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(54) **ARTIFICIAL INTELLIGENCE DIGITAL AGENT**

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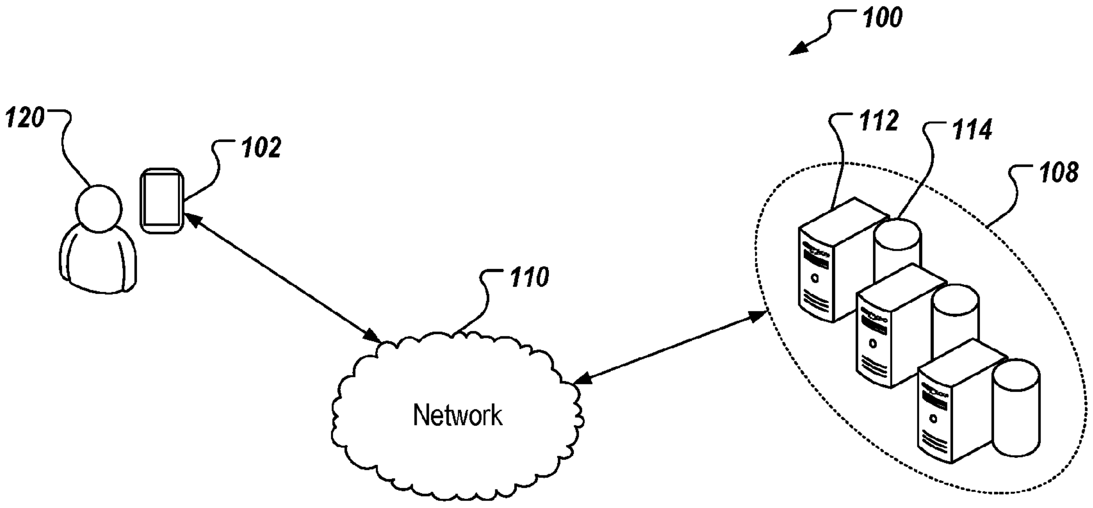
(57) **ABSTRACT**

Implementations are directed to receiving communication data from a device, the communication data including data input by a user of the device, receiving text data based on the communication data, providing an intent set and an entity set based on processing the text data through an artificial intelligence service, the intent set including one or more intents indicated in the text data, the entity set including one or more entities indicated in the text data, the artificial intelligence service implementing a convolution neural networks (CNN), identifying a set of actions based on one or more of the text data, the intent set, and the entity set, receiving a set of results including at least one result from executing an action of the set of actions, providing result data, and transmitting the result data to the device.



