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(54) **NATURAL LANGUAGE SKILL GENERATION FOR DIGITAL ASSISTANTS**

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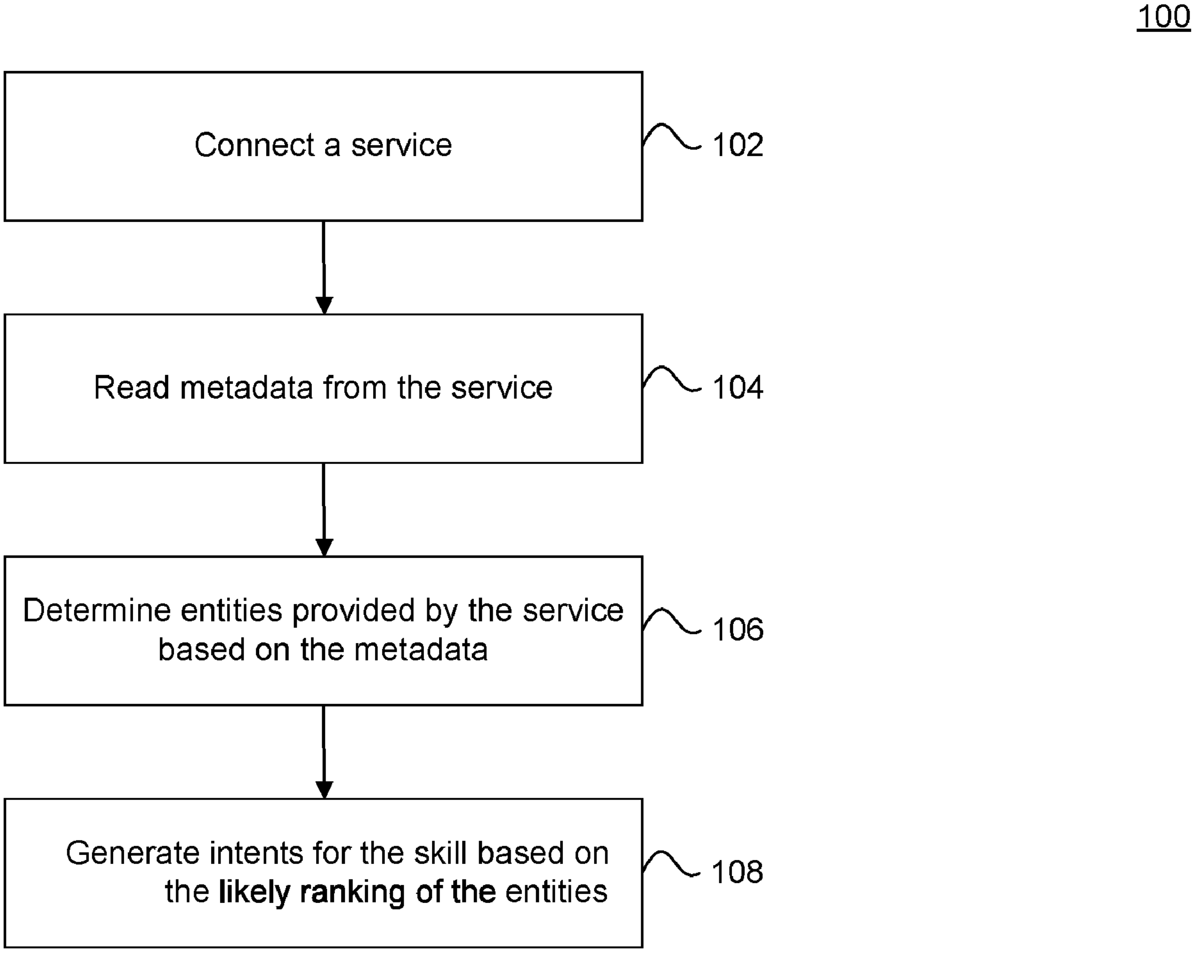
(57) **ABSTRACT**

Disclosed herein are system, method, and computer program product embodiments for developing natural language skills automatically. In order to generate a skill, metadata is read from a connected service, wherein the metadata specifies entities provided by the service. A relevant entity of the entities provided by the service is determined, and a likely request on the entity is generated.


100
Connect a service
102
Read metadata from the service
104
Determine entities provided by the service based on the metadata
106
Generate intents for the skill based on the likely ranking of the entities
108

