

A system generates a response to a change of state by an automated agent using structure-based constraints. The system receives input regarding an interaction with a client, external data, and current operations data. The received input is used to generate a content sketch. The content sketch can include a plan for how to generate the response. The program language can be constrained to a set of known atoms, such as for example particular specified function, values, and flow control. Relevant instructions for generating a response are generated from the content sketch and an instruction bank. The relevant instructions are then used to generate a response. The generated response may then be executed by the automated agent system.



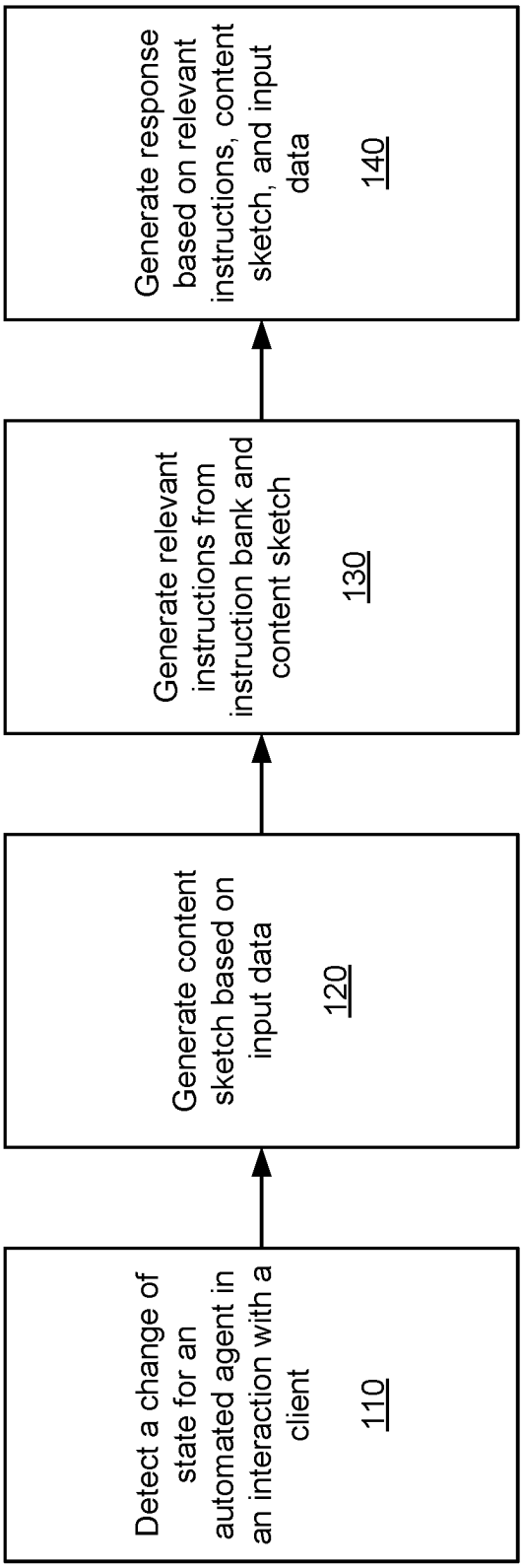

Detect a change of state for an automated agent in an interaction with a client
110
Generate content sketch based on input data
120
Generate relevant instructions from instruction bank and content sketch
130
Generate response based on relevant instructions, content sketch, and input data
140

FIGURE 1

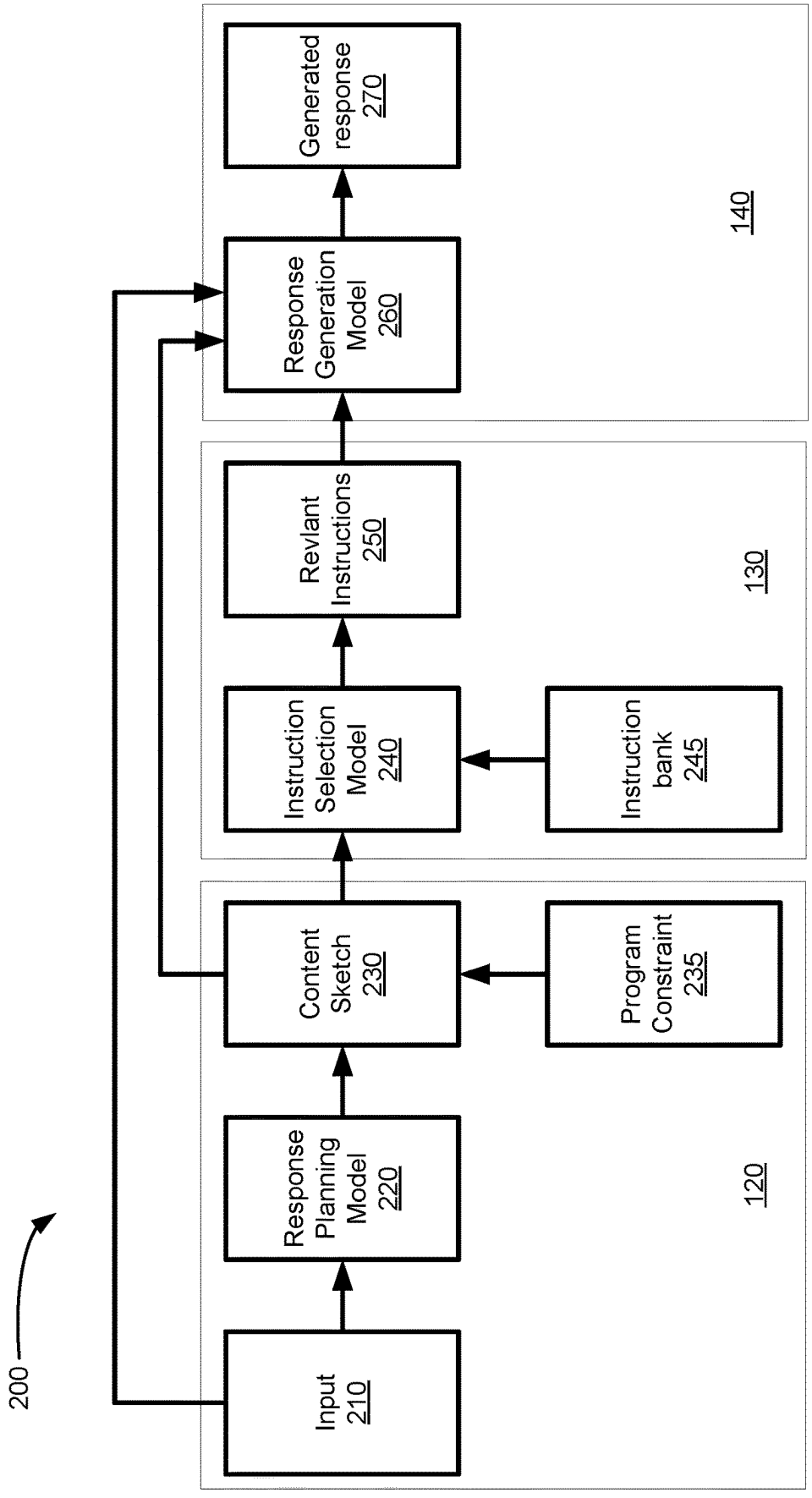

200
Input 210
Response Planning Model 220
Content Sketch 230
Program Constraint 235
120
Instruction Selection Model 240
Instruction bank 245
Revlant Instructions 250
130
Response Generation Model 260
Generated response 270
140

FIGURE 2

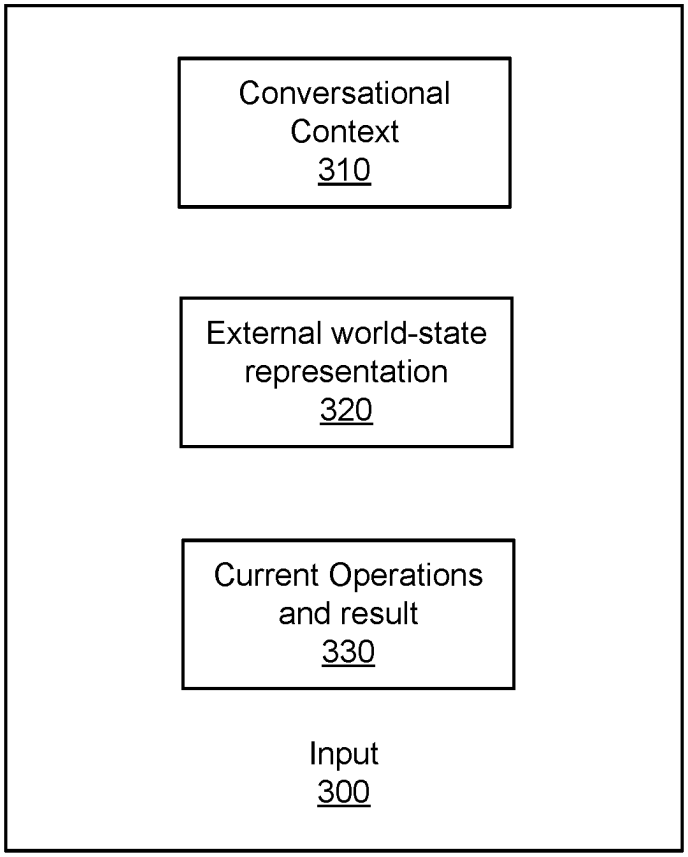

Conversational Context 310
External world-state representation 320
Current Operations and result 330
Input 300