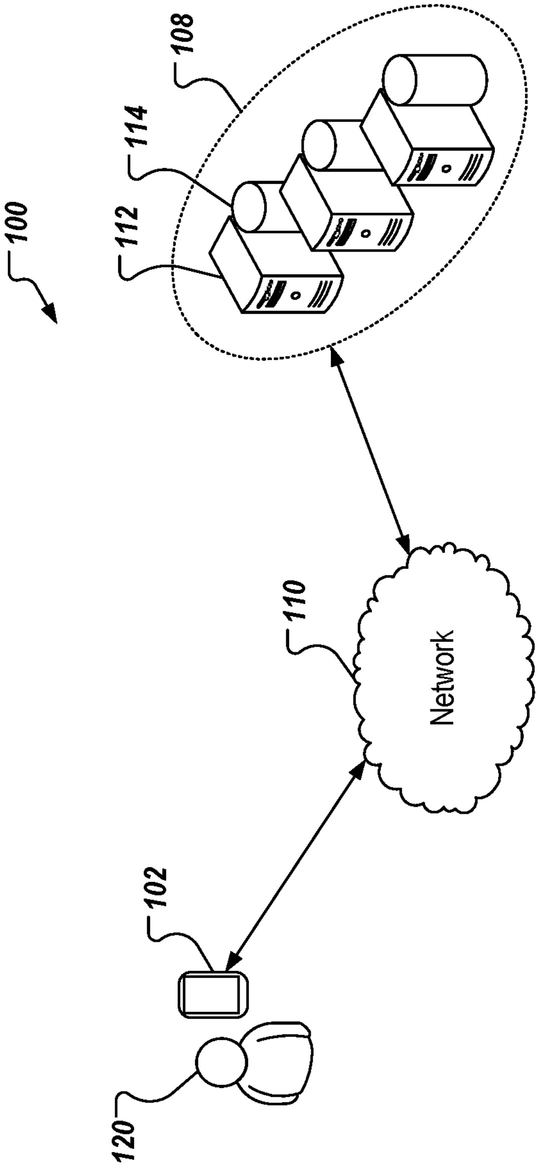


FIG. 1

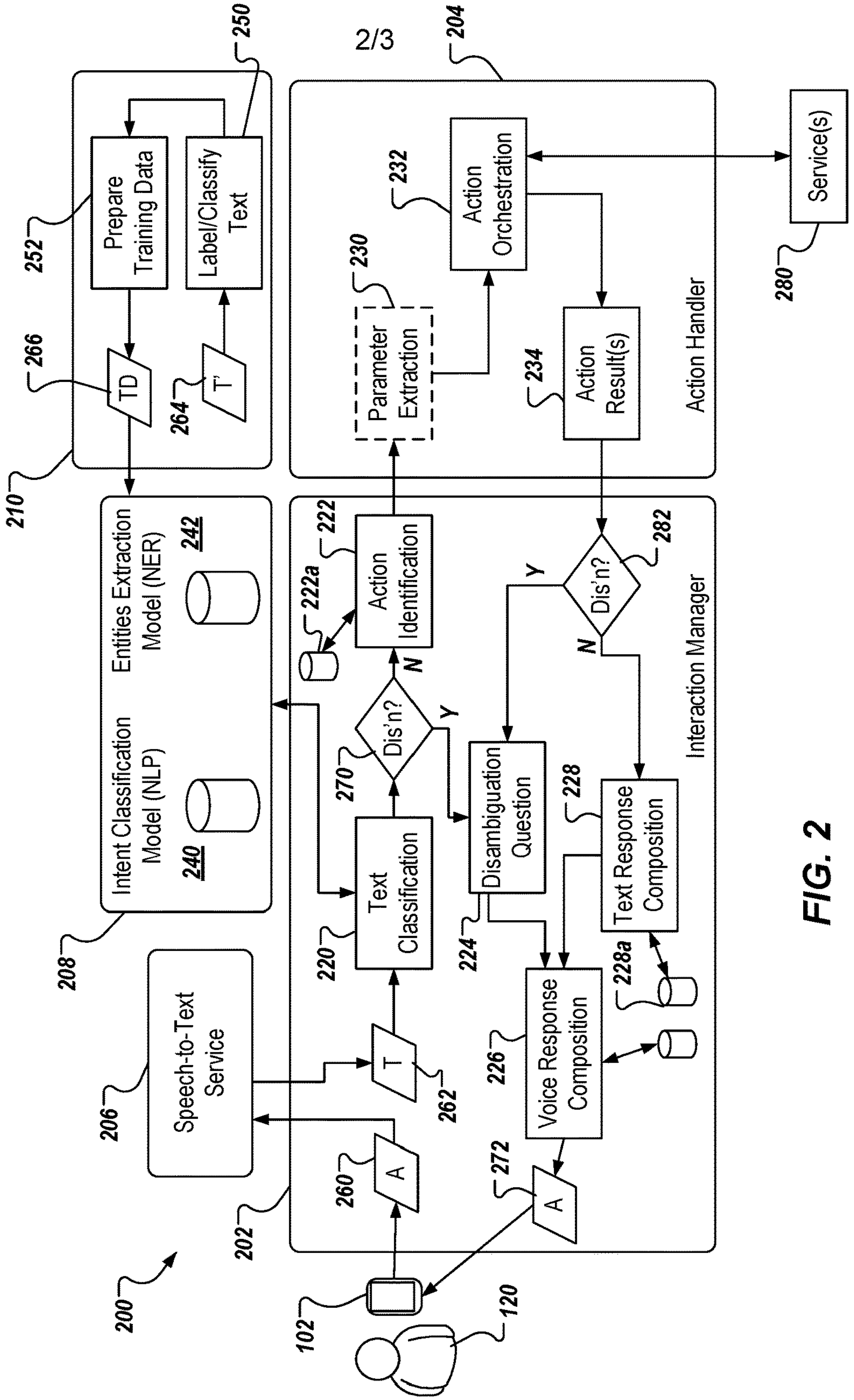

200
102
120
202
204
206
208
210
Speech-to-Text Service
Intent Classification Model (NLP)
240
Entities Extraction Model (NER)
242
Prepare Training Data
252
Label/Classify Text
250
TD
266
T'
264
A
260
T
262
Text Classification
220
Dis'n?
270
Y
N
Action Identification
222
222a
Disambiguation Question
224
Voice Response Composition
226
Text Response Composition
228
228a
A
272
Dis'n?
282
Y
N
Interaction Manager
Parameter Extraction
230
Action Orchestration
232
Action Result(s)
234
Action Handler
Service(s)
280

FIG. 2

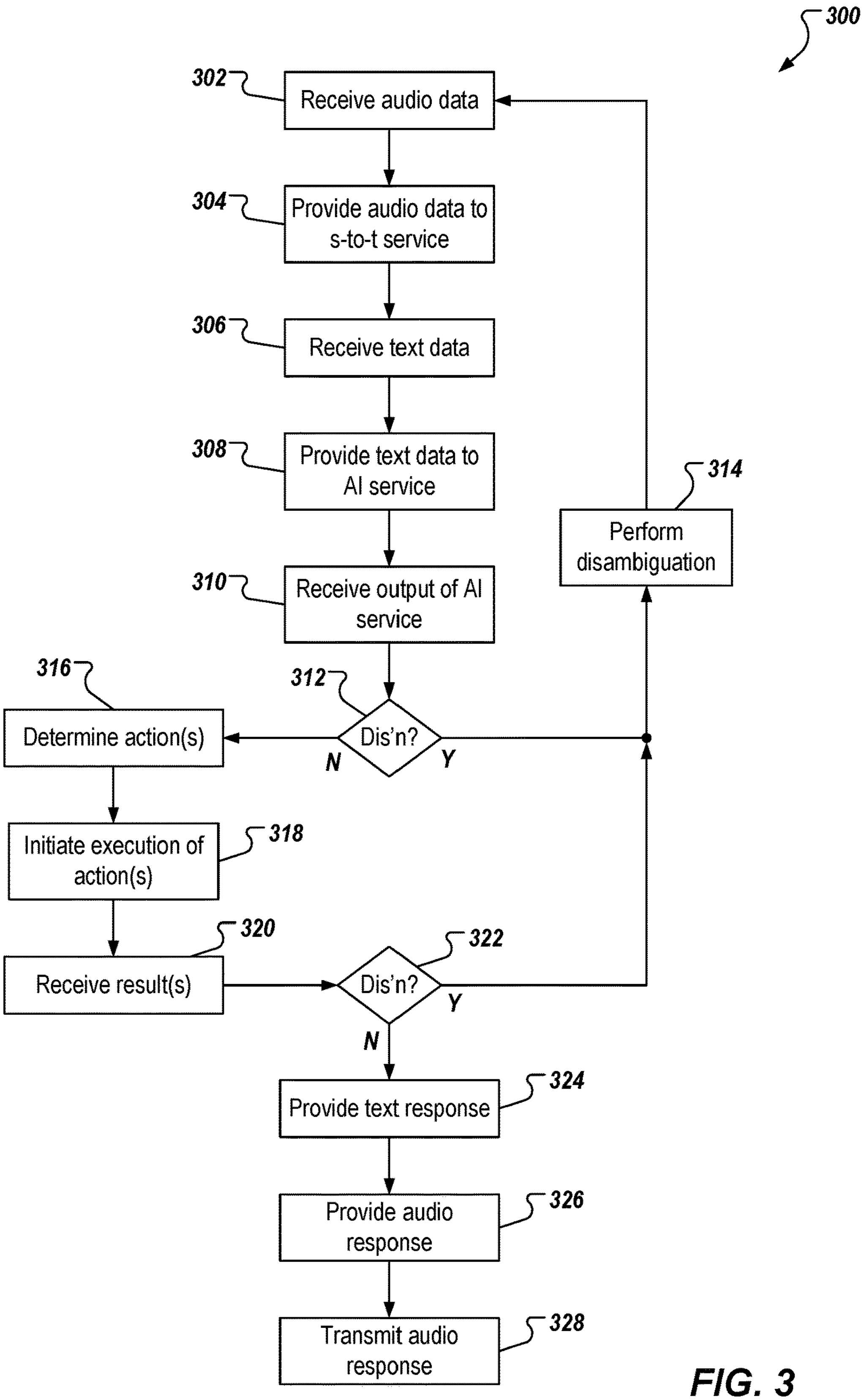

300
302
Receive audio data
304
Provide audio data to s-to-t service
306
Receive text data
308
Provide text data to AI service
310
Receive output of AI service
312
Dis'n?
N
Y
314
Perform disambiguation
316
Determine action(s)
318
Initiate execution of action(s)
320
Receive result(s)
322
Dis'n?
Y
N
324
Provide text response
326
Provide audio response
328
Transmit audio response

