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**TITLE OF THE INVENTION (500 characters max):**

Natural Language Interface with Autonomous Systems

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☒ Application Data Sheet. See 37 CFR 1.76

☐ CD(s), Number of CDs _____

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☒ Other (specify) Appendices and References, 3 pages

☒ Specification (e.g. description of the invention) *Number of Pages* 16

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# Natural Language Interface with Autonomous Systems

## Abstract

This specification describes technologies implementing a natural language interface is based on Embodied Construction Grammar and simulation semantics. The system described in this specification supports dialog with an autonomous system, e.g., a robot, but is flexible with respect to both input language and output task.

## Background

Autonomous systems are ones that act without direct human control. These range from thermostats to robots and self-driving vehicles. This application area is growing rapidly, often called the "internet of things", where ever more actions are being performed by web-connected devices. There are also many systems that act autonomously in cyberspace, such as shopping bots and interactive game agents. There are already simple interfaces to some of these, but none that support the richness of human expression or the complexity of the systems, e.g. robots, that are being deployed.

## Summary

This specification describes a novel, complete system that allows autonomous computer-based systems to understand and carry out general dialogs in a natural language, e.g., English.

This system incorporates several novel subsystems and data structures. One new element is an n-tuple data structure, which is a powerful, task and machine independent data representation that can be used to transmit task-relevant commands from a language subsystem to an action subsystem. N-tuples also support clarification interactions between the action system and a user, mediated by the language system. Appendix B depicts an N-tuple for the robot command domain. The bolded entries are from the task-independent N-tuple meta language. These primitives are similar to those of programming languages such as Lisp (Russell & Norvig, 2009). The specific items such as Protagonist:*Object-Descriptor* specify domain specific roles and their type. The collection of these comprises the N-tuple *template* for the domain. These templates are stored and used by the specializer in converting from the language structures to task-oriented n-tuples.

Another new element is the specializer. The specializer receives a task-independent meaning structure, called a SemSpec. The specializer traverses a SemSpec and, using task n-tuple templates, produces one or more task-oriented n-tuples to send to the autonomous system.

Another new element is the problem solver. The system supports the control of autonomous systems that have a text interface, an API ("application programming interface"), or other interface. The problem solver adds the functionality of context to the underlying API, and will be described below.

The problem solver receives n-tuples from the specializer. The problem solver interprets incoming n-tuples and does several things. If the n-tuple is ambiguous, the problem solver will generate a clarification question. If the n-tuple specifies a simple action, the problem solver invokes an appropriate action with parameters from the application using its command query interface. In the robot example, parameters include the desired agent, action, object, goal, etc. and are specified in ordinary language by the user. The mechanism on the left side of Figure 1 shows the machinery by which the user expression of these parameters is mapped to the elements of the application interface. Optionally, the problem solver will have additional data structures and procedures to carry out the specified operations using the autonomous system. For example, for a robot, the problem solver may incorporate a world model and procedures for computing a shortest safe path to some target place or object. Shortest-path algorithms are described in detail in Russell & Norvig, 2009.

The subject matter described in this specification can be implemented in particular embodiments so as to realize one or more of the following advantages. A new application of the system can be implemented simply by implementing a shared vocabulary and task n-tuples for communication between the language and action subsystems.

## Detailed Description

### Embodied Construction Grammar

The Embodied Construction Grammar (ECG) is described in Feldman, Dodge, and Bryant 2009.

ECG is used in the systems described in this specification to provide a front end for autonomous systems involving deep semantics. In particular, it is used to provide a natural language interface to a robot.

**System Architecture**

As shown in Figure 1, the system architecture is modular. The ECG grammar will work for a wide range of applications that have rich internal semantics.