FIGURE 3

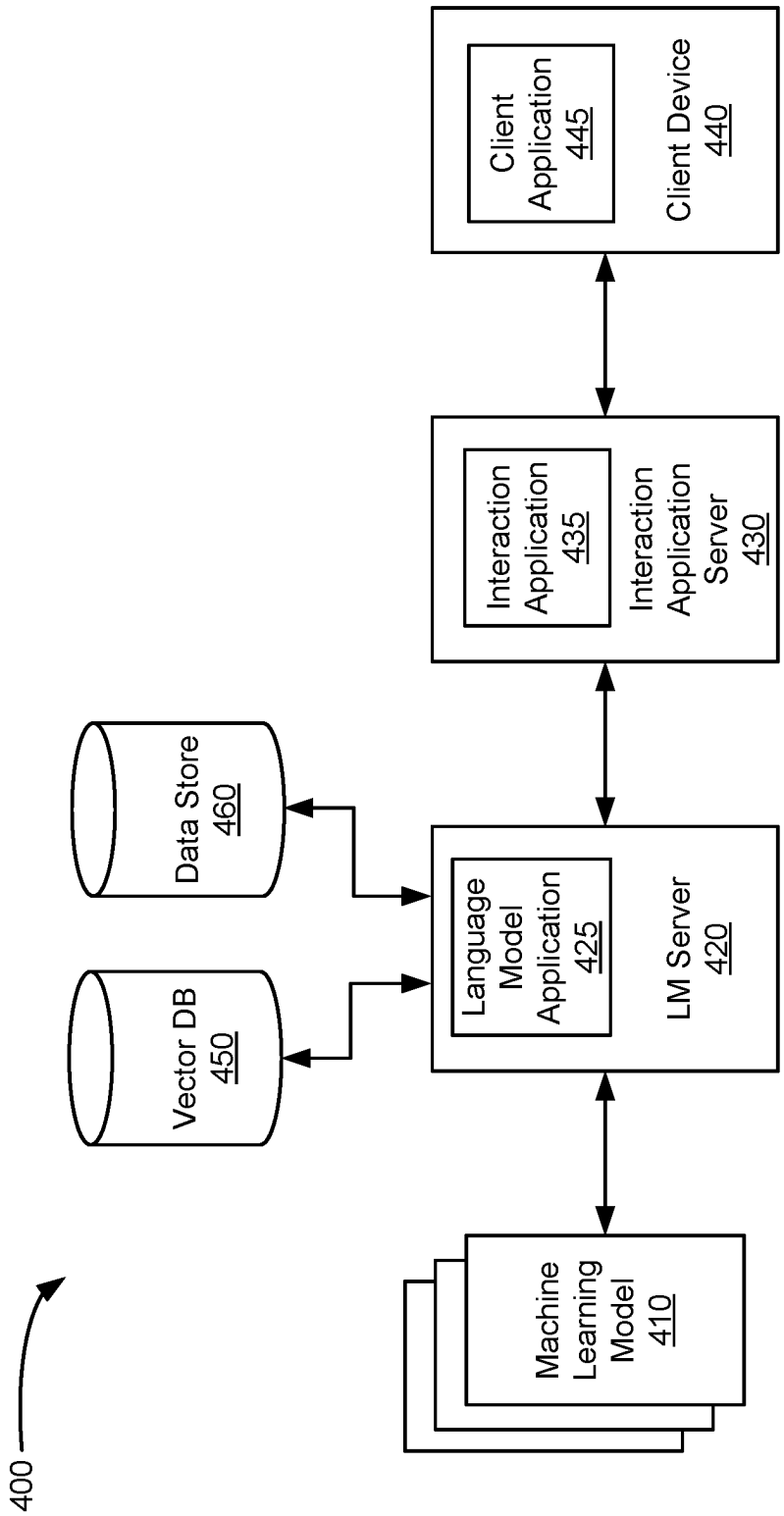

400
Machine Learning Model 410
LM Server 420
Language Model Application 425
Vector DB 450
Data Store 460
Interaction Application Server 430
Interaction Application 435
Client Device 440
Client Application 445

FIGURE 4

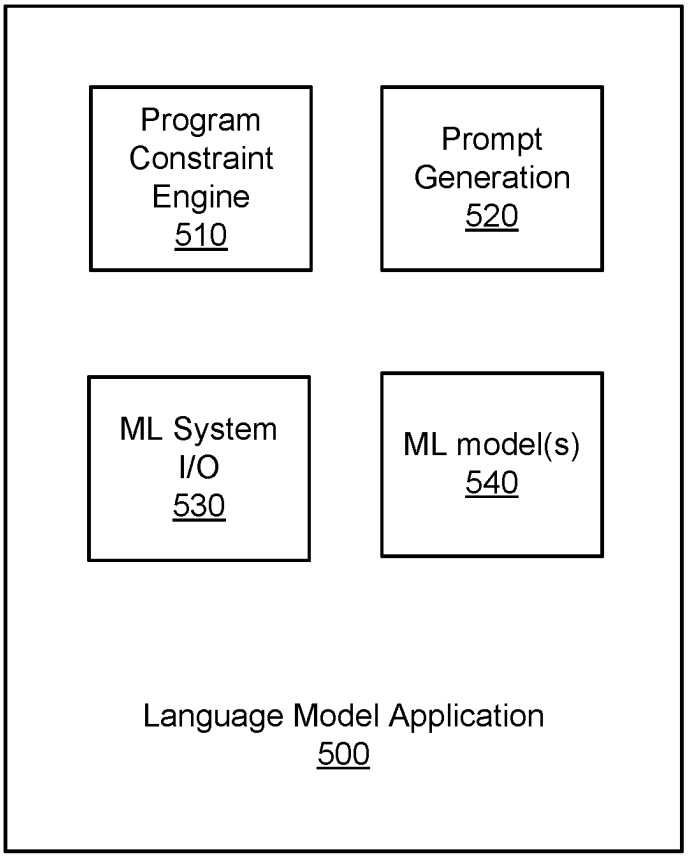

Program Constraint Engine 510
Prompt Generation 520
ML System I/O 530
ML model(s) 540
Language Model Application 500