FIG. 3

ARTIFICIAL INTELLIGENCE DIGITAL AGENT

BACKGROUND

[0001] Users (e.g., customers of an enterprise) can call into a call center in an effort to address issues, gather information, and/or use services. Call centers have introduced automated services that enable users to drill-down through menus, for example, in an effort to focus resources to attend to a particular user (e.g., identify a particular department, and/or customer service representative that may be best suited to address the user's needs). Example automated services can include artificial intelligence that processes the user's spoken words to route the call to particular resources. Such automated services, however, can have disadvantages. For example, although an automated service may be able to route a call, the automated service is limited in other functionality (e.g., performing requested services).

SUMMARY

[0002] Implementations of the present disclosure are generally directed to a computer-implemented platform for an artificial intelligence (AI) -based digital agent. More particularly, implementations of the present disclosure are directed to an AI-based digital agent that can audibly interact with users, and that can execute one or more actions based on user interactions.

[0003] In some implementations, actions include receiving communication data from a device, the communication data including data input by a user of the device, receiving text data based on the communication data, providing an intent set and an entity set based on processing the text data through an artificial intelligence service, the intent set including one or more intents indicated in the text data, the entity set including one or more entities indicated in the text data, the artificial intelligence service implementing one or more convolution neural networks (CNNs), identifying a set of actions based on one or more of the text data, the intent set, and the entity set, the set of actions including one or more actions to be executed by one or more computer-implemented services, receiving a set of results including at least one result from a computer-implemented service executing an action of the set of actions, providing result data including data describing the at least one result, and transmitting the result data to the device. Other implementations of this aspect include corresponding systems, apparatus, and computer programs, configured to perform the actions of the methods, encoded on computer storage devices.

[0004] These and other implementations can each optionally include one or more of the following features: the artificial intelligence service comprises an intent classification model using natural language processing (NLP) to provide the intent set; the NLP includes word embedding; the artificial intelligence service comprises an entity extraction model using named entity recognition (NER) to provide the entity set; actions further include determining that one or both of the intent set and the entity set is empty, and in response, transmitting at least one disambiguation question to the device; actions further include determining that an expected entity is absent from the entity set based on an intent of the intent set, and in response, transmitting at least one disambiguation question to the device; actions further include determining that the set of results includes a deficiency, and in response, transmitting at least one disambiguation question to the device; the communication data includes audio data, and the result data includes audio result data; the communication data includes text data, and the result data includes text result data; and the result data includes audio data that is provided by a voice response composition module based on text result data.

[0005] The present disclosure also provides a computer-readable storage medium coupled to one or more processors and having instructions stored thereon which, when executed by the one or more processors, cause the one or more processors to perform operations in accordance with implementations of the methods provided herein.

[0006] The present disclosure further provides a system for implementing the methods provided herein. The system includes one or more processors, and a computer-readable storage medium coupled to the one or more processors having instructions stored thereon which, when executed by the one or more processors, cause the one or more processors to perform operations in accordance with implementations of the methods provided herein.

[0007] It is appreciated that methods in accordance with the present disclosure can include any combination of the aspects and features described herein. That is, methods in accordance with the present disclosure are not limited to the combinations of aspects and features specifically described herein, but also include any combination of the aspects and features provided.

[0008] The details of one or more implementations of the present disclosure are set forth in the accompanying drawings and the description below. Other features and advantages of the present disclosure will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

[0009] FIG. **1** depicts an example high-level architecture in accordance with implementations of the present disclosure.

[0010] FIG. **2** depicts an example architecture in accordance with implementations of the present disclosure.

[0011] FIG. **3** depicts an example process that can be executed in accordance with implementations of the present disclosure.

DETAILED DESCRIPTION

[0012] Implementations of the present disclosure are generally directed to a computer-implemented platform for an artificial intelligence (AI) -based digital agent. More particularly, implementations of the present disclosure are directed to an AI-based digital agent that can audibly interact with users, and that can execute one or more actions based on user interactions.

[0013] As described in further detail herein, implementations of the present disclosure include actions of receiving communication data from a device, the communication data including data input by a user of the device, receiving text data based on the communication data, providing an intent set and an entity set based on processing the text data through an artificial intelligence service, the intent set including one or more intents indicated in the text data, the entity set including one or more entities indicated in the text data, the artificial intelligence service implementing one or more convolution neural networks (CNNs), identifying a set of actions based on one or more of the text data, the intent set, and the entity set, the set of actions including one or more actions to be executed by one or more computer-implemented services, receiving a set of results including at least one result from a computer-implemented service executing an action of the set of actions, providing result data including data describing the at least one result, and transmitting the result data to the device.

[0014] FIG. **1** depicts an example high-level architecture **100** in accordance with implementations of the present disclosure. The example architecture **100** includes a device **102**, a back-end system **108**, and a network **110**. In some examples, the network **110** includes a local area network (LAN), wide area network (WAN), the Internet, a cellular telephone network, a public switched telephone network (PSTN), a private branch exchange (PBX), or any appropriate combination thereof, and connects web sites, devices (e.g., the device **102**), and back-end systems (e.g., the back-end system **108**). In some examples, the network **110** can be accessed over a wired and/or a wireless communications link. For example, mobile devices, such as smartphones can utilize a cellular network to access the network **110**.