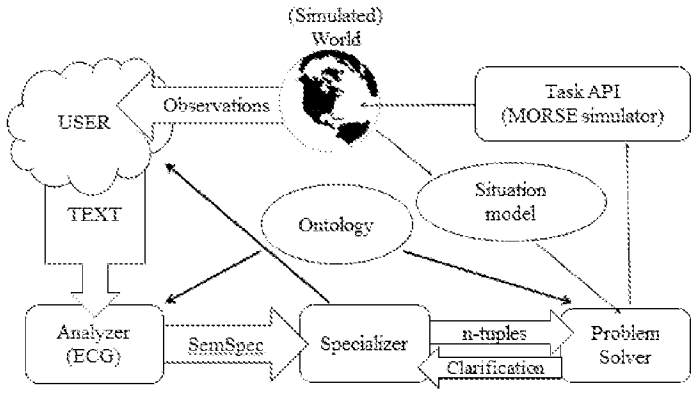



**Figure 1**

The main modules are the analyzer, the specializer, the problem solver, and the interface to the autonomous system. The following description will describe the system with reference to a robot; however, the system is not limited to robots, and is generally applicable to a wide range of autonomous systems. The modules can each be implemented as one or more computer programs deployed on a computer system made up of one or more computers in one or more locations.

The analyzer semantically parses the user input with an ECG grammar plus a language ontology and outputs a data structure called the SemSpec. The analyzer and the SemSpec data structure have been described, for example, in Feldman, Dodge, Bryant 2009, and Bryant 2008, cited below. Much of the language ontology is built into the system and new items can be added using the token tool, which will be described below. The token tool is also used to build mappings between the language and application ontologies. The language ontology is conventional for natural language understanding ("NLU") systems, and the application ontology will vary across applications. The Token Editor (described in reference to Figure 3) provides a novel mechanism for connecting the two ontologies.

The specializer crawls the SemSpec to capture the task relevant information, which it sends to the problem solver as a data structure. Any convenient data structure may be used. In

the following description, implementations using a data structure called an n-tuple will be described. The specializer will be described in more detail, below.

The problem solver then uses the information from the n-tuple, along with the problem solver's internal model of the world, to make decisions about the world and to carry out actions. Additionally, the problem solver updates its model of the world after each action, so it can continue to make informed decisions and actions. The world model is task-dependent; for the robot domain this includes the positions and features of all the robots and objects.

While this specification describes the system as one that interacts in English, the system will work in other languages as well. An example is illustrated below in reference to Table 3 for Spanish. The same analyzer, n-tuples, problem solver, and robot simulator can be used without alteration. The specializer, on the other hand, may have to be tailored to the particular natural language being used. The specializer extracts the relevant information and creates the same n-tuple. This allows the problem solver and robot simulator to remain unchanged.

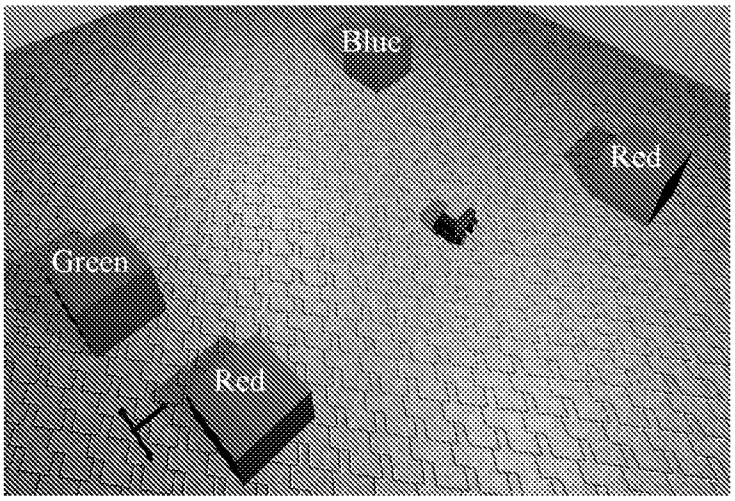



FIGURE 2

**Supported Input**

Table 2 highlights a representative sample of working input, corresponding to the scene in Figure 2. The location to which the robot (shown in the center of the figure) is instructed to move can include specific locations "location 1 2," and specific items "Box1." The system can also handle more complicated descriptions, using color and size. Additionally, when the user references an indefinite object, such as, "a red box," and there are multiple objects that fit the description, one of the objects that satisfies the condition is chosen randomly. For definite

objects, such as "*the* red box", the system asks for clarification, since the user is referring to a particular object: "which red box?"