FIGURE 5

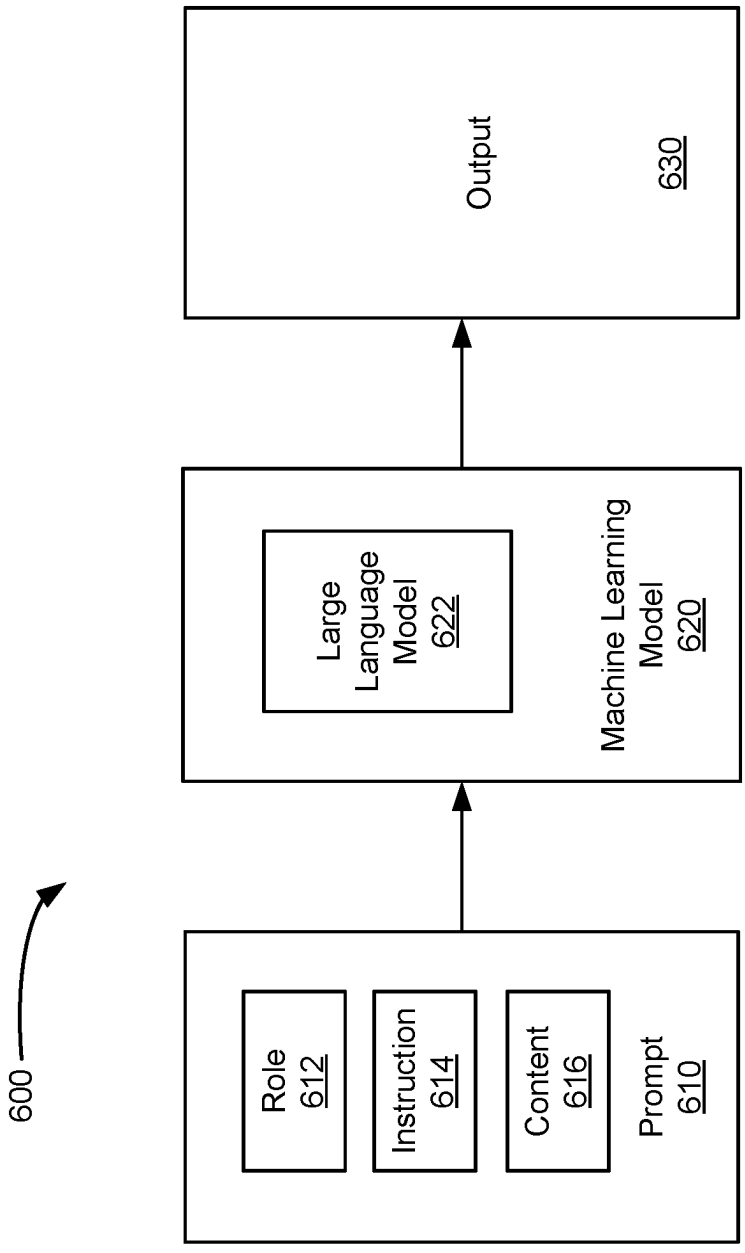

600
Prompt
610
Role
612
Instruction
614
Content
616
Machine Learning
Model
620
Large
Language
Model
622
Output
630

FIGURE 6

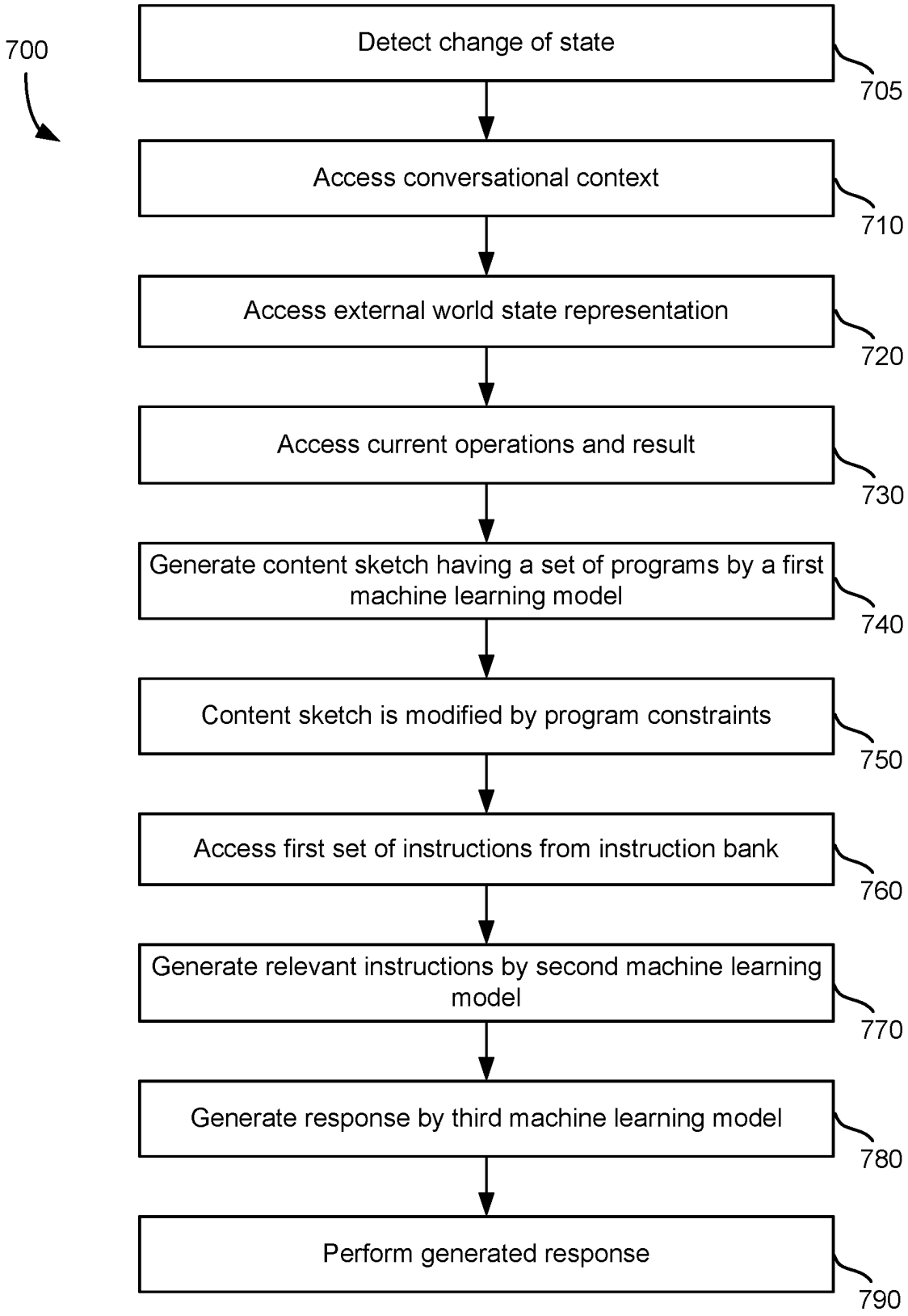
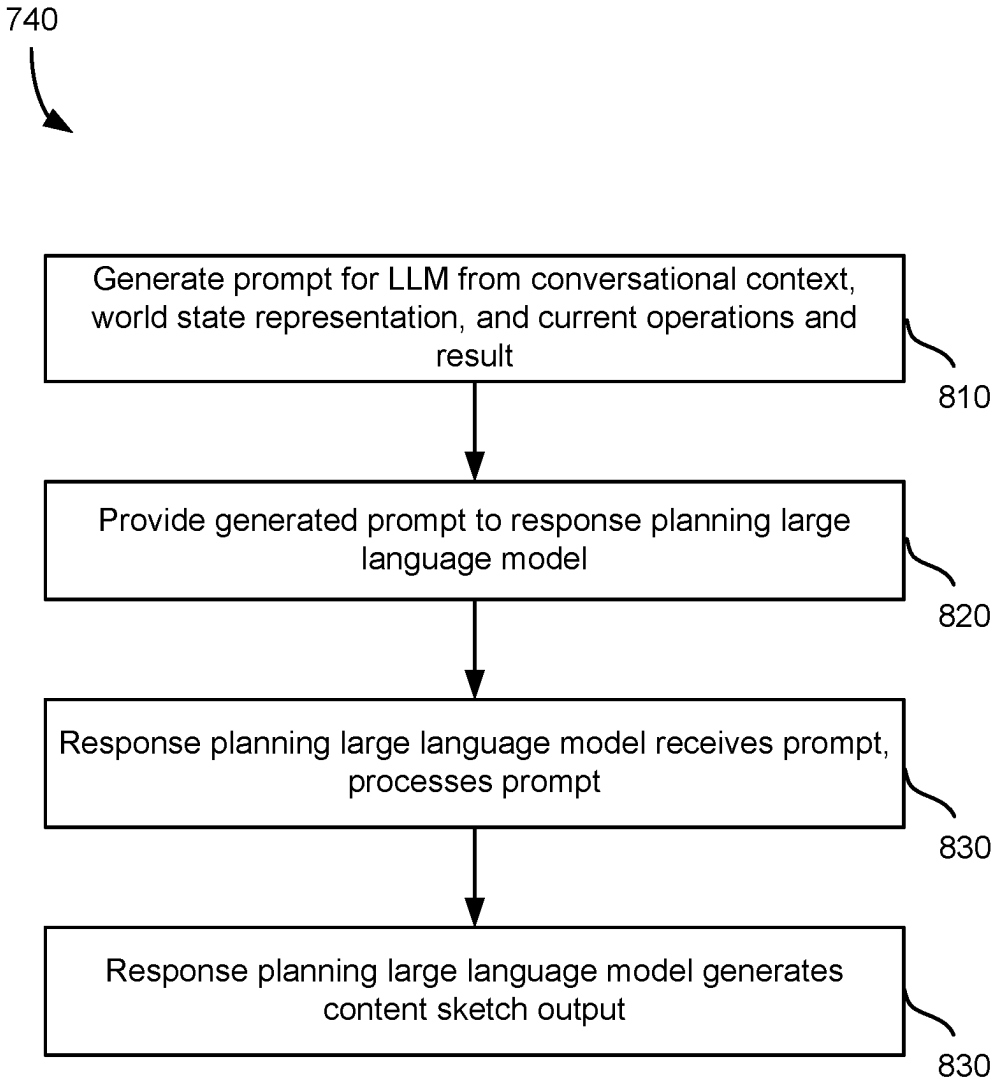

700
Detect change of state
705
Access conversational context
710
Access external world state representation
720
Access current operations and result
730
Generate content sketch having a set of programs by a first machine learning model
740
Content sketch is modified by program constraints
750
Access first set of instructions from instruction bank
760
Generate relevant instructions by second machine learning model
770
Generate response by third machine learning model
780
Perform generated response
790

FIGURE 7


740
Generate prompt for LLM from conversational context, world state representation, and current operations and result
810
Provide generated prompt to response planning large language model
820
Response planning large language model receives prompt, processes prompt
830
Response planning large language model generates content sketch output
830

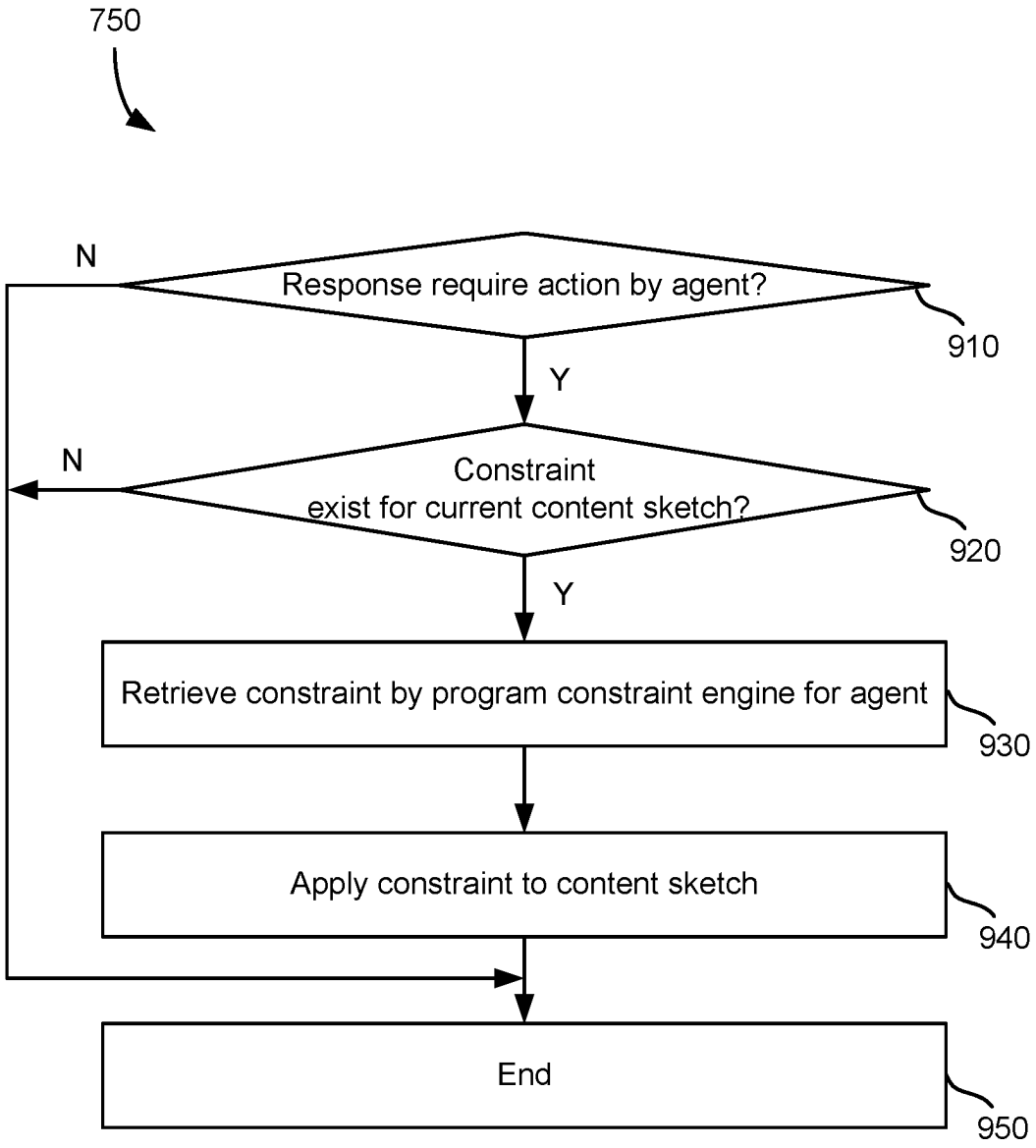

750
N
Response require action by agent?
910
Y
N
Constraint
exist for current content sketch?
920
Y
Retrieve constraint by program constraint engine for agent
930
Apply constraint to content sketch
940
End
950