[0015] In the depicted example, the back-end system **108** includes at least one server system **112**, and data store **114** (e.g., database). In some examples, at least one server system **112** hosts one or more computer-implemented services that users can interact with using devices. For example, the server system **112** can host an AI-based digital agent in accordance with implementations of the present disclosure. In some examples, the device **102** can each include any appropriate type of computing device such as a desktop computer, a laptop computer, a handheld computer, a tablet computer, a personal digital assistant (PDA), a cellular telephone, a network appliance, a camera, a smartphone, a telephone, a mobile phone, an enhanced general packet radio service (EGPRS) mobile phone, a media player, a navigation device, an email device, a game console, or an appropriate combination of any two or more of these devices, or other data processing devices.

[0016] In the depicted example, the device **102** is used by a user **120**. In accordance with the present disclosure, the user **120** uses the device **102** to audibly interact with the AI-based digital assistant of the present disclosure. In some examples, the user **120** can include a customer of an enterprise that provides the AI-based digital agent, or on behalf of which the AI-based digital assistant is provided. For example, the user **120** can include a customer that calls into a call center of the enterprise using the device **102**, and is connected to the AI-based digital assistant (e.g., hosted on the back-end system **108**). In accordance with implementations of the present disclosure, and as described in further detail herein, the user **120** can provide verbal input (e.g., speech) to the AI-based digital assistant, which can process the verbal input to request additional information (e.g., disambiguate), perform one or more actions, and/or provide one or more audible responses.

[0017] FIG. **2** depicts an example architecture **200** in accordance with implementations of the present disclosure. In some examples, components of the example architecture **200** can be hosted on one or more back-end systems (e.g., the back-end system **108** of FIG. **1**). In the depicted example, the example architecture **200** includes an interaction manager **202**, an action handler **204**, a speech-to-text service **206**, an artificial intelligence (machine intelligence) service **208**, and a training data service **210**. In some examples, each component of the example architecture **200** is provided as one or more computer-executable programs executed by one or more computing devices. In some examples, the interaction manager **202**, and the action handler **204** are operated by, or on behalf of an enterprise (e.g., hosted on the back-end system **108** of FIG. **1**, which is operated by, or on behalf of the enterprise).

[0018] In some examples, the speech-to-text service **206**, the artificial intelligence service **208**, and/or the training data service **210** are operated by, or on behalf of the enterprise (e.g., hosted on the back-end system **108** of FIG. **1**, which is operated by, or on behalf of the enterprise), or are provided by one or more third-party service providers (e.g., hosted on a back-end system other than the back-end system **108**, operated by, or on behalf of the one or more third-party service providers). An example speech-to-text service **206** includes Google Cloud Speech provided by Google, Inc. of Mountain View, Calif. In some examples, Google Cloud Speech converts audio data to text data by processing the audio data through neural network models. Although an example speech-to-text service **206** is referenced herein, implementations of the present disclosure can be realized using any appropriate speech-to-text service. An example artificial intelligence service **208** includes TensorFlow provided by Google, Inc. of Mountain View, Calif. In some examples, TensorFlow can be described as an open source software library for numerical computation using data flow graphs.

[0019] In the depicted example, the interaction manager **202** includes a text classification module **220**, an action identification module **222**, a disambiguation question module **224**, a text response composition module **226**, and a voice response composition module **228**. The action handler **204** includes a parameter extraction module **230** (optional), an action orchestration module **232**, and an action results module **234**. The artificial intelligence service **208** includes an intent classification model (e.g., based on natural language processing (NLP)), and an entity extraction model **242** (e.g., based on named entity recognition (NER)). The training data service **210** includes a text labeling/classifying module **250**, and a training data preparation module **252**.

[0020] In accordance with implementations of the present disclosure, the artificial intelligence service **208** implements a convolutional neural network (CNN). In some examples, the CNN enables more efficient and faster processing of the text data than other types of AI networks. In general, a CNN can be described as a neural network having overlapping “reception fields” that perform convolution tasks. More particularly, a CNN is a type of feed-forward artificial neural network, which includes connectivity patterns between neurons, where receptive fields of different neurons partially overlap. In a CNN, a response of an individual neuron to data (stimuli) within its receptive field is mathematically approximated by a convolution operation.

[0021] In contrast, other neural networks, such as a recurrent neural network (RNN) implement recurrent connections, which form cycles in the RNN’s topology. In some examples, a RNN can be described as being sequential, and not stateless. A RNN can suffer from the so-called vanishing (or exploding) gradient problem, where information is (rapidly) lost over time. Consequently, whatever the model learned in the past might be lost in the future, if it was overridden by intensive new information, for example.

[0022] In accordance with implementations of the present disclosure, the artificial intelligence service **108** implements word embedding in the NLP. In some examples, word embedding can be described as the collective name for a set of language modeling and feature learning techniques within the NLP, where words and/or phrases from a vocabulary are mapped to vectors of real numbers. Conceptually, word embedding involves a mathematical embedding from a space with one dimension per word to a continuous vector space with a much lower dimension. In general, word embedding enables the model to understand different words having the same meaning (synonyms), and understand such words without the need to actually teach the machine each word individually.

[0023] In accordance with implementations of the present disclosure, and as described in further detail herein, the interaction manager **202** receives communication data, and processes the communication data to provide a response, and/or to initiate execution of one or more actions. In some implementations, the communication data is provided as audio data. In some examples, the audio data corresponds to speech of a user that is recorded (e.g., during a user telephone). Accordingly, the response can include an audio response. In this manner, the AI-based digital assistant of the present disclosure can operate as a voice-based agent. In some implementations, the communication data is provided as text data. In some examples, the text data corresponds to a message transmitted by a user (e.g., a text message, a chat message). Accordingly, the response can include a text response. In this manner, the AI-based digital assistant of the present disclosure can operate as a chat bot, for example.

[0024] The example architecture **200** is described in further detail herein with reference to processing communication data including audio data, and providing an audio response. It is contemplated, however, that the communication data can include text data, as introduced above.

[0025] In the depicted example, the user **120** can audibly communicate with the interaction manager **202** using the device **102**. For example, the user **120** can establish a communication path (e.g., telephone call) to communicate data from the device **102** to the interaction manager **202** (e.g., over the network **110** of FIG. **1**). In some examples, the user **120** can speak to the device **102**, which records the speech as audio data **260** that is transmitted to the interaction manager **202** (e.g., as streaming audio data; in one or more audio data files). The audio data **260** can be provided in any appropriate format (e.g., .wav, .mp3, .wma).