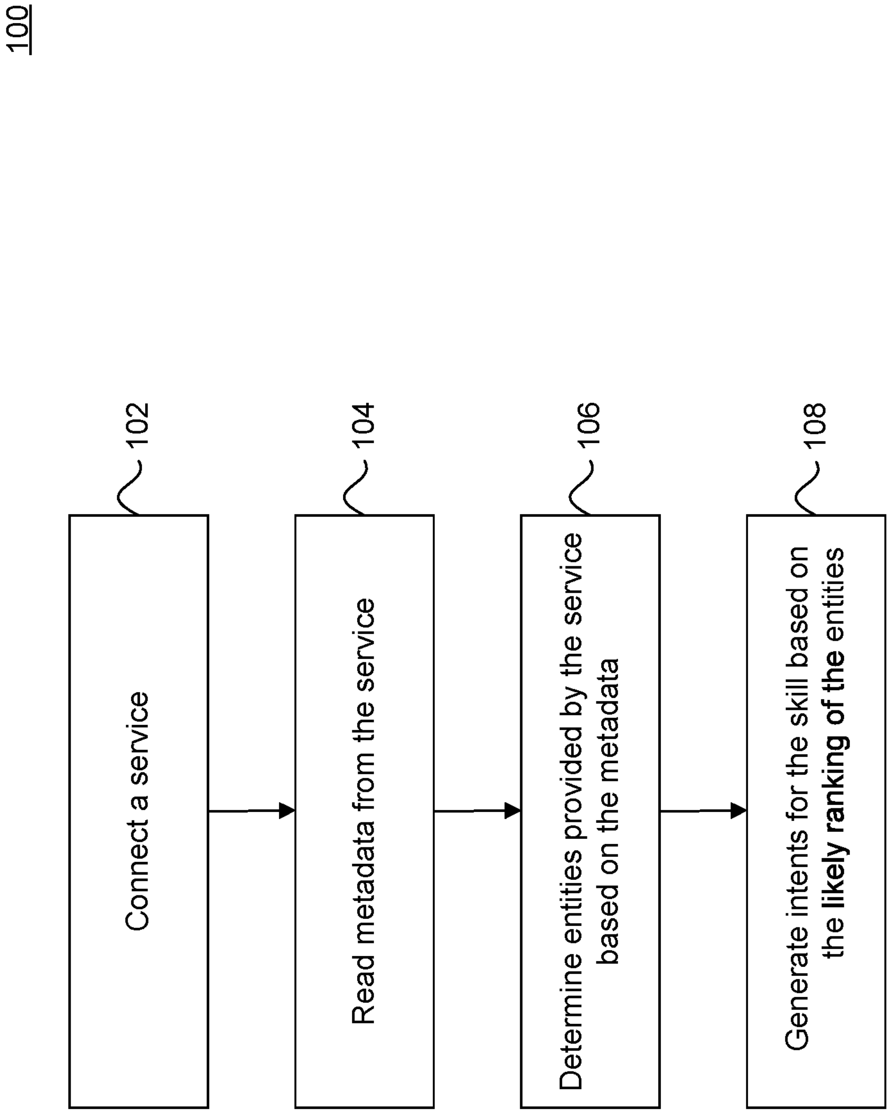

100
Connect a service
102
Read metadata from the service
104
Determine entities provided by the service based on the metadata
106
Generate intents for the skill based on the **likely ranking of the** entities
108