| | |
|---|---|
| 1) | Robot1, move to location 1 2! |
| 2) | Robot1, move to the north side of the blue box! |
| 3) | Robot1, push the blue box East! |
| 4) | Robot1, move to the green box then push the blue box South! |
| 5) | Robot1, if the small box is red, push it North! |
| 6) | where is the green box? |
| 7) | is the small red box near the blue box? |
| 8) | Robot1, move behind the big red box! |
| 9) | which boxes are near the green box? |

Table 2: Sample supported input (English)

| | |
|---|---|
| 1) | Robot1, muévete a posición 1 2! |
| 2) | Robot1, muévete al parte norte de la caja azul! |
| 3) | Robot1, empuje la caja azul al este! |
| 4) | Robot1, muévete a la caja verde y empuje la caja azul al sur! |
| 5) | Robot1, si la caja pequeña es roja, la empuje al norte! |
| 6) | dónde está la caja verde? |
| 7) | está la caja roja y pequeña cerca de la caja azul? |
| 8) | Robot1, muévete detrás de la caja roja y grande! |
| 9) | cuáles cajas están cerca de la caja verde? |

Table 3: Sample supported input (Spanish)

In addition to commands involving moving and pushing, the system can also handle yes or no questions—as demonstrated in Example 7, in Table 2. Example 5 demonstrates a conditional imperative; the robot will only perform the instruction if the condition is satisfied. The system can also handle basic referent resolution, as demonstrated in Example 5. This is done by choosing the most recent antecedent of the proper kind. One method for choosing the most recent antecedent of the proper kind is described in Oliva J.; Feldman J.; Giraldi L. and Dodge

E., Ontology Driven Contextual Reference Resolution in Embodied Construction Grammar; in the proceedings of the 7th Annual Constraint Solving and Language Processing Workshop; Orléans, France, 2012 ("Oliva").

The total range of supported input is considerably greater than the sentences included in the tables; these are intended to give a sense of the general type or structure of supported input in both English and Spanish.

If the analyzer cannot analyze the input, the user is notified and prompted to try entering the input again. If the user attempts to describe an object that does not exist in the simulation, the system informs the user, "there is no object that matches that description. Please try again."

If there is more than one object that matches an object's description, e.g., "red box", and a definite article is used, e.g. "*the* red box", the system asks for clarification, e.g., "which red box?" The user can then offer a more specific description, such as: "the small one".

**Extended Example: Robot**

In order to demonstrate the integration and functionality of the system, an extended example from text to action is now presented. Consider the command, "Robot1, if the box near the green box is red, push it South!" This is discussed in the context of the example world shown in Figure 2.

**Analyzer**

The input text is first parsed by the analyzer program using the ECG grammar. The analyzer uses syntactic and semantic properties to develop a best-fit model and produce a SemSpec. This SemSpec is a grammatical parse of the sentence, consisting of conceptual schemas and their bindings, as described in Bryant 2008. A constructional outline of the SemSpec for this example is shown in Appendix A.

**Specializer**

The specializer extracts the relevant information for the problem solver from the SemSpec. This output is in the form of an n-tuple, a data structure that can be implemented using Python dictionaries. The n-tuple for this example can be found in Appendix B. The n-tuples are a form of Agent Communication Language; although the content of the n-tuples changes across different tasks and domains (e.g., robotics or metaphor analysis), the structure and form can

remain the same. A "core" specializer performs many task-independent procedures, and its methods are used by task-specific specializers.

For any given application, the same "core" specializer can be used to crawl the SemSpec for task-relevant information. This procedure performs a standard search on the semantic parse tree; this search algorithm is generalizable across multiple languages and task domains. However, although some of the n-tuple templates are generalizable – such as a yes/no query – a designer will need to define new n-tuple templates for new applications to facilitate communication with the problem solver. Currently, this is done by adding templates to the task-specific specializer; these templates are represented as class fields in the specializer, so defining a new template simply consists of creating a new Python dictionary with the fields the user wants filled in. Then, the task-specific specializer's code must be modified to search for the values for those particular fields. Again, this search process is generalizable and is done using methods contained in the "core" specializer.