[0026] The interaction manager **202** provides the audio data **260** to the speech-to-text service **206** (e.g., through an application program interface (API) of the speech-to-text service **206**). The speech-to-text service **206** processes the audio data **260** to provide text data **262**. The text data **262** can be provided in any appropriate format (e.g., .txt, .csv). The text classification module **220** receives the text data **262**, and processes the text data in coordination with the artificial intelligence service **208**. In some examples, the text classification module **220** provides a request to the artificial intelligence service **208** (e.g., through an API of the artificial intelligence service **208**), the request including at least a portion of the text data **262**. In some examples, the text classification module **220** can inject one or more actions based on one or more classification rules. An example classification rule can include filtering curse words.

[0027] The artificial intelligence service **208** processes the received text data to provide an intent set, and an entity set. More particularly, the artificial intelligence service **208** processes the received text data through the intent classification model **240** using NLP to determine one or more intents of the text data, the one or more intents being included in the intent set. In some examples, an intent indicates a reason as to why the user is communicating with the AI-based digital assistant. For example, the text data can include "How many miles are in my frequent flier account," and example intents can be determined to be AccountQuery, and StatusQuery by the intent classification model **240**. In some examples, an intent might not be determined from the text data. Consequently, the intent set can be empty. The artificial intelligence service **208** processes the received text data through the entity extraction model **240** using NER to determine one or more entities implicated within the text data, the one or more entities being included in the entity set. In some examples, an entity indicates a person, place, or thing (e.g., persons, organizations, locations, expressions of times, quantities, monetary values, percentages, etc.) implicated in the text data. For example, the text data can include "I would like to book travel from Austin to Frankfurt," and example entities can be determined to be LocationAustin, LocationFrankfurt, ThingTravel by the entity extraction model **240**. In some examples, an entity might not be determined from the text data. Consequently, the entity set can be empty.

[0028] In some implementations, the text classification module **220** provides feedback for machine-learning. For example, the text classification module **220** can determine that some of the text data **262** was improperly, or poorly classified by the artificial intelligence service **208**. For example, the artificial intelligence service **208** can provide intent classification, as well as a score indicative of how accurately the class was identified (e.g., a confidence index). In some examples, the scores (one score for each classification) can be compared to respective, customizable thresholds (e.g., per class). If the score of a class does not exceed the threshold, it can be determined that the class is poor/improper.

[0029] In some examples, the text classification **220** provides at least a portion of text data **264** to the training data service **210**, which processes the text data **264** using the text labeling/classifying module **250**, and the training data preparation module **252** to provide training data **266**. The training data **266** is provided to the artificial intelligence service **208** to further train one or both of the intent classification model **240**, and the entities extraction model **242**. Although the training data service **210** is depicted as a separate service, the training data service **210** can be included as part of another service (e.g., the training data service **210** can be included in the artificial intelligence service **208**).

[0030] It is determined whether disambiguation **270** is required. Although the disambiguation **270** is schematically depicted as an independent function, the text classification module **220**, and/or the action identification module **222** can determine whether disambiguation is required. In some examples, disambiguation can be described as clarification of the text data **260**, one or more entities identified in the text data **260**, and/or one or more intents determined from the text data **260**.

[0031] In some examples, disambiguation is required, if the intent set, and/or the entity set are empty. For example, if an intent cannot be determined from the text data **262**, disambiguation can be required (e.g., request that the user repeat or clarify their question). In some examples, disambiguation is required, if an intent of the intent set does not correspond to a pre-defined list of intents. In some examples, a pre-defined list of intents can be provided for a particular domain, within which the AI-based digital agent is operating (e.g., flight reservations). In some examples, multiple pre-defined lists of intents can be provided, each pre-defined list of intents corresponding to a respective domain. In some examples, each intent provided in the intent set can be compared to intents of the pre-defined list of intents. If an intent of the intent set is not included in the pre-defined list of intents, disambiguation may be required. Continuing with the example above, an example intent in the intent set can include JewelryPurchase, which is not included in a pre-defined list of intents for the domain flight reservations. Consequently, disambiguation can be required in view of the intent JewelryPurchase being included in the set of intents.

[0032] In some examples, disambiguation can be required, if a number and or type of entities in the entity set do not correspond to an intent of the intent set. For example, to perform an action based on an intent, two or more entities can be required (e.g., a departure city, and an arrival city are required to determine flights). If, however, only a single entity is provided, or a single entity of the type required for the intent (e.g., only an arrival city is provided) in the entity set, disambiguation can be required (e.g., request the user to specify a departure city). In other words, for a given intent, one or more types of entities may be expected. If an expected entity (e.g., departure city) is absent from the entity set, disambiguation can be required. In some examples, disambiguation can be required, if an entity is too general. Continuing with the example above, an example entity set can include LocationAustin, LocationFrankfurt, and Thing-Travel. It can be determined that travel is too general for one or more actions to be determined. Consequently, disambiguation may be required to clarify what is meant in the text data **260** (e.g., request that the user clarify whether plane, train, or automobile travel is being requested).

[0033] If disambiguation is required, at least a portion of one or more of the text data **260**, the intent set, and the entity set is provided to the disambiguation question module **224**. In some examples, the disambiguation question module **224** provides one or more disambiguation questions. In some examples, the disambiguation module **224** includes a pre-defined list of disambiguation questions based on the use-case (domain) that the AI-based digital agent is operating in (e.g., flight reservations). In some examples, a disambiguation question can be selected based on a look-up (e.g., using an index of disambiguation question) using one or more deficiencies of the intent set, and/or the entity set. For example, if the intent set is empty, the disambiguation question "I'm sorry, I did not understand your request, please repeat your question" can be selected. As another example, and in the example domain of flight reservations, if the entity set is empty, or only a single entity is included, example disambiguation questions can respectively include "What is the departure city, and the arrival city?" or "What is the departure city?" Continuing with the example above, in which it is determined that travel is too general for one or more actions to be identified, an example disambiguation question can include "Would you like automobile, boat, train, and/or airplane travel?"

[0034] In some examples, the disambiguation question is provided as text data, which is provided to the voice response composition module **226**. The voice response composition module **226** processes the text data to provide audio data **272**. For example, the voice response composition module **226** accesses a library of audio data based on one or more segments of the text data. In some examples, an index can be searched based on a segment (e.g., portion of the text data), an audio data can be retrieved. In some examples, audio data of respective segments can be appended together to provide the audio data **272**. The audio data **272** is provided to the device **102** (e.g., over the network **110**), and the device **102** plays the audio to the user **120**.