FIG. 1

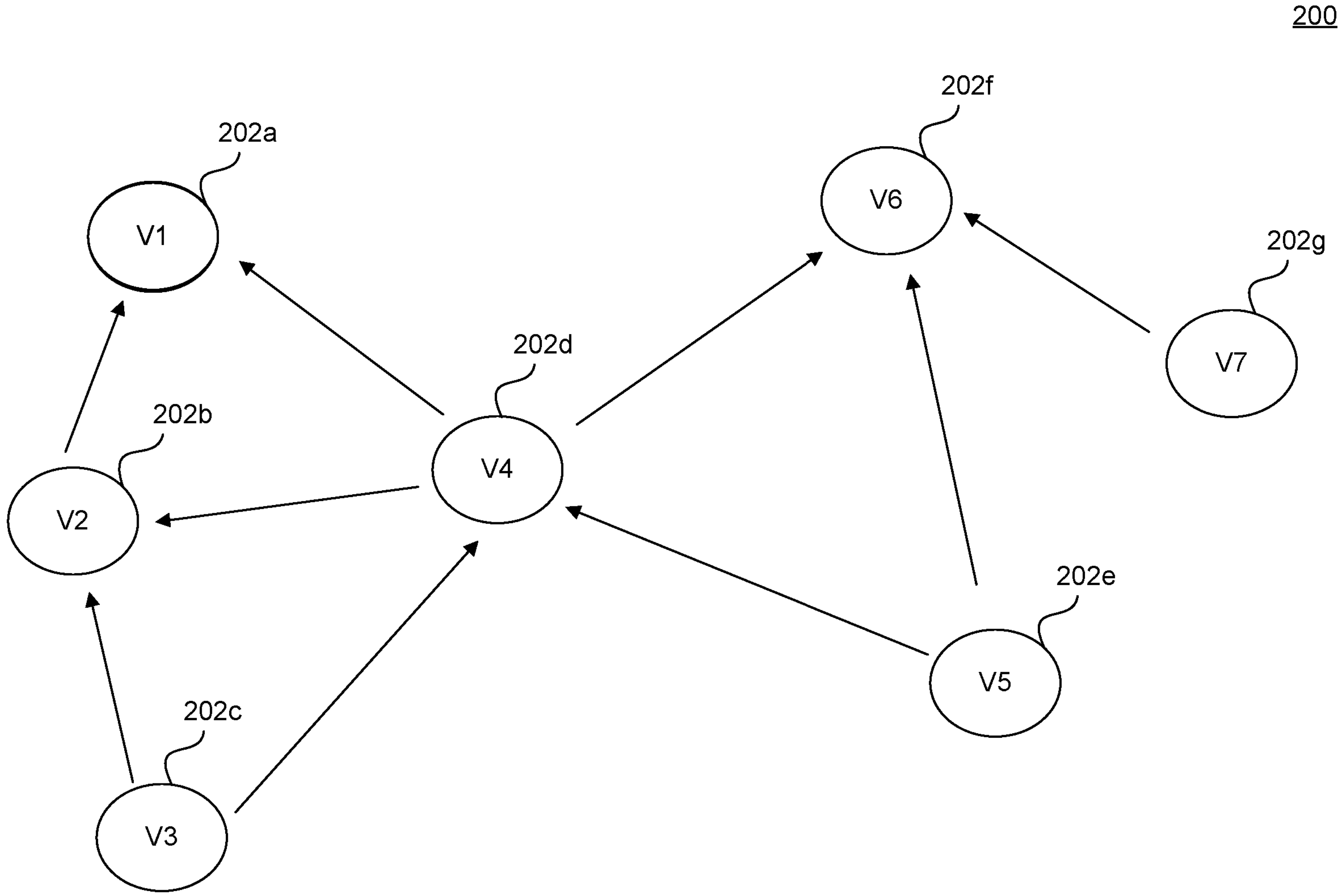


FIG. 2

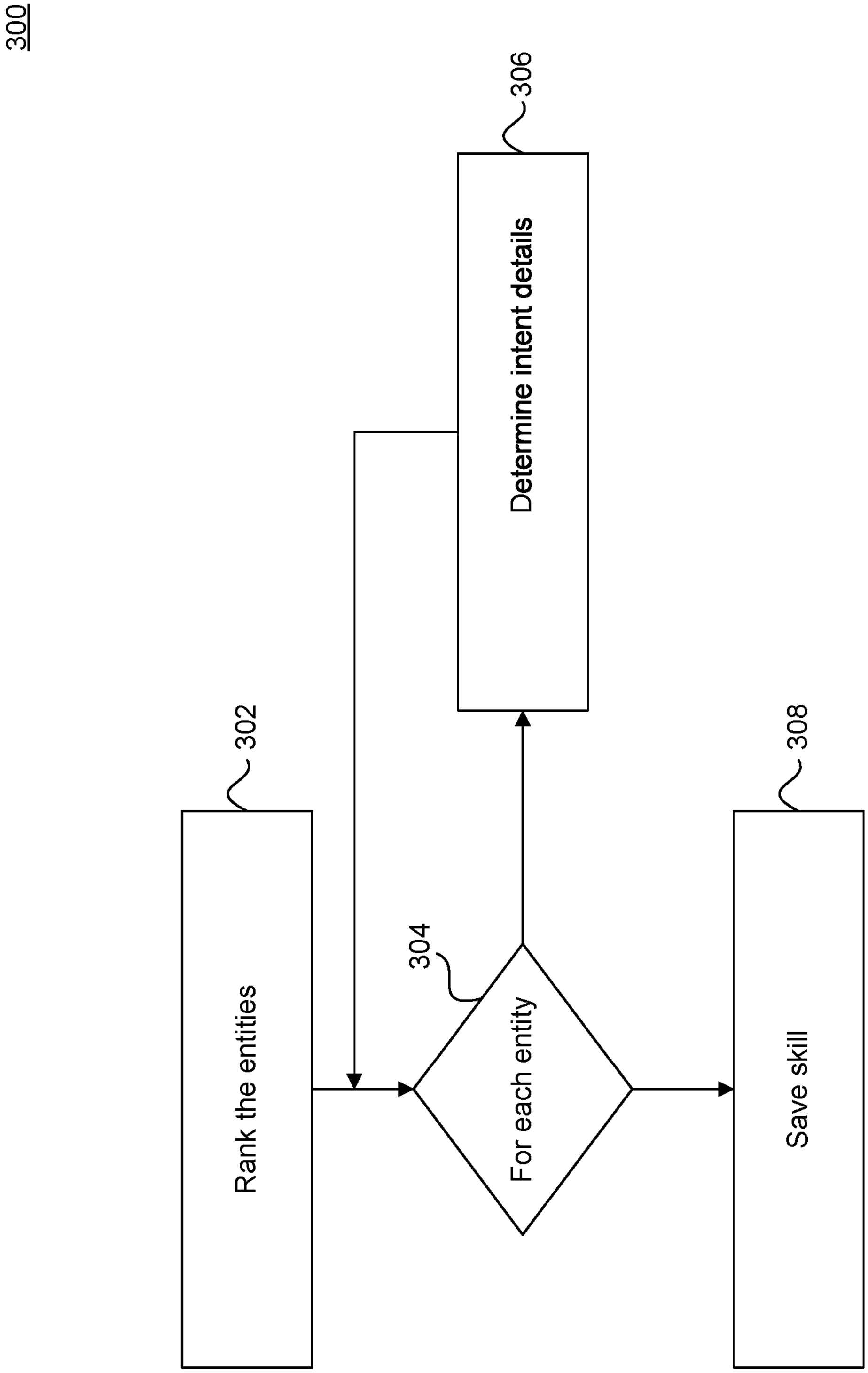

300
Rank the entities
302
For each entity
304
Determine intent details
306
Save skill
308

FIG. 3

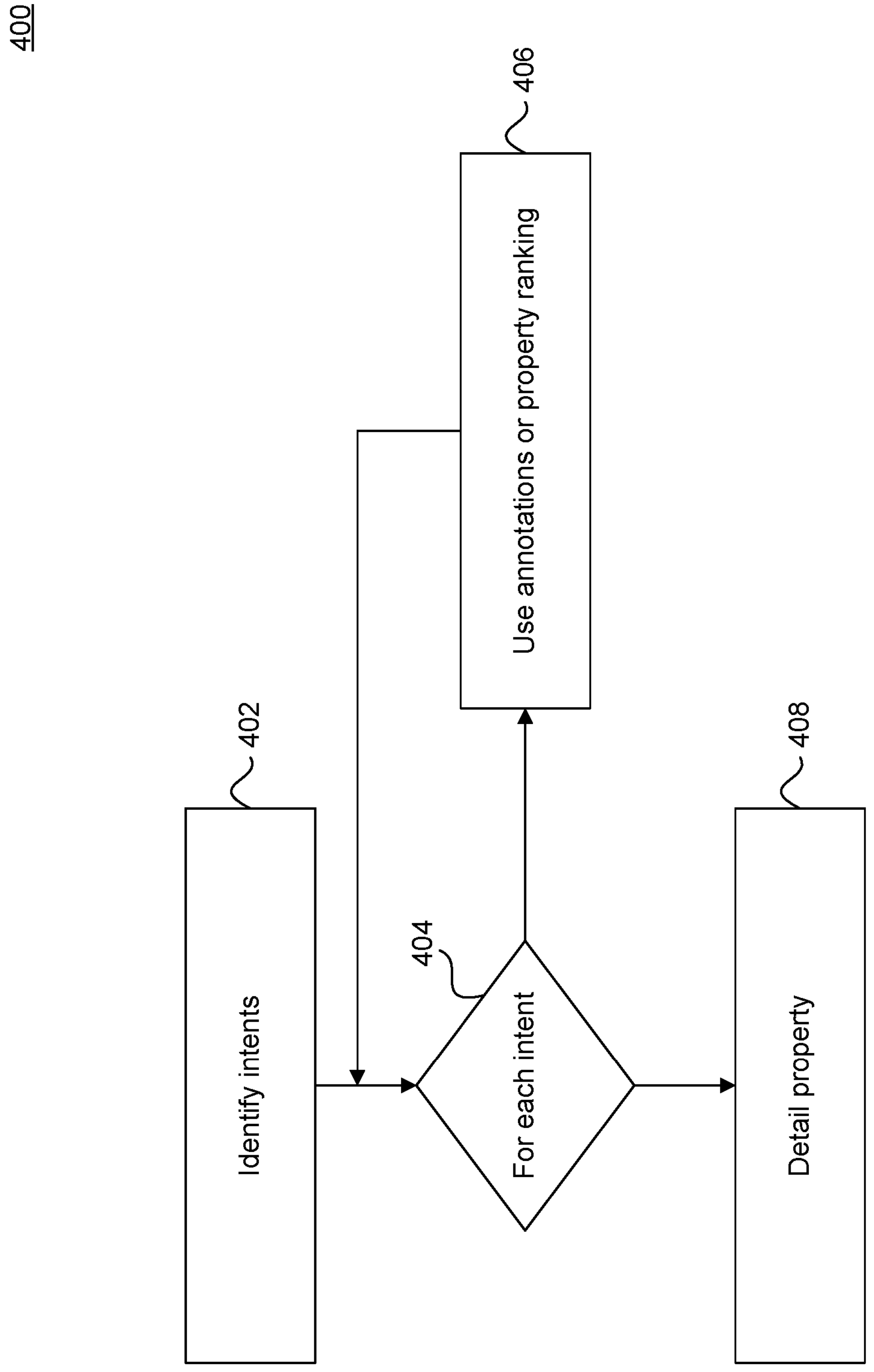

400
Identify intents
402
For each intent
404
Use annotations or property ranking
406
Detail property
408

FIG. 4

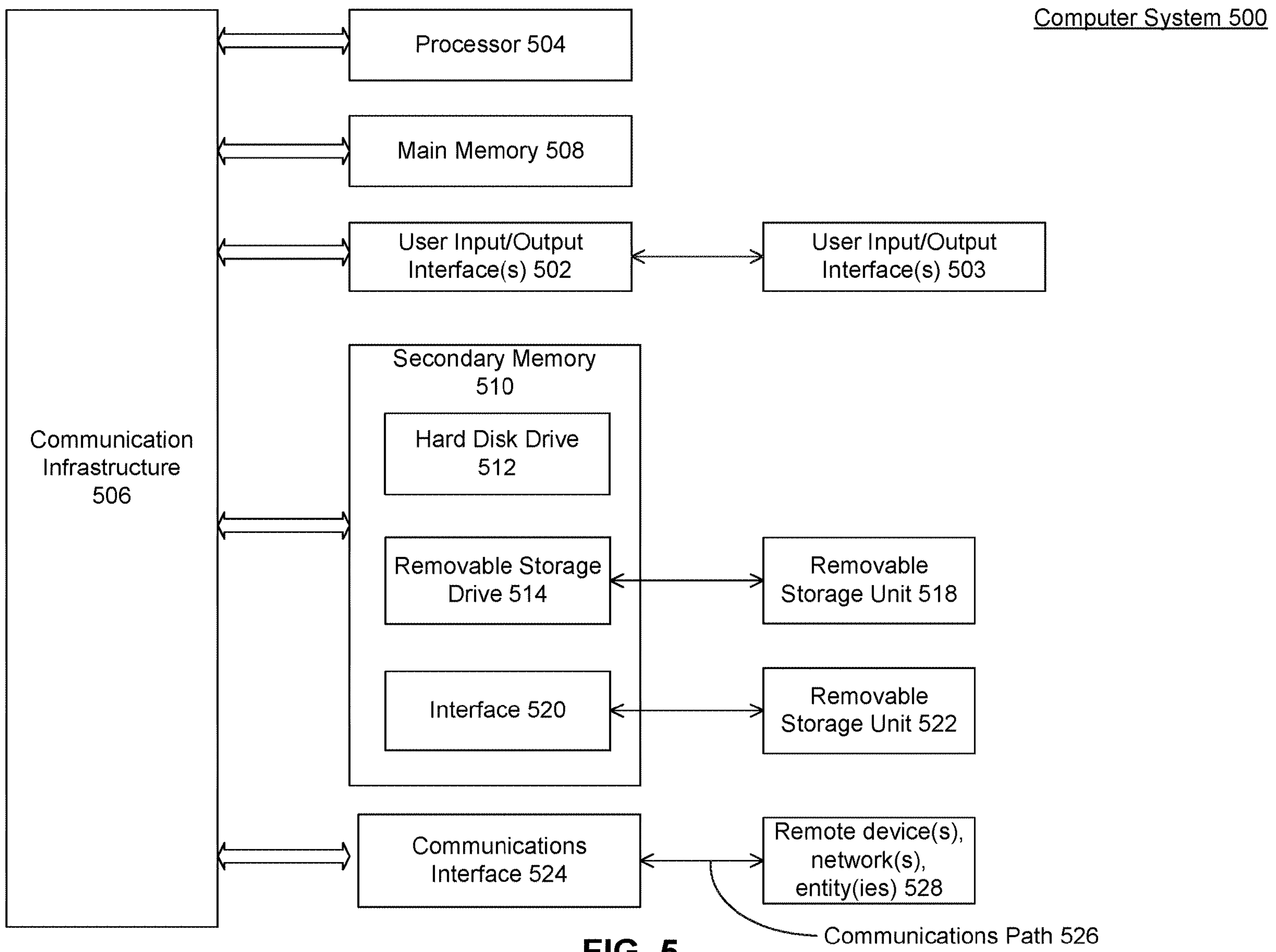

Computer System 500
Communication Infrastructure 506
Processor 504
Main Memory 508
User Input/Output Interface(s) 502
User Input/Output Interface(s) 503
Secondary Memory 510
Hard Disk Drive 512
Removable Storage Drive 514
Interface 520
Removable Storage Unit 518
Removable Storage Unit 522
Communications Interface 524
Remote device(s), network(s), entity(ies) 528
Communications Path 526

FIG. 5

NATURAL LANGUAGE SKILL GENERATION FOR DIGITAL ASSISTANTS

BACKGROUND

[0001] Digital assistants are typically artificial intelligence driven voice or text interfaces that make interactions with a system more natural to humans. Digital assistants are employed in a number of environments to simplify how users interact with systems. In their personal lives, users often interact with digital assistants on their phones to quickly check on the weather, sports scores, or other information that might otherwise require navigation through several menus and applications. For business applications, enterprise developers want to allow their users the same ease of access to their resources.

[0002] In order to intelligently respond to user requests, these digital assistants must be assigned and programmed with "skills." These skills inform behaviors of a digital assistant in responding to a particular type of request. Continuing the above example, one skill may allow the digital assistant to respond to inquiries about the weather, while another skill may allow the digital assistant to respond to inquiries about sport scores.