FIGURE 9

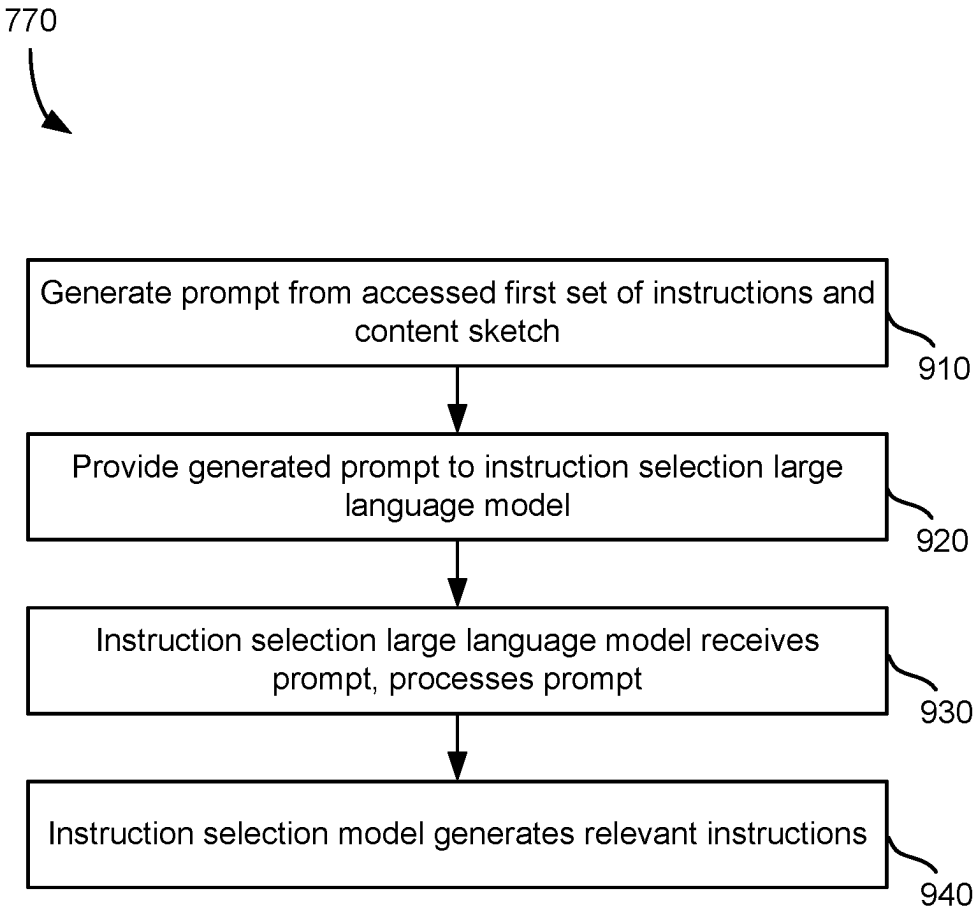

770
Generate prompt from accessed first set of instructions and content sketch
910
Provide generated prompt to instruction selection large language model
920
Instruction selection large language model receives prompt, processes prompt
930
Instruction selection model generates relevant instructions
940

FIGURE 9

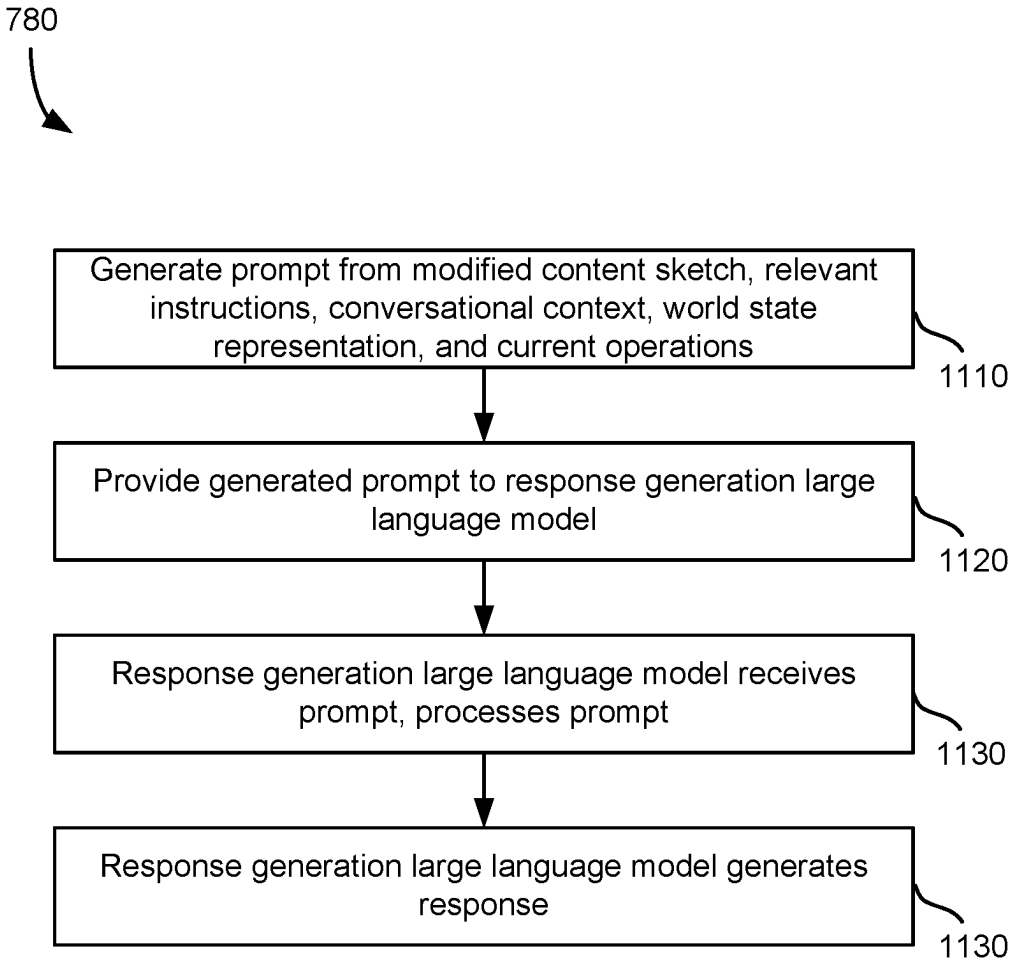

780
Generate prompt from modified content sketch, relevant instructions, conversational context, world state representation, and current operations
1110
Provide generated prompt to response generation large language model
1120
Response generation large language model receives prompt, processes prompt
1130
Response generation large language model generates response
1130

FIGURE 11

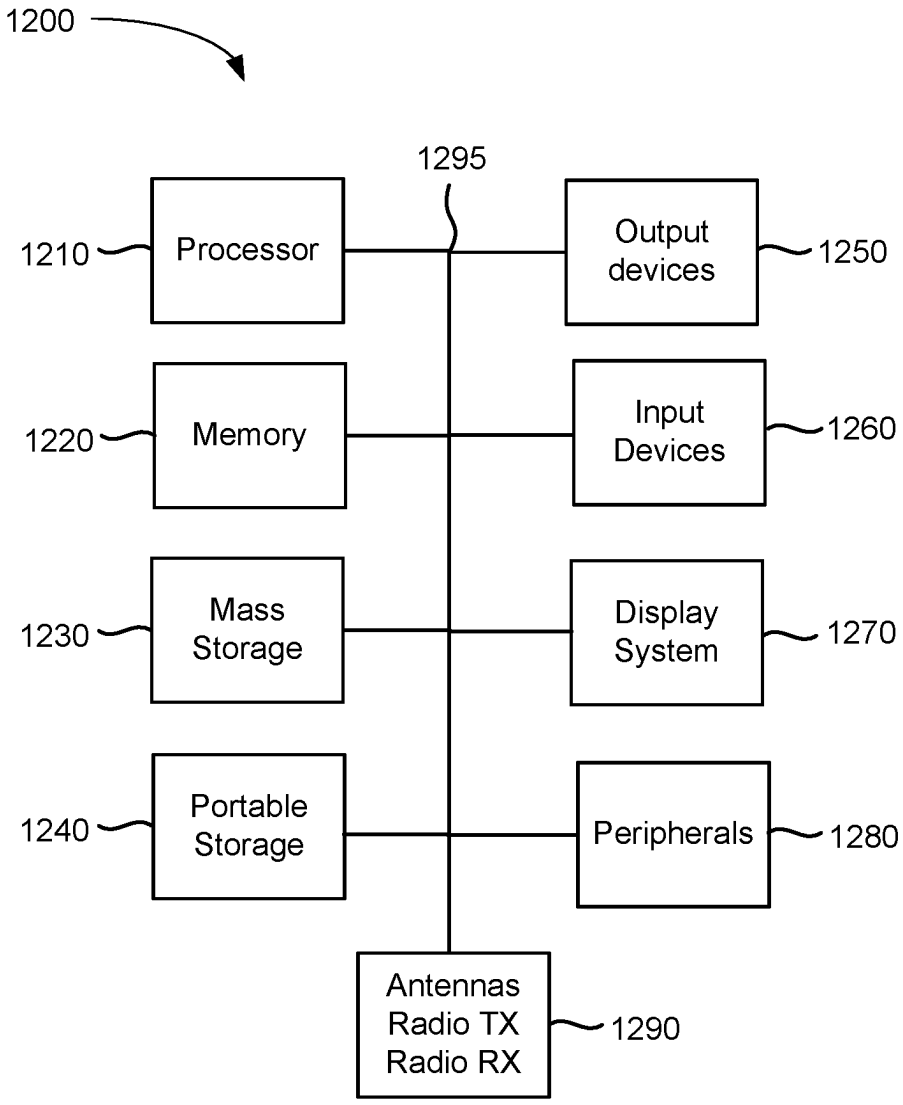

1200
1295
1210
Processor
Output devices
1250
1220
Memory
Input Devices
1260
1230
Mass Storage
Display System
1270
1240
Portable Storage
Peripherals
1280
Antennas Radio TX Radio RX
1290