[0035] If disambiguation is not required, at least a portion of one or more of the text data **260**, the intent set, and the entity set are provided to the action identification module **222**. The action identification module **222** provides a set of actions that are to be performed by the action handler **204**. In some examples, the action identification module **222** references a library of available actions **222***a*. In some examples, the action identification module **222** accesses an index of the library of available actions **222***a* based on the intent(s) and the entit(y/ies).

[0036] In some examples, the set of actions includes one or more actions. Continuing with the example above, it can be determined that the user **120** is to book a flight from Austin, Tex. to Frankfurt, Germany, departing on Feb. 26, 2017, and returning on Mar. 2, 2017 (e.g., after one or more rounds of disambiguation). Consequently, an example action can include submission of a search query to a flight search engine, the search query including one or more search terms (e.g., depCity:AUS, arrCity:FRA, depDate: 2/26/17, retDate: 3/2/17). As another example, it can be determined that the user **120** is to purchase the fare using a credit card with given number, expiration data, and security code. Consequently, an example action can include submission of a payment authorization request to a payment service (e.g., the user's credit card company).

[0037] The set of actions can be provided to the parameter extraction model **230** of the action handler **204**. The parameter extraction model **230** can process the set of actions to include one or more parameters. As introduced above, the response returned from the artificial intelligence service **208** to the text classification module **220** should be an intent set, and an entity set. After provision of the intent set, parameter extraction can be performed to select the proper/needed parameters to execute each action. Accordingly, the parameter extraction can eliminate any unnecessary parameters.

[0038] In some examples, the parameter extraction module **230** is optional. Consequently, the set of actions can be provided directly to the action orchestration module **232** from the action identification module **222**. In some examples, this is optional in the case that the entity set is empty.

[0039] The action orchestration module **232** processes the set of actions to initiate performance of each action in the set of actions. In some examples, for each action, the action orchestration module **232** identifies one or more services **280** that are to be called for performance of the actions. In some examples, a service **280** is identified based on a type of action that is to be performed (e.g., flight search, credit card payment) from a pre-defined list of services (e.g., corresponding to the domain). One or more of the services **280** can be provided by a third-party service provider, and can be hosted on a back-end system (e.g., other than the back-end system **108** of FIG. **1**). In some examples, the action orchestration module **232** transmits a request to one or more services **280** (e.g., through respective APIs of the services **280**), each request including information to be processed by a respective service **280** to provide a result. Each service **280** processes a respective request, and transmits one or more results to the action orchestration module **232**.

[0040] Continuing with the example above, the action orchestration module **232** can determine that a particular search service is to be called for performing a search using the example search query [depCity:AUS, arrCity:FRA, depDate: 2/26/17, retDate: 3/2/17]. The search service can process the request, and provide search results based thereon. Example search results can include one or more flights that are responsive to the search terms of the search query. The action orchestration module **232** provides a set of results to the action results module **234**. In some examples, the action results module **234** parses the results of the action orchestration (e.g., whether a result includes a set of database results, or API (SOAP/HTTP) response) to a form that can be read by the interaction manager **202**.

[0041] It can be determined whether disambiguation **282** is required. Although the disambiguation **282** is schematically depicted as an independent function, a module of the interaction handler **202** can determine whether disambiguation is required. If disambiguation is required, at least a portion of the set of results is provided to the disambiguation question module **224** to initiate provision of audio data **272** to the device **102**, the audio data **272** providing one or more disambiguation questions, as described herein. In some examples, disambiguation can be required, if it is determined that the set of results includes one or more deficiencies. Continuing with the example above, it can be determined that the set of results includes, as an example deficiency, too many results to be efficiently communicated to the user **120**. Consequently, an example disambiguation question can include "Would you like direct flights?" (e.g., a question having an answer that could be used to narrow results included in the set of results).

[0042] If disambiguation is not required, the set of results is provided to the text response composition module **228**. The text response composition module **228** provides text data based on each result in the set of results. In some examples, the text composition module **228** references a library of text responses **228***a*. In some examples, the text composition module **228** accesses an index of the library of available text responses **228***a* based on a type of action, and the respective results. For example, if the action included credit card payment authorization, a result can include parameters [Visa, $489.07, ABC123DEF] indicating that a Visa payment of $489.07 has been approved and assigned the confirmation number ABC123DEF. Continuing with this example, text retrieved from the library of text responses **228***a* can include [credit card, payment, amount, approved, confirmation].

[0043] The text response composition module **228** provides the text data to the voice response composition module **226**, which processes the text data to provide audio data **272**, as described herein. Continuing with the above example, an example voice response can include "Your Visa payment of $489.07 has been approved, and your payment confirmation is ABC123DEF.

[0044] In accordance with implementations of the present disclosure, the voice response composition (e.g., provided by the voice response composition module **226**) enables a more natural interaction between the AI-based digital assistant, and the user, and also enables a better representation of voice and better choice of correct words to deliver to the user. In this manner, the AI-based digital assistant of the present disclosure provides a seamless experience to the user, obviating potential user hesitation in interacting with the digital agent, because it is a machine. As described herein, the voice response composition composes voice responses" in real-time using multiple recorded voices. In this manner, the user experiences a seamless transition, in which differences between interacting with the AI-based digital assistant and a human being is minimized.

[0045] FIG. **3** depicts an example process **300** that can be executed in implementations of the present disclosure. In some examples, the example process **300** is provided using one or more computer-executable programs executed by one or more computing devices (e.g., the back-end system **108** of FIG. **1**). In some examples, the example process **300** can be executed to provide an AI-based digital assistant, as described herein.

[0046] Audio data is received (**302**). For example, the interaction manager **202** receives the audio data **260** from the device **102** over the network **110**. Audio data is provided to a speech-to-text service (**304**). For example, the interaction manager **202** provides the audio data **260** to the speech-to-text service **206**. Text data is received (**306**). For example, the interaction manager **202** receives the text data **262** from the speech-to-text service **206**.

[0047] Text data is provided to an artificial intelligence service (**308**). For example, the interaction manager **202** (e.g., the text classification module **220**) provides the text data **262** (or at least a portion of the text data **262**) to the artificial intelligence system **208**. Output of the artificial intelligence service is received (**310**). For example, the interaction manager **202** (e.g., the text classification module **220**) receives output of the artificial intelligence system **208**. The output includes an intent set, and an entity set, as described herein.