In the example given, the command is in the form of a conditional imperative, so the specializer must fill in the corresponding template by extracting the bindings from the SemSpec. The specializer identifies the correct template to use by examining the utterance's "mood", which is a property of the Discourse schema; this is a part of understanding a command's context and the speaker's intentionality. The "mood" is set in the grammar, and ranges over "Conditional-Imperative" to "WH-Question".

Additionally, the direct object of the "push" command is a pronoun; the analyzer cannot match pronouns with their antecedents, so the specializer uses a combination of syntactic and semantic information to perform reference resolution, performing the methods described in Oliva. In this case, the antecedent of "it" is "the box near the green box", so the specializer passes this information to the problem solver in the n-tuple. The procedure for reference resolution is also contained in the "core" specializer, and is generalizable across multiple task domains.

The specializer performs basic co-reference resolution between pronouns and their antecedents. This is done by maintaining a LIFO (last in first out) stack of the syntactic heads of past Nominal Phrases; when a pronoun is encountered, the specializer matches its syntactic and semantic context with the most recent object reference on the stack. This procedure incorporates semantic features, as well as syntactic ones, in determining the compatibility of a pronoun and its

antecedent. For example, if the robot is instructed to "push" something, the specializer checks that the antecedent is "movable", using the ontology lattice.

The "core" specializer also resolves cases of the anaphoric *one* using a related but distinct method. The usage of the anaphoric *one* is problematic because it often refers simply to an antecedent's *category*. For example, in the sentence "John has a red cup and I have a green *one*", *one* refers to the category of "cup". The system has semantic and world knowledge, and it uses these contextual features in the resolution process; qualifiers in the antecedent, such as "red", are compared with the anaphora's qualifiers, such as "green", and are added iteratively until the system is able to locate a referent in the model world. The model world is the continually updated data structure contained in the problem solver, containing contextual world knowledge.

**Problem solver**

The problem solver parses the n-tuple to determine the actions needed, and then performs those actions. It begins by determining the type of command, which in this example is a conditional. Before it performs the command, it must evaluate the truth of the condition.

In this example, the problem solver must determine which box is "near the green box" and then determine whether that box has the property *red*. Using the information provided by the specializer, the solver searches through its data structure, which contains the current and updated state of the simulated world. In a real world physical robot, this might also involve visual or other search of the environment. The language and interface capabilities would apply equally to a physical robot. Once the solver identifies the box that is located near the green box, it can evaluate whether that box is red using its vision system or world knowledge.

If the condition is satisfied, the robot performs the specified action: in this case, "push it [the box near the green box] South!" This action is considerably more complex than simply moving to a box, and involves a nontrivial amount of trajectory planning. First, the problem solver disambiguates the location of the box by searching through its data structures. Then, it determines that to push the box South, it must move to the North side of the box, avoiding obstacles along the way, rotate to face the box, and move South. This results in pushing the box South. This kind of path and task planning can be implemented using any of a number of techniques that are standard in robotics, as described in Russell & Norvig 2009. In addition, the problem solver can optionally operate together with a separate planner, e.g., much more complex planners.

Finally, the call to execute a move action is made through the wrapper class of the robot API. MORSE is an example of such an API (Echeverria et al, 2011). This additional level of abstraction allows the system to work with an arbitrary robot or other autonomous system assuming it supports the same primitives.

The system handles under-specified input in the form of a clarification dialog. The problem solver has information about the simulated world, so it can determine when to query the user for more information. If the user instructs the robot to move to "the red box", and there are two red boxes, the system asks: "which red box?" The user might reply: "the small one". This clarification process allows the system to interact with the user, and continues until the input is properly specified . It uses one-anaphora resolution to determine the correct referent.

**Token Editor**

A morphological pre-processing system reduces the number of necessary constructions and exploits the existing schema lattices in the grammar. A major innovation to support the integration of new applications is the type/token system depicted in Figure 3.