FIGURE 12

AUTOMATED AGENT CHAIN-OF-THOUGHT RESPONSE GENERATION USING STRUCTURE-BASED CONSTRAINTS

REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the priority benefit of U.S. provisional patent application 63/551,536, filed on Feb. 9, 2024, titled "Automated Agent Chain-of-Thought Response Generation Using Structure-Based Constraint," the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] Computer systems that reason, plan, and communicate with machine learning models often rely on multi-step generation to determine an appropriate action or response. In some cases, a computer system produces a natural language response in response to a customer query. Previous systems utilize pre-planned messages which are provided to a customer based on the customer query. These pre-planned messages limit the scope of a response allowed for the computer system, and often times are not correct. What is needed is an improved system for interacting with a customer.

SUMMARY OF THE INVENTION

[0003] The present technology, roughly described, generates a response to a change of state by an automated agent using structure-based constraints. The system receives input regarding an interaction with a client, external data, and current operations data. The received input is used to generate a content sketch. In some instances, a response planning model receives the input and generates the content sketch. The content sketch can include a plan for how to generate the response. The content sketch can be constrained, unconstrained, or include both constrained and unconstrained components.

[0004] In some instances, the content sketch may be expressed as or include a program or some other schematized abstract meaning representation. The program language can be constrained to a set of known atoms, such as for example particular specified function, values, and flow control. In some instances, the content sketch can be represented in an unconstrained form such as arbitrary text or a vectorial representation.

[0005] Relevant instructions for generating a response are generated from the content sketch and an instruction bank. The relevant instructions are then used to generate a response. In some instances, an instruction selection model is used to generate the relevant instructions, and a response generation model is used to generate the response. The generated response may then be executed by the automated agent system.

[0006] In some instances, the present technology performs a method for generating a response to a change of state using structure-based constraints. The method begins with detecting a change of state by an automated agent during a conversation. Conversational context, external world state representation, and current agent operations data associated with the conversation are accessed. A content sketch is generated based on the accessed conversational context, external world state representation, and current agent operations data. The content sketch is generated using a first machine learning model, wherein the content sketch includes a set of one or more programs. A response is prepared based at least in part on the content sketch and a first set of instructions, the first set of instructions identified based on the content sketch and the change of state.

[0007] In some instances, the present technology includes a non-transitory computer readable storage medium having embodied thereon a program, the program being executable by a processor to generate a response to a change of state using structured based constraints. The process begins with detecting a change of state by an automated agent during a conversation. Conversational context, external world state representation, and current agent operations data associated with the conversation are accessed. A content sketch is generated based on the accessed conversational context, external world state representation, and current agent operations data. The content sketch is generated using a first machine learning model, wherein the content sketch includes a set of one or more programs. A response is prepared based at least in part on the content sketch and a first set of instructions, the first set of instructions identified based on the content sketch and the change of state.

[0008] In some instances, the present technology includes a system having one or more servers, each including memory and a processor. One or more modules are stored in the memory and executed by one or more of the processors to detect a change of state by an automated agent during a conversation, access conversational context, external world state representation, and current agent operations data associated with the conversation, generate a content sketch based on the accessed conversational context, external world state representation, and current agent operations data, the content sketch generated using a first machine learning model, the content sketch including a set of one or more programs, and prepare a response based at least in part on the content sketch and a first set of instructions, the first set of instructions identified based on the content sketch and the change of state.

BRIEF DESCRIPTION OF FIGURES

[0009] FIG. **1** illustrates a flow chart for generating a response to a change of state by an automated agent using structured based constraints.

[0010] FIG. **2** illustrates more detail for the flow chart of FIG. **1**.

[0011] FIG. **3** illustrates a block diagram of input received for a response planning model.

[0012] FIG. **4** illustrates a block diagram of a system for generating a response to a change of state by an automated agent using structured based constraints.

[0013] FIG. **5** illustrates a block diagram of an automated agent application.

[0014] FIG. **6** illustrates a block diagram of dataflow for a machine learning model.

[0015] FIG. **7** illustrates a method for implementing a structured chain of thought.

[0016] FIG. **8** illustrates a method for generating a content sketch.

[0017] FIG. **9** illustrates a method for modifying a content sketch based on program constraints.

[0018] FIG. **10** illustrates a method for generating relevant instructions by a machine learning model.

[0019] FIG. **11** illustrates a method of generating a response by a machine learning model.

[0020] FIG. **12** is a block diagram of a computing environment.

DETAILED DESCRIPTION

[0021] The present technology, roughly described, generates a response to a change of state by an automated agent using structure-based constraints. The system receives input regarding an interaction with a client, external data, and current operations data. The received input is used to generate a content sketch. In some instances, a response planning model receives the input and generates the content sketch. The content sketch can include a plan for how to generate the response. The content sketch can be constrained, unconstrained, or include both constrained and unconstrained components.

[0022] In some instances, the content sketch may be expressed as or include a program or some other schematized abstract meaning representation. The program language can be constrained to a set of known atoms, such as for example particular specified function, values, and flow control. In some instances, the content sketch can be represented in an unconstrained form such as arbitrary text or a vectorial representation.

[0023] Relevant instructions for generating a response are generated from the content sketch and an instruction bank. The relevant instructions are then used to generate a response. In some instances, an instruction selection model selects the relevant instructions from the instruction bank based on the content sketch and the received input, and a response generation model is used to generate the response. The generated response may then be executed by the automated agent system.

[0024] The present application is advantageous over prior systems for several reasons. Previous systems have attempted to generate a response based on conversation data alone. The current system generates a response based on multiple inputs including conversational data, external world state representation, and current operations and results. Further, the present system generates a content sketch based on these multiple inputs. The content sketch is generated as a plan for generating a response, based on the multiple inputs. Additionally, the content sketch is constrained to a set of known functions and values. Hence, the content sketch may include one or more programs, and the constraint applied to the content sketch may further limit, modify, or "constrain" one or more programs in the content sketch in some way.

[0025] In some instances, the advantage of the present technology is that the generated response is more likely to be correct and useful because the content sketch serves as a planning step. The presence of an explicit plan shifts the system from short-horizon decision making to long-horizon decision making.

[0026] The present system is not forced to choose between a set of known responses. Rather, the present system is constrained, through a content sketch, to using a set number of programs, but allows the present system to freely generate a response, conditioned on the constrained choice. In some instances, there may be no limit to the number of programs. While previous systems have attempted use of LLMs to generate totally unconstrained responses, the present technology uses, in some instances, a mixed approach of some constrained pre-planning but still unconstrained responses.

[0027] Some examples of a change of state include, but are not limited to, a message from the user, a response received from a remote procedure call (e.g. whether a reservation attempt succeeded and what the confirmation number is), an overlong delay since the last message received from the user, and, in a robotics context, some sensory input received.

[0028] FIG. **1** illustrates a flow chart for generating a response to a change of state by an automated agent using structure-based constraints. The flowchart of FIG. **1** begins with detecting a change of state for an automated agent at step **110**. The automated agent may be involved with an interaction with a client. The interaction can include a conversation, a navigation of an environment, or other interaction. The change of state may be detected in response to receiving a communication from a client, such as for example through a conversational application between a client and the automated agent. The change of state may also be an operation performed by an automated agent, such as for example determining a location of a destination, a result obtained by an automated agent in response to a client query, or a program executed by the automated agent.

[0029] Once a change state is detected, a content sketch may be generated at step **120**. The content sketch is based on input data received by the present system from a remote source or a local source. The content sketch can include a plan for how to generate a response and be expressed as a program or other schema tied to an abstract meaning representation.

[0030] Relevant instructions may be generated at step **130**. The relevant instructions can be generated from an instruction bank and the content sketch generated at step **120**. The relevant instructions are used to generate a response.

[0031] A response can be generated at step **140**. The response is generated based on one or more of the relevant instructions, the content sketch, and the input data. The input data may include the data used to generate the content sketch at step **120**. The response may be generated by a machine learning model, such as for example a large language model, and may be executed or performed by the automated agent. For example, the response can be a message to the client regarding a flight that was booked in response to a client query, a confirmation number for a car rental, instructions for moving forward in a navigational application, or some other action.

[0032] FIG. **2** illustrates more detail for the flow chart of FIG. **1**. In particular, the flow cart of FIG. **2** provides more detail for steps **120**, **130** and **140** of FIG. **1**.