[0048] It is determined whether disambiguation is required (**312**). For example, the interaction manager **202** determines whether disambiguation is required, as described herein. If disambiguation is required, disambiguation is performed (**314**). For example, and as described herein, the disambiguation question module **224** provides a disambiguation question as text data, which is provided to the voice response composition module **226**. The voice response composition module **226** processes the text data to provide audio data **272**. The audio data **272** is provided to the device **102** (e.g., over the network **110**), and the device **102** plays the audio to the user **120**.

[0049] If disambiguation is not required, one or more actions are determined (**316**). For example, and as described herein, the action identification module **222** provides a set of actions that are to be performed by the action handler **204** by referencing the library of available actions **222***a*. Execution of each of the one or more actions is initiated (**318**). For example, and as described herein, the action orchestration module **232** processes the set of actions to initiate performance of each action in the set of actions, by identifying one or more services **280** that are to be called for performance of the actions, and transmitting respective requests to the one or more services **280**.

[0050] Results of execution of the one or more actions are received (**320**). For example, the action orchestration module **232** receives respective results from each of the one or more services **280**. It is determined whether disambiguation is required (**322**). For example, if the set of results includes too many results to be efficiently communicated to the user **120**, disambiguation can be required. If disambiguation is required, disambiguation is performed (**314**), as described herein. If disambiguation is not required, one or more text responses are provided (**324**). For example, the text response composition module **228** provides text data based on each result in the set of results (e.g., referencing the library of text responses **228***a*). An audio response is provided (**326**). For example, the text response composition module **228** provides the text data to the voice response composition module **226**, which processes the text data to provide audio data **272**. The audio response is transmitted (**328**). For example, the interaction handler **202** transmits the audio data **272** to the device **102** over the network **110**.

[0051] Implementations and all of the functional operations described in this specification may be realized in digital electronic circuitry, or in computer software, firmware, or hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them. Implementations may be realized as one or more computer program products, i.e., one or more modules of computer program instructions encoded on a computer readable medium for execution by, or to control the operation of, data processing apparatus. The computer readable medium may be a machine-readable storage device, a machine-readable storage substrate, a memory device, a composition of matter effecting a machine-readable propagated signal, or a combination of one or more of them. The term "computing system" encompasses all apparatus, devices, and machines for processing data, including by way of example a programmable processor, a computer, or multiple processors or computers. The apparatus may include, in addition to hardware, code that creates an execution environment for the computer program in question (e.g., code that constitutes processor firmware, a protocol stack, a database management system, an operating system, or any appropriate combination of one or more thereof). A propagated signal is an artificially generated signal (e.g., a machine-generated electrical, optical, or electromagnetic signal) that is generated to encode information for transmission to suitable receiver apparatus.

[0052] A computer program (also known as a program, software, software application, script, or code) may be written in any appropriate form of programming language, including compiled or interpreted languages, and it may be deployed in any appropriate form, including as a stand alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A computer program does not necessarily correspond to a file in a file system. A program may be stored in a portion of a file that holds other programs or data (e.g., one or more scripts stored in a markup language document), in a single file dedicated to the program in question, or in multiple coordinated files (e.g., files that store one or more modules, sub programs, or portions of code). A computer program may be deployed to be executed on one computer or on multiple computers that are located at one site or distributed across multiple sites and interconnected by a communication network.

[0053] The processes and logic flows described in this specification may be performed by one or more programmable processors executing one or more computer programs to perform functions by operating on input data and generating output. The processes and logic flows may also be performed by, and apparatus may also be implemented as, special purpose logic circuitry (e.g., an FPGA (field programmable gate array) or an ASIC (application specific integrated circuit)).

[0054] Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any appropriate kind of digital computer. Generally, a processor will receive instructions and data from a read only memory or a random access memory or both. Elements of a computer can include a processor for performing instructions and one or more memory devices for storing instructions and data. Generally, a computer will also include, or be operatively coupled to receive data from or transfer data to, or both, one or more mass storage devices for storing data (e.g., magnetic, magneto optical disks, or optical disks). However, a computer need not have such devices. Moreover, a computer may be embedded in another device (e.g., a mobile telephone, a personal digital assistant (PDA), a mobile audio player, a Global Positioning System (GPS) receiver). Computer readable media suitable for storing computer program instructions and data include all forms of non-volatile memory, media and memory devices, including by way of example semiconductor memory devices (e.g., EPROM, EEPROM, and flash memory devices); magnetic disks (e.g., internal hard disks or removable disks); magneto optical disks; and CD ROM and DVD-ROM disks. The processor and the memory may be supplemented by, or incorporated in, special purpose logic circuitry.

[0055] To provide for interaction with a user, implementations may be realized on a computer having a display device (e.g., a CRT (cathode ray tube), LCD (liquid crystal display) monitor) for displaying information to the user and a keyboard and a pointing device (e.g., a mouse, a trackball, a touch-pad), by which the user may provide input to the computer. Other kinds of devices may be used to provide for interaction with a user as well; for example, feedback provided to the user may be any appropriate form of sensory feedback (e.g., visual feedback, auditory feedback, tactile feedback); and input from the user may be received in any appropriate form, including acoustic, speech, or tactile input.

[0056] Implementations may be realized in a computing system that includes a back end component (e.g., as a data server), a middleware component (e.g., an application server), and/or a front end component (e.g., a client computer having a graphical user interface or a Web browser, through which a user may interact with an implementation), or any appropriate combination of one or more such back end, middleware, or front end components. The components of the system may be interconnected by any appropriate form or medium of digital data communication (e.g., a communication network). Examples of communication networks include a local area network ("LAN") and a wide area network ("WAN"), e.g., the Internet.

[0057] The computing system may include clients and servers. A client and server are generally remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

[0058] While this specification contains many specifics, these should not be construed as limitations on the scope of the disclosure or of what may be claimed, but rather as descriptions of features specific to particular implementations. Certain features that are described in this specification in the context of separate implementations may also be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation may also be implemented in multiple implementations separately or in any suitable sub-combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination may in some cases be excised from the combination, and the claimed combination may be directed to a sub-combination or variation of a sub-combination.

[0059] 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 the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain 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, and it should be understood that the described program components and systems may generally be integrated together in a single software product or packaged into multiple software products.