This new component has been added to the ECG Workbench, an interface for designing grammars and analyzing sentences (Gilardi et al, 2008). This new component allows a user to expand the lexicon by inserting "tokens" of various syntactic and semantic categories or "types" into a token list – e.g., "red" is a token of the "color" type – which reduces the need for lexical constructions. The Token Editor interacts with the ontology lattice of the ECG grammar by adding new items and updating the language ontology, which is a component of the Analyzer (Figure 1). For coupling the general NLU front end (depicted on the left side of Figure 1) to varying application domains, the ontology referenced by the Analyzer needs to be shared with that of the Problem Solver; thus, when a user adds a new token, the user can also use the Token Editor to specify mappings between the language and application ontologies, as seen in Figure 3.

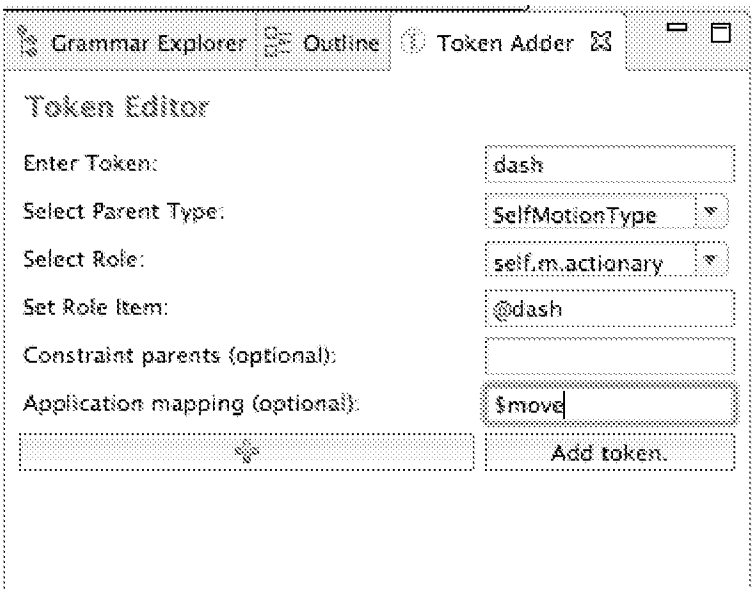



Figure 3

The Token Editor generates a table in a tokens file, which contains a list of tokens, along with their parent types and role items. The result of the operation in Figure 3 would be:

dash :: SelfMotionType :: self.m.actionary <-- @dash :: self.m.speed <-- ".8"

The token list does not need to be read in when the grammar is compiled, which allows the user to significantly increase the size of the lexicon and maintain the complex grammar semantics without sacrificing speed or efficiency. When a sentence is parsed, the token specifications and morphological information is added to the SemSpec.

Embodiments of the subject matter and the functional operations described in this specification can be implemented in digital electronic circuitry, in tangibly-embodied computer software or firmware, in computer hardware, including the structures disclosed in this specification and their structural equivalents, or in combinations of one or more of them. Embodiments of the subject matter described in this specification can be implemented as one or more computer programs, i.e., one or more modules of computer program instructions encoded on a tangible non-transitory storage medium for execution by, or to control the operation of, data processing apparatus. The computer storage medium can be a machine-readable storage device, a machine-readable storage substrate, a random or serial access memory device, or a

combination of one or more of them. Alternatively or in addition, the program instructions can be encoded on an artificially-generated propagated signal, e.g., a machine-generated electrical, optical, or electromagnetic signal, that is generated to encode information for transmission to suitable receiver apparatus for execution by a data processing apparatus.

The term "data processing apparatus" refers to data processing hardware and encompasses all kinds of apparatus, devices, and machines for processing data, including by way of example a programmable processor, a computer, or multiple processors or computers. The apparatus can also be, or further include, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application-specific integrated circuit). The apparatus can optionally include, in addition to hardware, code that creates an execution environment for computer programs, e.g., code that constitutes processor firmware, a protocol stack, a database management system, an operating system, or a combination of one or more of them.

A computer program, which may also be referred to or described as a program, software, a software application, a module, a software module, a script, or code, can be written in any form of programming language, including compiled or interpreted languages, or declarative or procedural languages; and it can be deployed in any form, including as a stand-alone program or as a module, component, subroutine, or other unit suitable for use in a computing environment. A program may, but need not, correspond to a file in a file system. A program can 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 can 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 data communication network.