[0033] Step **120** involves input data **210**, response planning model **220**, content sketch **230**, and program constraint **235**. After detecting a state, response planning model **220** receives input data **210**. The input data can include conversation data, external world state representation data, and operation and results data. Conversation data may include a record of previous turns of an interaction between an automated agent and the client, the world, or some other entity. Conversation data may include the messages exchanged as well as actions taken by the present system in response to the client messages, queries, or other interactions. The external world state representation can include a representation of the state of systems which the automated agent interacts with. Examples of these systems may include sensor inputs, input devices, microphones, and other devices. The operations data may include programs, procedures, and partial reasoning traces generated during the present turn of the interaction

between the automated agent application communicating with a client. The operations data generated in the present turn can be generated to effectuate a goal, for example a program to book a client's flight and the resulting confirmation number. Another example of operation data includes a command to move forward in an environment in the resulting uploaded coordinates from a world model. In some instances, where no operations are performed in the present turn within the interaction, the operations data may include a null.

[0034] The input is received by response planning module **220**. The response planning model can be a machine learning model, content generation logic, or some other tool that can generate a content sketch. In some instances, the input is provided to response planning model **220** in the form of a prompt.

[0035] Model **220** receives the input, processes the input, and generates a content sketch **230**. The content sketch can be expressed as a program or some other schema tied to an abstract meaning representation. In this instance, the program language can be constrained to a set of known atoms, such as particular specified functions, values, and flow control. In some instances, the content sketch may be represented in an unconstrained form such as arbitrary text or vectorial representation. In some instances, the content sketch may include both constrained and unconstrained components.

[0036] A program constraint **235** may be applied to content sketch **232**. The program constraint can constrain a program within the content sketch. The constraint can limit the values of a value, a variable, a particular program to access or execute, or provide some other constraint. For example, a program constraint generated by response planning model **220** may be a program to provide a client with a refund. The program constraint, in this example, may provide that the refund is limited to no more than $100.00. By applying the constraint, the present system can select instructions and/or generate a response more efficiently.

[0037] Within step **130**, content sketch **230** provided to instruction selection model **240** along with a set of instructions from instruction bank **245**. The instruction bank may include a collection of instructions expressed in natural language or formal rules. The collection of instructions may validate the content sketch and optionally provide additional information for how to generate a response. There may be general instructions pertaining to the agent in all scenarios, as well as specific instructions for specific scenarios. In some instances, for example as an optimization, when a parser or recognizer is used to validate a constrained content sketch, a validation can occur in-line rather than post hoc by, for example, constrained decoding.

[0038] The instruction selection model selects a relevant subset of the set of instructions from instruction bank **245** based on the content sketch **230**. The relevant instructions can be generated by a machine learning model, such as a large language model, which receives the content sketch and a set of instructions from the instruction bank as input. The machine learning model processes the input and then outputs the instructions.

[0039] In step **140**, a response generation model generates a response to the detected change of state. Response generation model **260** receives the relevant instructions, content sketch **230**, and input **210**. In some instances, these inputs may be received in the form of a prompt for a large language model that implements response generation module **260**. The response generation model receives the inputs, processes the inputs to generate a response, and outputs a generated response **270** at step **140**.

[0040] The generated response **270** may be generated by a machine learning model, such as for example a large language model. For example, the response can be a message to the client regarding a flight that was booked in response to a client query, a confirmation number for a car rental, instructions for moving forward in a navigational application, or some other action.

[0041] FIG. **3** illustrates a block diagram of input received by a response planning model. Input **300** of FIG. **3** provides more detail for input **210** of FIG. **2**. Input **300** includes conversational context, external world state representations, and current operations and results. Conversational context can include a record of previous turns of interactions between an automated agent and a client. For example, when the automated agent provides a customer service system. In some instances, the interaction may be between the automated agent and the world, for example in the case of a navigation system. The conversation context may include data exchange between the two entities during the interaction. For example, for a customer service system, the conversational context may include text messages provided by each of the automated agent and the client to each other during the interaction. The conversational context may also include actions performed by the automated agent in response to client messages or other events. In the case of a navigation system, the conversational context may include or search terms for a destination, and directions provided. The conversational context may also provide speed information and other data for a navigation system.

[0042] The external world state presentation may include a representation of the state of systems with which the automated agent interacts. The agent may interact with sensor inputs, global positioning system inputs, computing device inputs, and other inputs that provide data or information to an automated agent during an interaction with a client.

[0043] Current operations and results include programs, procedures, and partial reasoning traces generated during the present interaction by the present system in order to effectuate a goal. For example, the current operations and result may include a program to book a client's flight and the resulting confirmation number, a car rental and a confirmation number, or a command to move forward in the environment and the resulting updated coordinates from the world model. In some instances, the current operations and result may include a null value if no operation is performed.

[0044] FIG. **4** illustrates a block diagram of a system for generating a response to a change of state by an automated agent using structured based constraints. Machine learning model **410** may include one or more models or prediction engines that may receive an input, process the input, and provide an output based on the processing of the input. In some instances, machine learning model **410** may be implemented on LM server **420**, on the same physical or logical machine as language model application **425**. In some instances, machine learning model **410** may be implemented by a large language model, on one or more servers external to LM server **420**. Implementing the machine learning model **410** as one or more large language models is discussed in more detail with respect to FIG. **6**.

[0045] LM server **420** may include an LM application **425**, and may communicate with machine learning model **410**, chat application server **430**, and vector database **450**. LM application **425** may be implemented on one or more servers **420**, may be distributed over multiple servers and platforms, and may be implemented as one or more physical or logical servers.

[0046] LM application **425** may include several modules that implement the functionality described herein. For example, language model application **425** can generate a content sketch, generate relevant instructions, and generate a response using one or more machine learning models **410**. More details for language model application **425** are discussed with respect to FIG. **5**.

[0047] Interaction application server **430** may communicate with LM server **420**, client device **440**, and may implement an interaction over a network, such as for example a "chat," between an automated agent application provided by LM server **420** and client device **440** associated with a client. The interaction may be a chat, text conversation between an automated agent and a client, interaction between a client and a navigation system, or some other interaction.

[0048] Vector database **450** may be implemented as a data store that stores vector data. In some instances, vector database **450** may be implemented as more than one data store, internal to the automated agent system provided by LM server **420** and exterior to system **420**. In some instances, a vector database can serve as an LLMs' long-term memory and expand an LLMs' knowledge base. Vector database **450** can store private and/or confidential data or domain-specific information outside the LLM as embeddings. In some instances, vector database provides an instruction bank to LM application **425**. When a client asks a question to the automated agent system, the system can have the vector database search for the top results, such as for example instructions, most relevant to the received question. Vector database **450** may include data such as prompt templates, instructions, training data, and other data used by LM application **425** and machine learning model **410**.

[0049] In some instances, the present system may include one or more additional data stores, such as data store **460**, in place of or in addition to vector database **450**, at which the system stores searchable data such as instructions, private data, domain-specific data, and other data.

[0050] Each of model **410**, servers **420**-**440**, vector database **450**, and data store **460** may communicate over one or more networks. The networks may include one or more the Internet, an intranet, a local area network, a wide area network, a wireless network, Wi-Fi network, cellular network, or any other network over which data may be communicated.

[0051] In some instances, one or more of machines associated with **410**, **420**, **430**, **440**, **450** and **460** may be implemented in one or more cloud-based service providers, such as for example AWS by Amazon Inc, AZURE by Microsoft, GCP by Google, Inc., Kubernetes, or some other cloud based service provider.

[0052] The system of FIG. **4** illustrates a language model application within a chat system formed with ML model **410**, LM server **420**, interaction application server **430**, and client device **440**. Illustration of the language model in a chat or automated agent system is for purposes of discussion only, and the language model of the present technology is not intended to be limited to chat systems alone.

[0053] FIG. **5** illustrates a block diagram of a language model application. Language model application **500** of FIG. **5** provides more detail for application **425** of the system of FIG. **4**. Language model application **500** includes program constraint engine **510**, prompt generation **520**, machine learning system input-output **530**, and machine learning models **540**.

[0054] Program constraint engine **510** may apply a program constraint to a content sketch. The program constraint may apply a constraint on the programs contained in content sketch **230**. The constraint can limit a program value, variable, a particular program to access or execute, or provide some other constraint. For example, a content sketch generated by response planning model **220** may be a program to provide a client with a refund. The program constraint on the program sketch, in this example, may provide that the refund is limited to no more than $100.00, or that an approval by a manager role is required before a refund is provided that is greater than $100.00. By applying the constraint, the present system can select instructions and/or generate a response more efficiently. Additionally, the system will be more likely to follow its instructions if it can select the instructions accurately.

[0055] Prompt Generation **520** may generate a prompt to be received by measuring learning model, including but not limited to a large language model. Prompt generation **520** may prepare elements of a prompt such as a role, instructions, content, and other data or information within a prompt. A generated prompt may include a request to generate a content sketch, select relevant instructions, or generate a response based on a changed state.

[0056] Machine learning system I/O **530** may provide a prompt as input to a machine learning model and receive an output from the machine learning model. In some instances, machine learning system input/output **530** may provide inputs to and retrieve outputs from response planning module **220**, instruction selection model **240**, in response generation model **260** of the system of FIG. **2**.

[0057] Machine learning models **540** may include one or more models that can receive input and provide an output. The machine learning models may include one or more machine learning models that generate a content sketch, select relevant instructions, prepare a response, prepare a prediction, as well as perform other tasks. The machine learning models **240** can include one or more LLMs, as well as a combination of LLMs and ML models.

[0058] Modules illustrated in language model application **200** are exemplary, and could be implemented in additional or fewer modules. Language model application **200** is intended to at least implement functionality described herein. The design of specific modules, objects, programs, and platforms to implement the functionality is not specific and limited by the modules illustrated in FIG. **2**.

[0059] FIG. **6** is a block diagram of data flow for a machine learning model. The block diagram of FIG. **6** includes prompt **610**, machine learning model **620**, and output **630**.