[0003] Developing and rolling out new digital assistant skills is a time consuming process. Approaches that simplify the creation of skills that respond to natural language requests are in demand by enterprise developers, and will greatly expand access to business application resources.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The accompanying drawings are incorporated herein and form a part of the specification.

[0005] FIG. **1** is a flowchart illustrating steps for natural language processing skill generation, in accordance with an embodiment.

[0006] FIG. **2** is a graph showing entities as vertices and relationships between the entities as edges, in accordance with an embodiment.

[0007] FIG. **3** is a flowchart illustrating steps by which a skill is created, in accordance with an embodiment.

[0008] FIG. **4** is a flowchart illustrating steps by which intents on an entity are detailed, in accordance with an embodiment.

[0009] FIG. **5** is an example computer system useful for implementing various embodiments.

[0010] In the drawings, like reference numbers generally indicate identical or similar elements. Additionally, generally, the left-most digit(s) of a reference number identifies the drawing in which the reference number first appears.

DETAILED DESCRIPTION

[0011] Provided herein are system, apparatus, device, method and/or computer program product embodiments, and/or combinations and sub-combinations thereof, for automating a skill building process for a digital assistant.

[0012] Digital assistants are becoming ubiquitous as a way for users of a system to request information from large data sets and across multiple applications. Digital assistants allow users of the system to type in or speak requests for information using natural language requests. For example, a user may write (or speak) a natural language request such as, "show me products from supplier Talpa," indicating that the user wants to receive a list of all of the products held in a database where a 'supplier' field matches the value 'Talpa.'