The processes and logic flows described in this specification can be performed by one or more programmable computers executing one or more computer programs to perform functions by operating on input data and generating output. The processes and logic flows can also be performed by special purpose logic circuitry, e.g., an FPGA or an ASIC, or by a combination of special purpose logic circuitry and one or more programmed computers.

Computers suitable for the execution of a computer program can be based on general or special purpose microprocessors or both, or any other kind of central processing unit. Generally,

a central processing unit will receive instructions and data from a read-only memory or a random access memory or both. The essential elements of a computer are a central processing unit for performing or executing instructions and one or more memory devices for storing instructions and data. The central processing unit and the memory can be supplemented by, or incorporated in, special purpose logic circuitry. 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 can be embedded in another device, e.g., a mobile telephone, a personal digital assistant (PDA), a mobile audio or video player, a game console, a Global Positioning System (GPS) receiver, or a portable storage device, e.g., a universal serial bus (USB) flash drive, to name just a few.

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.

Control of the various systems described in this specification, or portions of them, can be implemented in a computer program that includes instructions that are stored on one or more non-transitory machine-readable storage media, and that are executable on one or more processing devices. The systems described in this specification, or portions of them, can each be implemented as an apparatus, method, or electronic system that may include one or more processing devices and memory to store executable instructions to perform the operations described in this specification.

To provide for interaction with a user, embodiments of the subject matter described in this specification can be implemented on a computer having a display device, e.g., a CRT (cathode ray tube) or LCD (liquid crystal display) monitor, for displaying information to the user and a keyboard and a pointing device, e.g., a mouse, trackball or touchpad, by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback, e.g., visual feedback, auditory feedback, or tactile feedback; and input from the user can be received in any form, including acoustic, speech, or tactile input. In addition, a computer can

interact with a user by sending documents to and receiving documents from a device that is used by the user; for example, by sending web pages to a web browser on a user's device in response to requests received from the web browser.

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

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 modules and components in the embodiments described above should not be understood as requiring such separation in all embodiments, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products.

Particular embodiments of the subject matter have been described. Other embodiments are within the scope of the following claims. For example, the actions recited in the claims can be performed in a different order and still achieve desirable results. As one example, the processes depicted in the accompanying figures do not necessarily require the particular order shown, or sequential order, to achieve desirable results. In some cases, multitasking and parallel processing may be advantageous.

What is claimed is:

## CLAIMS

1. A system comprising:

a user device; and

one or more computers configured by computer programs to interact with a user device and an autonomous system and to perform operations comprising:

receiving a SemSpec from an analyzer processing text input originating from a user and generating an n-tuple from the SemSpec;

receiving an n-tuple and generating from the n-tuple either one or more actions for the autonomous system or a question for the user; and

submitting the one or more actions to the autonomous system or the question to the user.

2. The system of claim 1, wherein:

the autonomous system is a robot.

3. The system of claim 1, wherein

the user device is a personal computing device operable to receive text input form the user and present text output to the user.

4. The system of claim 1, wherein

the user device is a personal computing device operable to receive voice input from the user.

5. The system of claim 4, wherein

the user device is a personal computing device operable to provide voice output to the user.

6. The system of claim 1, further comprising:

deriving the text input from speech input received from a user.

7. The system of claim 1, wherein the operations further comprise:

the autonomous system implements an internal vocabulary; and

receiving a mapping from the language of the text input to the internal vocabulary.

8. The system of claim 8, wherein the operations further comprise:

generating the mapping based on input received from a system designer using a token editor.

9. A method comprising:

receiving by a system of one or more computers a SemSpec from an analyzer processing text input originating from a user and generating an n-tuple from the SemSpec;

receiving by the system an n-tuple and generating from the n-tuple either one or more actions for the autonomous system or a question for the user; and

submitting by the system the one or more actions to the autonomous system or the question to the user.