[0060] Prompt **610** of FIG. **6** can be provided as input to a machine learning model **620**. A prompt can include information or data such as a role **612**, instructions **614**, and content **616**. The role indicates the authority level at which the automated agent is to assume while working to assist a

user. For example, a role can include an entry-level customer service representative, a manager, a director, or some other customer service job with a particular level of permissions and rules that apply to what they can do and cannot do when assisting a customer.

[0061] Instructions **614** can indicate what the machine learning model (e.g., a large language model) is supposed to do with the other content provided in the prompt. For example, the machine learning model instructions may request, via instructions **614**, an LLM to select the most relevant instructions from content **616** to train or guide a customer service representative having a specified role **612**, determine if a predicted response was generated with each instruction followed correctly, determine what function to execute, determine whether or not to transition to a new state within a state machine, and so forth. The instructions can be retrieved or accessed from vector database **450**, data store **460**, a combination of these sources, as well as other sources.

[0062] Content **616** may include data and/or information that can assist an ML model or LLM generate an output. For an ML model, the content can include a stream of data that is put in a processable format (for example, normalized) for the ML model to read. For an LLM, the content can include a user inquiry, retrieved instructions, a content sketch, data associated with the present interaction, external world system, and current operations and data, policy data, checklist and/or checklist item data, programs and functions executed by a state machine, results of an audit or evaluation, and other content. In some instances, where only a portion of the content or a prompt will fit into an LLM input, the content and/or other portions of the prompt can be provided to an LLM can be submitted in multiple prompts.

[0063] Machine learning model **620** of FIG. **6** provides more detail for machine learning model **410** of FIG. **4**. The ML model **620** may receive one or more inputs and provide an output. In some instances, the ML model may predict an output in the form of whether a policy was followed, whether a particular instruction is relevant, or some other prediction.

[0064] ML model **620** may be implemented by a large language model **622**. A large language model is a machine learning model that uses deep learning algorithms to process and understand language. LLMs can have an encoder, a decoder, or both, and can encode positioning data to their input. In some instances, LLMs can be based on transformers, which have a neural network architecture, and have multiple layers of neural networks. An LLM can have an attention mechanism that allows them to focus selectively on parts of text. LLMs are trained with large amounts of data and can be used for different purposes.

[0065] The transformer model learns context and meaning by tracking relationships in sequential data. LLMs receive text as an input through a prompt and provide a response to one or more instructions. For example, an LLM can receive a prompt as an instruction to analyze data. The prompt can include a context (e.g., a role, such as 'you are an agent'), a bulleted list of itemized instructions, and content to apply the instructions to.

[0066] In some instances, the present technology may use an LLM such as a BERT LLM, Falcon 30B on GitHub, Galactica by Meta, GPT-3 by OpenAI, or other LLM. In some instances, machine learning model **415** may be implemented by one or more other models or neural networks.

[0067] Output **630** is provided by machine learning model **620** in response to processing prompt **610** (e.g., an input). For example, when the prompt includes a request that the machine learning model identify the most relevant instructions from a set of content, the output will include a list of the most relevant instructions. In some instances, when the prompt includes a request that the machine learning model determine if an automated agent properly followed a set of instructions, a policy, or a checklist item during a conversation with a user, the machine learning model may return a confidence score, prediction, or other indication as to whether the instructions were followed correctly by the automated agent.

[0068] FIG. **7** illustrates a flow chart for generating a response to a change of state by an automated agent using structured based constraints. First, a change of state is detected at step **705**. The change of state may be a new communication received in the interaction between the automated agent system and a client, an operation result received by the automated agent system, or some other event.

[0069] Once the change of state is detected, a response planning model is used to determine a content sketch. To generate the content sketch, the response planning model is provided with an input. The input can include conversational context, external world state representation, and current operations and results.

[0070] Conversational context is accessed at step **710**. The conversational context can include a record of previous turns of interactions between the automated agent system and a client, such as for example in a customer service system environment. In some instances, the conversational context includes a record of previous turns of interactions between the automated agent system and the world, such as for example in the case of a navigation system. In some instances, the conversation context input provided as input to the response planning model is based on, a digest of, or trace of the record of previous turns of interactions between the system and the other entity in the current interaction.

[0071] External world state representation is accessed at step **720**. The external state representation includes data and/or a representation of the state of systems with which the automated agent interacts. Examples of these systems include sensors, computing device keyboards or other inputs, or other devices that can provide data, signals, or information to the automated agent system.

[0072] Current operations and results are accessed at step **730**. The current operations can include programs, procedures, partial reasoning traces, and other operations generated during the current turn by the system in an interaction with an entity (i.e., a client, the world, or other entity). The operation (program, procedure, trace, etc.) performed during the current turn can be in order to effectuate a goal by the automated agent system. Examples of operations and goals include a program to book a client's flight and the resulting confirmation number, a procedure to process a refund, an indication to move forward in an environment and the resulting updated coordinates from the world-model.

[0073] A content sketch can be generated at step **740**. A content sketch is a plan for generating a response to the change in state. The content sketch can include a set of programs and is generated by a response planning model. In some instances, the response planning model is implemented as a machine learning model. In some instances, the

content sketch is generated by providing inputs to the response planning model as shown in FIG. **2**. More details for generating a content sketch are discussed with respect to the method of FIG. **8**.

[0074] A content sketch output is modified by one or more program constraints at step **750**. The content sketch may include one or more programs to execute based on the input received by the system. The one or more programs may be constrained to make them even more relevant to handling the change of state. Modifying a content sketch using program constraints is discussed in more detail with respect to the method of FIG. **10**.

[0075] A first set of instructions is accessed from an instruction bank at step **760**. In some instances, information from the change of state, such as content from an interaction between an automated agent system and client entity, is used to retrieve a first set of instructions from an instruction bank **245**. The instruction bank **245** may be located at vector database **450**, data store **460**, locally from language model server **420**, or some other location. The instructions contained in the instructions can be expressed in natural language or formal rules (e.g., parser/recognizer). The instructions can validate the content sketch, and can provide some additional information for how to generate a response to the change in state. The instructions can include general instructions that pertain to the automated agent in all scenarios as well as specific instructions that should only be followed in specific circumstances (e.g., "do not state [X] until information [Y] is obtained.")

[0076] Relevant instructions may be generated by a machine learning model at step **770**. The relevant instructions may be a subset of the instructions retrieved from the instruction bank and include instructions that are deemed most relevant to processing the change of state. In some instances, the first set of instructions and the content sketch may be provided to an instruction selection model to generate the relevant instructions. Generating relevant instructions is discussed in more detail with respect to the method of FIG. **9**.

[0077] A response to the change of state is generated by a third machine learning model at step **780**. The response is based on the relevant instructions, content sketch, and the input received by the automated agent system. Generating a response by third machine learning model is discussed in more detail below with respect to the method of FIG. **11**.

[0078] The generated response is executed at step **790**. The response may be performed in response to the change of state detected at step **705**. The response may include generating a message for a client based on a client's recent message, performing an action, executing a program, processing a result, or some other response.

[0079] FIG. **8** illustrates a flow chart for generating a content sketch. The method of FIG. **8** provides more detail for step **740** in the method of FIG. **7**. In some instances, the content sketch is generated when a response planning model is implemented as a large language model (LLM). When implemented by an LLM, a prompt is generated for the LLM from conversational context, world state representation, and current operations and results at step **810**. The prompt may include the role of the automated agent or system, instructions to the large language model, and content. The generated prompt is provided to the response planning model at step **820**. The response planning model receives the prompt and processes the prompt at step **830**. The response planning model then generates a content sketch output at step **830**.

A content sketch can include one or more programs and have several forms. A first example of a content sketch is below:

```
(r / respond-failure
:booking (b / booking-592653589)
:user (u / user-2643383279)
:reason (r1/ reason-date-constraint-violated)
```

[0080] The content sketch above is simple, where there is no ability or need to generate free text. The response is generated from a predefined set of "atoms." The "reason" is given as one element from a set of possible reasons. The possible reasons are represented as an "enum" (short for "enumerated type").

[0081] A second example of a content sketch is below:

```
(r / respond-failure
:booking (b / booking-592653589)
:user (u / user-2643383279)
:reason "Booking outside date window"
```

[0082] The second content sketch example, above, allows for generation of free text to provide an explanation for the response. A third example of a content sketch is below:

```
(p / possible
:ARG1 (b / book
   :ARG0 (i / I)
   :ARG1 (r / reservation)
   :booking-id 592653589
   :user user-2643383279
   :time (n / now))
:cause (o / outside
   :ARG0 r
   :ARG1 (w / window
      :ARG1-of (p2 / permit
         :polarity -)
      :modifier (d / date)))
:polarity -)
```

[0083] The third content sketch example, above, is an alternative expression of the second content sketch example. The third content sketch example avoids free text by using a larger set of atoms than the second content sketch example. Hence, a content sketch can include a constraint that the response does not include freely generated text.

[0084] FIG. **9** illustrates a flow chart for modifying a content sketch based on program constraints. The method of FIG. **9** provides more detail for step **750** in the method of FIG. **7**. First, a determination is made as to whether the response requires an action by an agent at step **910**.

[0085] The constraint can limit a value, variable, a particular program to access or execute, or provide some other constraint. For example, a content sketch used to generate a response may include a program to provide a client with a refund. The program constraint, in this example, may provide that the refund is limited to no more than $100.00. By applying the constraint, the present system can select instructions and/or generate a response more efficiently be reducing the work required to generate a more focused response.

[0086] If the response does not require an action by an automated agent, the method of FIG. **9** ends at step **950**. If a response is required, a determination is made as to whether a constraint exists for the current content sketch at step **920**. If no constraint exists, the method of FIG. **9** ends at step **950**. If a constraint does exist for the content sketch, a program constraint engine retrieves a constraint for the current content sketch at step **930**. The constraint may then be applied to the content sketch at step **940**.