[0060] A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. For example, various forms of the flows shown above may be used, with steps re-ordered, added, or removed. Accordingly, other implementations are within the scope of the following claims.

What is claimed is:

1. A computer-implemented method for providing an artificial intelligence (AI) -based digital assistant, the method being executed by one or more processors and comprising:

receiving, by the one or more processors, communication data from a device, the communication data comprising data input by a user of the device;

receiving, by the one or more processors, text data based on the communication data;

providing, by the one or more processors, an intent set and an entity set based on processing the text data through an artificial intelligence service, the intent set comprising one or more intents indicated in the text data, the entity set comprising one or more entities indicated in the text data, the artificial intelligence service implementing one or more convolution neural networks (CNNs);

identifying, by the one or more processors, a set of actions based on one or more of the text data, the intent set, and the entity set, the set of actions comprising one or more actions to be executed by one or more computer-implemented services;

receiving, by the one or more processors, a set of results comprising at least one result from a computer-implemented service executing an action of the set of actions;

providing, by the one or more processors, result data comprising data describing the at least one result; and

transmitting, by the one or more processors, the result data to the device.

2. The method of claim **1**, wherein the artificial intelligence service comprises an intent classification model using natural language processing (NLP) to provide the intent set.

3. The method of claim **2**, wherein the NLP comprises word embedding.

4. The method of claim **1**, wherein the artificial intelligence service comprises an entity extraction model using named entity recognition (NER) to provide the entity set.

5. The method of claim **1**, further comprising determining that one or both of the intent set and the entity set is empty, and in response, transmitting at least one disambiguation question to the device.

6. The method of claim **1**, further comprising determining that an expected entity is absent from the entity set based on an intent of the intent set, and in response, transmitting at least one disambiguation question to the device.

7. The method of claim **1**, further comprising determining that the set of results includes a deficiency, and in response, transmitting at least one disambiguation question to the device.

8. The method of claim **1**, wherein the communication data comprises audio data, and the result data comprises audio result data.

9. The method of claim **1**, wherein the communication data comprises text data, and the result data comprises text result data.

10. The method of claim **1**, wherein the result data comprises audio data that is provided by a voice response composition module based on text result data.

11. One or more non-transitory computer-readable storage media coupled to one or more processors and having instructions stored thereon which, when executed by the one or more processors, cause the one or more processors to perform operations for providing an artificial intelligence (AI) -based digital assistant, the operations comprising:

receiving communication data from a device, the communication data comprising data input by a user of the device;

receiving text data based on the communication data;

providing an intent set and an entity set based on processing the text data through an artificial intelligence service, the intent set comprising one or more intents indicated in the text data, the entity set comprising one or more entities indicated in the text data, the artificial intelligence service implementing one or more convolution neural networks (CNNs);

identifying a set of actions based on one or more of the text data, the intent set, and the entity set, the set of actions comprising one or more actions to be executed by one or more computer-implemented services;

receiving a set of results comprising at least one result from a computer-implemented service executing an action of the set of actions;

providing result data comprising data describing the at least one result; and

transmitting the result data to the device.

12. The computer-readable storage media of claim **11**, wherein the artificial intelligence service comprises an intent classification model using natural language processing (NLP) to provide the intent set.

13. The computer-readable storage media of claim **12**, wherein the NLP comprises word embedding.

14. The computer-readable storage media of claim **11**, wherein the artificial intelligence service comprises an entity extraction model using named entity recognition (NER) to provide the entity set.

15. The computer-readable storage media of claim **11**, wherein operations further comprise determining that one or both of the intent set and the entity set is empty, and in response, transmitting at least one disambiguation question to the device.

16. The computer-readable storage media of claim **11**, wherein operations further comprise determining that an expected entity is absent from the entity set based on an intent of the intent set, and in response, transmitting at least one disambiguation question to the device.

17. The computer-readable storage media of claim **11**, wherein operations further comprise determining that the set of results includes a deficiency, and in response, transmitting at least one disambiguation question to the device.

18. The computer-readable storage media of claim **11**, wherein the communication data comprises audio data, and the result data comprises audio result data.

19. The computer-readable storage media of claim **11**, wherein the communication data comprises text data, and the result data comprises text result data.

20. The computer-readable storage media of claim **11**, wherein the result data comprises audio data that is provided by a voice response composition module based on text result data.

21. A system, comprising:

one or more processors; and

a computer-readable storage device coupled to the one or more processors and having instructions stored thereon which, when executed by the one or more processors, cause the one or more processors to perform operations for providing an artificial intelligence (AI) -based digital assistant, the operations comprising:

receiving communication data from a device, the communication data comprising data input by a user of the device;

receiving text data based on the communication data;

providing an intent set and an entity set based on processing the text data through an artificial intelligence service, the intent set comprising one or more intents indicated in the text data, the entity set comprising one or more entities indicated in the text data, the artificial intelligence service implementing one or more convolution neural networks (CNNs);

identifying a set of actions based on one or more of the text data, the intent set, and the entity set, the set of actions comprising one or more actions to be executed by one or more computer-implemented services;

receiving a set of results comprising at least one result from a computer-implemented service executing an action of the set of actions;

providing result data comprising data describing the at least one result; and

transmitting the result data to the device.

22. The system of claim **21**, wherein the artificial intelligence service comprises an intent classification model using natural language processing (NLP) to provide the intent set.

23. The system of claim **22**, wherein the NLP comprises word embedding.

24. The system of claim **21**, wherein the artificial intelligence service comprises an entity extraction model using named entity recognition (NER) to provide the entity set.

25. The system of claim **21**, wherein operations further comprise determining that one or both of the intent set and the entity set is empty, and in response, transmitting at least one disambiguation question to the device.

26. The system of claim **21**, wherein operations further comprise determining that an expected entity is absent from the entity set based on an intent of the intent set, and in response, transmitting at least one disambiguation question to the device.

27. The system of claim **21**, wherein operations further comprise determining that the set of results includes a deficiency, and in response, transmitting at least one disambiguation question to the device.

28. The system of claim **21**, wherein the communication data comprises audio data, and the result data comprises audio result data.

29. The system of claim **21**, wherein the communication data comprises text data, and the result data comprises text result data.

30. The system of claim **21**, wherein the result data comprises audio data that is provided by a voice response composition module based on text result data.

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