10. One or more computer-readable storage media encoded with instructions that, when executed by one or more computers, cause the one or more computers to perform operations comprising:

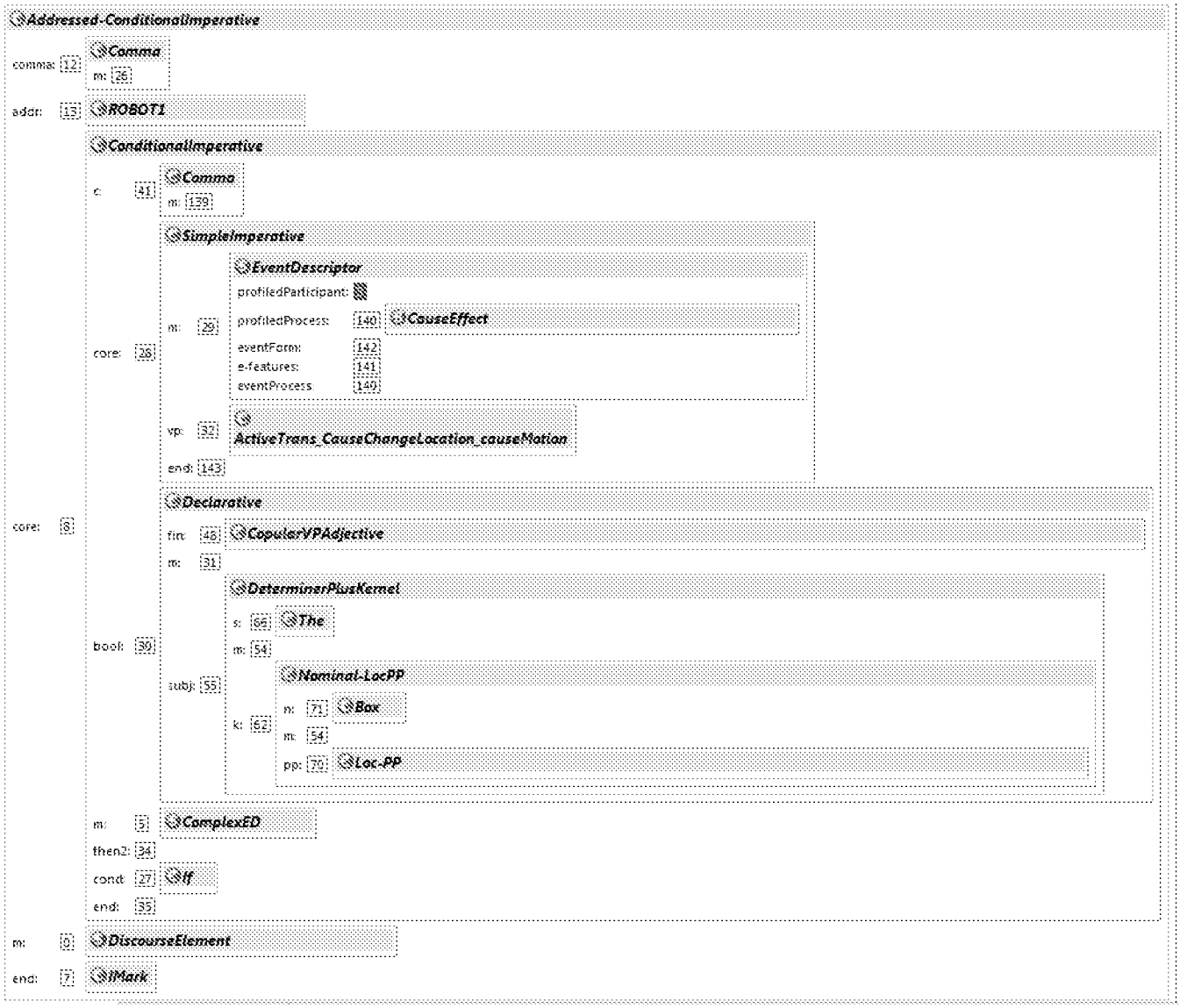
receiving by a system of one or more computers a SemSpec from an analyzer processing text input originating from a user and generating an n-tuple from the SemSpec;

receiving by the system an n-tuple and generating from the n-tuple either one or more actions for the autonomous system or a question for the user; and

submitting by the system the one or more actions to the autonomous system or the question to the user.

## Appendix A: SemSpec example

(Below is the Analyzer's SemSpec output for the sentence: "Robot1, if the box near the green box is red, push it South!" In order to conserve space and also illustrate the entire constructional tree, many of the constructional roles and schemas have been collapsed.)