[0087] FIG. **10** illustrates a flow chart for generating relevant instructions by a machine learning model. The method of FIG. **10** provides more detail for step **770** in the method of FIG. **7**. A prompt is generated from the accessed first set of instructions and the content sketch at step **1010**. The prompt can include a role for the automated agent system, instructions to the model to identify the most relevant instructions, and content that includes a set of instructions from an instruction bank and a content sketch. The generated prompt is then provided to an instruction selection model at step **1020**. The instruction selection model receives and processes the prompt at step **1030**. The instruction selection model then generates relevant instructions at step **1040**. The instructions will be selected as a subset of the instruction bank set of instructions based on the one or programs or other content within the content sketch.

[0088] FIG. **11** illustrates a flow chart of generating a response by a machine learning model. The method of FIG. **11** provides more detail for step **780** of the method of FIG. **7**. First, a prompt is generated from a modified content sketch, relevant instructions, conversational context, world state representation, and current operations and results at step **1110**. The prompt includes a role for the automated agent, instructions for the machine learning model, in some instances implemented as a large language model, to generate a response to the change in state, and content including the modified content sketch, relevant instructions, and input (conversational context, world state representation, and current operation and result). The generated prompt is then provided to a response generation model at step **1120**. The response generation model receives the prompt and processes the prompt at step **1130**. The response generation model then generates a proposed response as an output based on the prompt at step **1130**.

[0089] FIG. **12** is a block diagram of a computing environment for implementing the present technology. System **1200** of FIG. **12** may be implemented in the contexts of the likes of machines that implement machine learning model **110**, application server **120**, chat application server **130**, and simulation server **140**. The computing system **1200** of FIG. **12** includes one or more processors **1210** and memory **1220**. Main memory **1220** stores, in part, instructions and data for execution by processor **1210**. Main memory **1220** can store the executable code when in operation. The system **1200** of FIG. **12** further includes a mass storage device **1230**, portable storage medium drive(s) **1240**, output devices **1250**, user input devices **1260**, a graphics display **1270**, and peripheral devices **1280**.

[0090] The components shown in FIG. **12** are depicted as being connected via a single bus **1295**. However, the components may be connected through one or more data transport means. For example, processor unit **1210** and main memory **1220** may be connected via a local microprocessor bus, and the mass storage device **1230**, peripheral device(s) **1280**, portable storage device **1240**, and display system **1270** may be connected via one or more input/output (I/O) buses.

[0091] Mass storage device **1230**, which may be implemented with a magnetic disk drive, an optical disk drive, a flash drive, or other device, is a non-volatile storage device for storing data and instructions for use by processor unit **1210**. Mass storage device **1230** can store the system software for implementing embodiments of the present invention for purposes of loading that software into main memory **1220**.

[0092] Portable storage device **1240** operates in conjunction with a portable non-volatile storage medium, such as a floppy disk, compact disk or Digital video disc, USB drive, memory card or stick, or other portable or removable memory, to input and output data and code to and from the computer system **1200** of FIG. **12**. The system software for implementing embodiments of the present invention may be stored on such a portable medium and input to the computer system **1200** via the portable storage device **1240**.

[0093] Input devices **1260** provide a portion of a user interface. Input devices **1260** may include an alpha-numeric keypad, such as a keyboard, for inputting alpha-numeric and other information, a pointing device such as a mouse, a trackball, stylus, cursor direction keys, microphone, touchscreen, accelerometer, and other input devices. Additionally, system **1200** as shown in FIG. **12** includes output devices **1250**. Examples of suitable output devices include speakers, printers, network interfaces, and monitors.

[0094] Display system **1270** may include a liquid crystal display (LCD) or other suitable display device. Display system **1270** receives textual and graphical information and processes the information for output to the display device. Display system **1270** may also receive input as a touchscreen.

[0095] Peripherals **1280** may include any type of computer support device to add additional functionality to the computer system. For example, peripheral device(s) **1280** may include a modem or a router, printer, and other device.

[0096] The system of **1200** may also include, in some implementations, antennas, radio transmitters and radio receivers **1290**. The antennas and radios may be implemented in devices such as smart phones, tablets, and other devices that may communicate wirelessly. The one or more antennas may operate at one or more radio frequencies suitable to send and receive data over cellular networks, Wi-Fi networks, commercial device networks such as a Bluetooth device, and other radio frequency networks. The devices may include one or more radio transmitters and receivers for processing signals sent and received using the antennas.

[0097] The components contained in the computer system **1200** of FIG. **12** are those typically found in computer systems that may be suitable for use with embodiments of the present invention and are intended to represent a broad category of such computer components that are well known in the art. Thus, computer system **1200** of FIG. **12** can be a personal computer, handheld computing device, smart phone, mobile computing device, tablet computer, workstation, server, minicomputer, mainframe computer, or any other computing device. The computer can also include different bus configurations, networked platforms, multiprocessor platforms, etc. The computing device can be used to implement applications, virtual machines, computing nodes, and other computing units in different network com-

puting platforms, including but not limited to AZURE by Microsoft Corporation, Google Cloud Platform (GCP) by Google Inc., AWS by Amazon Inc., IBM Cloud by IBM Inc., and other platforms, in different containers, virtual machines, and other software. Various operating systems can be used including UNIX, LINUX, WINDOWS, MACINTOSH OS, CHROME OS, IOS, ANDROID, as well as languages including Python, PHP, Java, Ruby,.NET, C, C++, Node.JS, SQL, and other suitable languages.

[0098] The foregoing detailed description of the technology herein has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the technology to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. The described embodiments were chosen to best explain the principles of the technology and its practical application to thereby enable others skilled in the art to best utilize the technology in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the technology be defined by the claims appended hereto.

1. A method for generating a response to a change of state using structured based constraints, comprising:

detecting a change of state by an automated agent during a conversation;

accessing conversational context, external world state representation, and current agent operations data associated with the conversation;

generating a content sketch based on the accessed conversational context, external world state representation, and current agent operations data, the content sketch generated using a first machine learning model, the content sketch including a set of one or more programs; and

preparing a response based at least in part on the content sketch and a first set of instructions, the first set of instructions identified based on the content sketch and the change of state.

2. The method of claim **1**, further including applying a program constraint to the content sketch before the response is prepared, the program constraint associated with at least one program in a set of one or more programs included in the content sketch.

3. The method of claim **1**, further comprising:

accessing instructions from an instruction bank; and

selecting a set of relevant instructions as a sub-set of the instructions accessed from the instruction bank, the set of relevant instructions selected at least in part on the content sketch, the set of relevant instructions being relevant to preparing a response to the communication.

4. The method of claim **1**, wherein identified instructions are selected as a subset of relevant instructions from a second larger set of instructions.

5. The method of claim **1**, wherein the content sketch provides a constraint that the response does not include freely generated text.

6. The method of claim **1**, wherein the content sketch allows for generation of free text to provide an explanation for the response.

7. The method of claim **1**, wherein the response is generated by a large language machine, wherein the prompt for the large language machine is based at least in part on the content sketch, the relevant instructions, and conversational context, external world state representation, and current agent operations data.

8. The method of claim **1**, wherein the change of state includes receipt of a message from a client.

9. The method of claim **1**, wherein the change of state includes a development while executing a program related to a client request.

10. A non-transitory computer readable storage medium having embodied thereon a program, the program being executable by a processor to generating a response to a change of state using structured based constraints, the method comprising:

detecting a change of state by an automated agent during a conversation;

accessing conversational context, external world state representation, and current agent operations data associated with the conversation;

generating a content sketch based on the accessed conversational context, external world state representation, and current agent operations data, the content sketch generated using a first machine learning model, the content sketch including a set of one or more programs; and

preparing a response based at least in part on the content sketch and a first set of instructions, the first set of instructions identified based on the content sketch and the change of state.

11. The non-transitory computer readable storage medium of claim **10**, further including applying a program constraint to the content sketch before the response is prepared, the program constraint associated with at least one program in a set of one or more programs included in the content sketch.

12. The non-transitory computer readable storage medium of claim **10**, the method further comprising:

accessing instructions from an instruction bank; and

selecting a set of relevant instructions as a sub-set of the instructions accessed from the instruction bank, the set of relevant instructions selected at least in part on the content sketch, the set of relevant instructions being relevant to preparing a response to the communication.

13. The non-transitory computer readable storage medium of claim **10**, wherein identified instructions are selected as a subset of relevant instructions from a second larger set of instructions.

14. The non-transitory computer readable storage medium of claim **10**, wherein the content sketch provides a constraint that the response does not include freely generated text.

15. The non-transitory computer readable storage medium of claim **10**, wherein the content sketch allows for generation of free text to provide an explanation for the response.

16. The non-transitory computer readable storage medium of claim **10**, wherein the response is generated by a large language machine, wherein the prompt for the large language machine is based at least in part on the content sketch, the relevant instructions, and conversational context, external world state representation, and current agent operations data.

17. The non-transitory computer readable storage medium of claim **10**, wherein the change of state includes receipt of a message from a client.

18. The non-transitory computer readable storage medium of claim **10**, wherein the change of state includes a development while executing a program related to a client request.

19. A system for generating a response to a change of state using structured based constraints, comprising:

one or more servers, wherein each server includes a memory and a processor; and

one or more modules stored in the memory and executed by at least one of the one or more processors to detect a change of state by an automated agent during a conversation, access conversational context, external world state representation, and current agent operations data associated with the conversation, generate a content sketch based on the accessed conversational context, external world state representation, and current agent operations data, the content sketch generated using a first machine learning model, the content sketch including a set of one or more programs, and prepare a response based at least in part on the content sketch and a first set of instructions, the first set of instructions identified based on the content sketch and the change of state.

20. The system of claim **1**, the one or more modules further executable to apply a program constraint to the content sketch before the response is prepared, the program constraint associated with at least one program in a set of one or more programs included in the content sketch.

* * * * *