[0013] In order to be able to respond to such a request, a developer would build a skill to handle the request. Specifically, the developer would need to first determine an 'intent' (intention)—an action that is being requested—such as, by way of non-limiting example, 'create' (to add a record), 'update' (to update a record), 'read' (to read a particular record), or 'query' (to identify records that match a property) and their synonyms. In this example, the request is a 'query' intent on a set of products ("show me products . . . "). One skilled in the relevant arts will readily recognize that various natural language processing techniques may be used to determine an intent, which are usable here.

[0014] The intent of a request is performed on what is termed an "entity." In the case of the foregoing example, we can term the entity "Product." The Product entity provides access to the records of interest. In this case, the Product entity can be queried in order to return records that match a certain property (in this case, where the 'supplier' property is 'talpa').

[0015] While this approach is rather straightforward in this example, the reality is that many entities are exposed and available for action in a production system. In order to operate effectively, a digital assistant should possess a variety of skills. In an enterprise environment, there are many different queries and actions that an end user may be expected to perform on these many and wide-ranging entities. Developing a skill requires a developer to manually sift through these entities to select the appropriate one that can be used to address the request. Building a single skill manually is a time-consuming process; building a large number of skills becomes a heavy investment.

[0016] FIG. **1** is a flowchart **100** illustrating steps for natural language processing skill generation, in accordance with an embodiment. The skill being generated relies on information provided by a service (e.g., a web service). At step **102**, a connection is made to the service by a skill builder component. In accordance with a non-limiting embodiment, the service is an Open Data Protocol (OData) service, but one skilled in the relevant art will appreciate that any service providing sufficient metadata for understanding entities provided by the service and connections between those entities can be used instead.

[0017] At step **104**, metadata is read from the service. In the case of OData services, every service exposes metadata, although one skilled in the relevant arts would appreciate that other services may be used that expose such metadata. This metadata includes information regarding properties, entities, and their relationships. At step **106**, entities provided by the service are determined based on this metadata.

[0018] And at step **108**, the skill builder component generates intents for a skill based on a likely ranking on the entities. This process can be resolved in several different ways, described further herein.

[0019] When the metadata of any service is accessed, typically there will be many entities available, each with many properties. In order to create a natural language skill to access this service, the relevant entities should be identified on which to create intents.

[0020] Relevant entities can be identified using entity ranking. FIG. **2** is a graph **200** showing entities as vertices and relationships between the entities as edges, in accordance with an embodiment. For example, the entity at vertex

V**4** **202***d* references the entities at vertices V**1** **202***a*, V**2** **202***b*, and V**6** **202***f*, and is referenced by the entities at V**3** **202***c* and V**5** **202***e*. Based on these relationships, a transaction that could be performed at the entity of V**6** **202***f* could also be performed through the entity of V**4** **202***d*, by in turn referencing V**6** **202***f*. But the entity of V**4** **202***d* could also resolve transactions at V**1** **202***a*, V**2** **202***b*, V**3** **202***c*, and V**5** **202***e* because of the relationships between V**4** **202***d* and those entities.

[0021] In short, the underlying assumption is that the more relationships an entity has, the more dependencies that can be resolved across the entire graph and therefore a greater number of transactions can be performed on that entity.

[0022] Using the exemplary set of nodes V={V**1**, V**2**, V**3**, V**4**, V**5**, V**6**, V**7**} of FIG. **2**, these would be ranked from greatest number of relationships to least, where each edge is a relationship, as output={V**4**, V**6**, V**2**, V**3**, V**5**, V**1**, V**7**}, in accordance with an embodiment. Accordingly, intents would be created on the entity at vertex V**4** **202***d*.

[0023] One skilled in the relevant arts will appreciate that other approaches for ranking entities based on these relationships can be used. For example, the ranking may consider quality of a relationship between two entities (such as based on a type of relationship between two entities), participation constraints, and the availability of specific annotations (e.g., a "HeaderInfo" annotation) in the metadata. Additionally, entities in a parameterized entity set may be treated as the main entity over a result entity set.

[0024] Relevant entities can also be identified using entity classification, instead of or in conjunction with entity ranking. In an embodiment, for a given entity having a set of features describing the entity, a machine learning model can be used to determine whether intents should be created on that entity or not. This approach allows for more refined solutions than simply creating intents on entities that have a large number of relationships.

[0025] In the machine learning context, this problem is a classification problem. Each entity being considered is classified as either one for which intents should be created, or one for which intents should not be created, based on the features describing the entity.

[0026] For the purposes of discussion, the process of classifying the entities is handled by a classifier module, in accordance with an embodiment, although one skilled in the relevant arts will appreciate that such process may be integrated into other components of a digital assistant, or separated further into additional components. For brevity, this classifier module, however structured, will be referred to as a classifier.

[0027] The machine learning model can be trained using algorithms readily understood by one skilled in the relevant arts, such as logic regression, support vector machine (SVM), or random forests. If the dataset is highly non-linear, for example, deep neural networks can be used. The data sets used for training and test can be split into positive and negative samples, where an entity on which intents are created can be treated as a positive sample, and an entity on which intents are not created can be treated as a negative sample.

[0028] As previously noted, these approaches for identifying relevant entities can be used separately or together, depending on the data sets and the needed results. Machine learning algorithms can identify underlying hidden patterns in the entities, but require large pre-labeled data sets and periodic retraining. Entity ranking may miss some of these patterns, but do not require training and can be shipped ready to go with the digital assistant.

[0029] Another way to use the entity ranking and entity classification approaches together is to use entity ranking as a data generator for the classifier. Specifically, entities that rank highly in the entity ranking algorithm can be treated as positive samples, and entities that rank low as negative samples. A machine learning model of the classifier can be trained on the resulting data set. This approach works well if there is no annotated data for training a model, but enough system resources to deploy computationally-intensive machine learning algorithms.

[0030] FIG. **3** is a flowchart **300** illustrating steps by which a skill is created, in accordance with an embodiment. At step **302**, the entities obtained from a service's metadata may be ranked according to an entity ranker, as described above in accordance with an embodiment. At step **304**, each of these entities is considered (or some subset thereof, based on the ranking), and intent details are determined at step **306**. The skill is saved at step **308**.

[0031] FIG. **4** is a flowchart **400** illustrating steps by which intents on an entity are detailed, in accordance with an embodiment. For a given entity, identified as described above, intents are identified at step **402**.

[0032] At step **404**, each of these intents is considered. For each intent, the type of action it performs is considered. Identification of these actions is performed using annotations that indicate whether the action is equivalent to a 'create' (to add a record), 'update' (to update a record), 'read' (to read a particular record), or 'query' (to identify records that match a property) action. By way of non-limiting example, these annotations may specifically identify the action as "creatable," "filterable," or "updateable."

[0033] At step **408**, properties are added to each intent. Specifically, relevant properties that need to be supplied as part of the request should be identified. By way of non-limiting example, this is accomplished through the further use of annotations. These annotations identify, in human-readable form, which properties may be acted upon by the various actions (intents).

[0034] In case of missing annotations, properties could be ranked by either considering properties that are used to identify an object (primary keys) or properties that serve as linking properties to other objects (foreign keys). In another embodiment, machine learning can be used to identify relevant properties.

[0035] In the end, having identified the relevant entities, intents, and properties, this approach allows for the automatic building of skills based on those elements.

[0036] Various embodiments may be implemented, for example, using one or more well-known computer systems, such as computer system **500** shown in FIG. **5**. One or more computer systems **500** may be used, for example, to implement any of the embodiments discussed herein, as well as combinations and sub-combinations thereof.

[0037] Computer system **500** may include one or more processors (also called central processing units, or CPUs), such as a processor **504**. Processor **504** may be connected to a communication infrastructure or bus **506**.

[0038] Computer system **500** may also include user input/output device(s) **503**, such as monitors, keyboards, pointing devices, etc., which may communicate with communication infrastructure **506** through user input/output interface(s) **502**.

[0039] One or more of processors **504** may be a graphics processing unit (GPU). In an embodiment, a GPU may be a processor that is a specialized electronic circuit designed to process mathematically intensive applications. The GPU may have a parallel structure that is efficient for parallel processing of large blocks of data, such as mathematically intensive data common to computer graphics applications, images, videos, etc.

[0040] Computer system **500** may also include a main or primary memory **508**, such as random access memory (RAM). Main memory **508** may include one or more levels of cache. Main memory **508** may have stored therein control logic (i.e., computer software) and/or data.

[0041] Computer system **500** may also include one or more secondary storage devices or memory **510**. Secondary memory **510** may include, for example, a hard disk drive **512** and/or a removable storage device or drive **514**. Removable storage drive **514** may be a floppy disk drive, a magnetic tape drive, a compact disk drive, an optical storage device, tape backup device, and/or any other storage device/drive.

[0042] Removable storage drive **514** may interact with a removable storage unit **518**. Removable storage unit **518** may include a computer usable or readable storage device having stored thereon computer software (control logic) and/or data. Removable storage unit **518** may be a floppy disk, magnetic tape, compact disk, DVD, optical storage disk, and/any other computer data storage device. Removable storage drive **514** may read from and/or write to removable storage unit **518**.

[0043] Secondary memory **510** may include other means, devices, components, instrumentalities or other approaches for allowing computer programs and/or other instructions and/or data to be accessed by computer system **500**. Such means, devices, components, instrumentalities or other approaches may include, for example, a removable storage unit **522** and an interface **520**. Examples of the removable storage unit **522** and the interface **520** may include a program cartridge and cartridge interface (such as that found in video game devices), a removable memory chip (such as an EPROM or PROM) and associated socket, a memory stick and USB port, a memory card and associated memory card slot, and/or any other removable storage unit and associated interface.

[0044] Computer system **500** may further include a communication or network interface **524**. Communication interface **524** may enable computer system **500** to communicate and interact with any combination of external devices, external networks, external entities, etc. (individually and collectively referenced by reference number **528**). For example, communication interface **524** may allow computer system **500** to communicate with external or remote devices **528** over communications path **526**, which may be wired and/or wireless (or a combination thereof), and which may include any combination of LANs, WANs, the Internet, etc. Control logic and/or data may be transmitted to and from computer system **500** via communication path **526**.

[0045] Computer system **500** may also be any of a personal digital assistant (PDA), desktop workstation, laptop or notebook computer, netbook, tablet, smart phone, smart watch or other wearable, appliance, part of the Internet-of-Things, and/or embedded system, to name a few non-limiting examples, or any combination thereof.

[0046] Computer system **500** may be a client or server, accessing or hosting any applications and/or data through any delivery paradigm, including but not limited to remote or distributed cloud computing solutions; local or on-premises software ("on-premise" cloud-based solutions); "as a service" models (e.g., content as a service (CaaS), digital content as a service (DCaaS), software as a service (SaaS), managed software as a service (MSaaS), platform as a service (PaaS), desktop as a service (DaaS), framework as a service (FaaS), backend as a service (BaaS), mobile backend as a service (MBaaS), infrastructure as a service (IaaS), etc.); and/or a hybrid model including any combination of the foregoing examples or other services or delivery paradigms.

[0047] Any applicable data structures, file formats, and schemas in computer system **500** may be derived from standards including but not limited to JavaScript Object Notation (JSON), Extensible Markup Language (XML), Yet Another Markup Language (YAML), Extensible Hypertext Markup Language (XHTML), Wireless Markup Language (WML), MessagePack, XML User Interface Language (XUL), or any other functionally similar representations alone or in combination. Alternatively, proprietary data structures, formats or schemas may be used, either exclusively or in combination with known or open standards.

[0048] In some embodiments, a tangible, non-transitory apparatus or article of manufacture comprising a tangible, non-transitory computer useable or readable medium having control logic (software) stored thereon may also be referred to herein as a computer program product or program storage device. This includes, but is not limited to, computer system **500**, main memory **508**, secondary memory **510**, and removable storage units **518** and **522**, as well as tangible articles of manufacture embodying any combination of the foregoing. Such control logic, when executed by one or more data processing devices (such as computer system **500**), may cause such data processing devices to operate as described herein.

[0049] Based on the teachings contained in this disclosure, it will be apparent to persons skilled in the relevant art(s) how to make and use embodiments of this disclosure using data processing devices, computer systems and/or computer architectures other than that shown in FIG. **5**. In particular, embodiments can operate with software, hardware, and/or operating system implementations other than those described herein.

[0050] It is to be appreciated that the Detailed Description section, and not any other section, is intended to be used to interpret the claims. Other sections can set forth one or more but not all exemplary embodiments as contemplated by the inventor(s), and thus, are not intended to limit this disclosure or the appended claims in any way.

[0051] While this disclosure describes exemplary embodiments for exemplary fields and applications, it should be understood that the disclosure is not limited thereto. Other embodiments and modifications thereto are possible, and are within the scope and spirit of this disclosure. For example, and without limiting the generality of this paragraph, embodiments are not limited to the software, hardware, firmware, and/or entities illustrated in the figures and/or described herein. Further, embodiments (whether or not explicitly described herein) have significant utility to fields and applications beyond the examples described herein.

[0052] Embodiments have been described herein with the aid of functional building blocks illustrating the implementation of specified functions and relationships thereof. The boundaries of these functional building blocks have been arbitrarily defined herein for the convenience of the description. Alternate boundaries can be defined as long as the specified functions and relationships (or equivalents thereof) are appropriately performed. Also, alternative embodiments can perform functional blocks, steps, operations, methods, etc. using orderings different than those described herein.

[0053] References herein to "one embodiment," "an embodiment," "an example embodiment," or similar phrases, indicate that the embodiment described can include a particular feature, structure, or characteristic, but every embodiment can not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it would be within the knowledge of persons skilled in the relevant art(s) to incorporate such feature, structure, or characteristic into other embodiments whether or not explicitly mentioned or described herein. Additionally, some embodiments can be described using the expression "coupled" and "connected" along with their derivatives. These terms are not necessarily intended as synonyms for each other. For example, some embodiments can be described using the terms "connected" and/or "coupled" to indicate that two or more elements are in direct physical or electrical contact with each other. The term "coupled," however, can also mean that two or more elements are not in direct contact with each other, but yet still co-operate or interact with each other.

[0054] The breadth and scope of this disclosure should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

What is claimed is:

1. A computer implemented method, comprising:

reading, by one or more computing devices, metadata from a connected service, wherein the metadata specifies entities provided by the service;

determining, by the one or more computing devices, a relevant entity of the entities provided by the service; and

generating, by the one or more computing devices, a likely request on the entity.

2. The method of claim **1**, wherein determining the relevant entity comprises:

ranking the entities provided by the service based on a number of relationships of the entities provided by the service; and

selecting the entity from the ranked entities.

3. The method of claim **2**, wherein ranking the entities comprises:

ranking the entities provided by the service based on a quality of the relationships.

4. The method of claim **1**, wherein determining the relevant entity comprises:

analyzing features of the entities provided by the service using a machine learning model, wherein the machine learning model classifies the relevant entity as relevant.

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

ranking, by the one or more computing devices, the entities provided by the service; and

training, by the one or more computing devices, a machine learning model using the ranked entities, wherein the machine learning model is usable to analyze features of the entities provided by the service in order to classify the relevant entity as relevant.

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

determining, by the one or more computing devices, an intent of the entity and a property of the intent; and

building, by the one or more computing devices, a skill on the entity using the intent and the property.

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

determining, by the one or more computing devices, a plurality of intents of the entity; and

ranking, by the one or more computing devices, the plurality of intents.

8. A system, comprising:

a memory configured to store operations; and

one or more processors configured to perform the operations, the operations comprising:

reading metadata from a connected service, wherein the metadata specifies entities provided by the service,

determining a relevant entity of the entities provided by the service, and

generating a likely request on the entity.

9. The system of claim **8**, wherein determining the relevant entity comprises:

ranking the entities provided by the service based on a number of relationships of the entities provided by the service; and

selecting the entity from the ranked entities.

10. The system of claim **9**, wherein ranking the entities comprises:

ranking the entities provided by the service based on a quality of the relationships.

11. The system of claim **8**, wherein determining the relevant entity comprises:

analyzing features of the entities provided by the service using a machine learning model, wherein the machine learning model classifies the relevant entity as relevant.

12. The system of claim **8**, the operations further comprising:

ranking the entities provided by the service; and

training a machine learning model using the ranked entities, wherein the machine learning model is usable to analyze features of the entities provided by the service in order to classify the relevant entity as relevant.

13. The system of claim **8**, the operations further comprising:

determining an intent of the entity and a property of the intent; and

building a skill on the entity using the intent and the property.

14. The system of claim **8**, the operations further comprising:

determining a plurality of intents of the entity; and

ranking the plurality of intents.

15. A computer readable storage device having instructions stored thereon execution of which, by one or more processing devices, causes the one or more processing devices to perform operations comprising:

reading metadata from a connected service, wherein the metadata specifies entities provided by the service;

determining a relevant entity of the entities provided by the service; and

generating a likely request on the entity.

16. The computer readable storage device of claim **15**, wherein determining the relevant entity comprises:

ranking the entities provided by the service based on a number of relationships of the entities provided by the service; and

selecting the entity from the ranked entities.

17. The computer readable storage device of claim **16**, wherein ranking the entities comprises:

ranking the entities provided by the service based on a quality of the relationships.

18. The computer readable storage device of claim **15**, wherein determining the relevant entity comprises:

analyzing features of the entities provided by the service using a machine learning model, wherein the machine learning model classifies the relevant entity as relevant.

19. The computer readable storage device of claim **15**, the operations further comprising:

ranking the entities provided by the service; and

training a machine learning model using the ranked entities, wherein the machine learning model is usable to analyze features of the entities provided by the service in order to classify the relevant entity as relevant.

20. The computer readable storage device of claim **15**, the operations further comprising:

determining an intent of the entity and a property of the intent; and

building a skill on the entity using the intent and the property.

* * * * *