## Appendix B: n-tuple example

**"Robot1, if the box near the green box is red, push it South!"**

(Below is a representation of the N-Tuple; the actual Python code is shown in the supplementary materials.)

Return_type: error_descriptor,

Predicate_type: conditional

Parameters:

**Kind**: Conditional

**Condition**:

Protagonist: *Object-Descriptor:*

Type: box

Givenness: uniquely-Identifiable

*Location-Descriptor:*

Relation: Near

*Object-Descriptor:*

Type: box

Givenness: Uniquely-Identifiable

Color: green

Predication: (Color: Red)

Kind: Query

Action: be

**Command**:

Kind: cause

Causal-Process:

Protagonist: Robot1_instance

Control_State: Ongoing

Speed: 0.5

Distance: (units: square, value: 8)

Acted-Upon: *Object-Descriptor:*

Type: Box

Givenness: Uniquely-Identifiable

*Location-Descriptor*:

Relation: Near

*Object-Descriptor:*

Type: box

Givenness: Uniquely-Identifiable

Color: green

Kind: Execute

Action: Force-Application

Affected-Process:

Direction: None

Protagonist: *Object-Descriptor*

Type: Box

Givenness: Uniquely-Identifiable

*Location-Descriptor:*

Relation: Near

*Object-Descriptor:*

Type: box

Givenness: Uniquely-Identifiable

Color: green

Heading: South

Control_state: Ongoing

Speed: 0.5

Distance: (units: square, value: 8)

Kind: Execute

Causer: Robot1_instance

Action: push_move

## References

The following references are cited in the foregoing specification. The pertinent part of each reference is incorporated in the specification by this reference.

Bryant, J. E. 2008. Best-Fit Constructional Analysis. Ph.D. diss., Department of Computer Science, University of California at Berkeley

Echeverria, G.; Lassabe, N.; Degroote, A. and Lemaignan, S. 2011. Modular open robots simulation engine: Morse. In the proceedings of the 2011 IEEE International Conference Robotics and Automation, 46-51 IEEE.

Feldman J.; Dodge E.; and Bryant J. A Neural Theory of Language and Embodied Construction Grammar. In The Oxford Handbook of Linguistic Analysis, Heine B. and Narrog H. 111-138, Oxford University Press, 2009

Gilardi, Luca; Feldman, Jerome. 2008. A Brief Introduction to ECG Workbench and a First English Grammar. (http://www1.icsi.berkeley.edu/~lucag/)

Oliva J.; Feldman J.; Giraldi L. and Dodge E. Ontology Driven Contextual Reference Resolution in Embodied Construction Grammar. 2012. In the proceedings of the 7th Annual Constraint Solving and Language Processing Workshop. Orléans, France

Russell, S., Norvig, P. 2009. Artificial Intelligence: A Modern Approach (3rd edition).

PTO/AIA/14 (12-13)
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| Application Data Sheet 37 CFR 1.76 | Attorney Docket Number | 10637-0013P01 |
|---|---|---|
| | Application Number | |
| Title of Invention | Natural Language Interface with Autonomous Systems | |

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

## Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

## Inventor Information:

**Inventor 1** Remove

**Legal Name**

| Prefix | Given Name | Middle Name | Family Name | Suffix |
|---|---|---|---|---|
| | Jerome | A. | Feldman | |

**Residence Information (Select One)** ◉ US Residency ○ Non US Residency ○ Active US Military Service

| City | Emeryville | State/Province | CA | Country of Residence i | US |
|---|---|---|---|---|---|

**Mailing Address of Inventor:**

| Address 1 | 2 Anchor Drive, #399 | | |
|---|---|---|---|
| Address 2 | | | |
| City | Emeryville | State/Province | CA |
| Postal Code | 94608 | Country i | US |

**Inventor 2** Remove

**Legal Name**

| Prefix | Given Name | Middle Name | Family Name | Suffix |
|---|---|---|---|---|
| | Srinivas | | Narayanan | |

**Residence Information (Select One)** ○ US Residency ◉ Non US Residency ○ Active US Military Service

| City | Zurich | Country of Residence i | CH |
|---|---|---|---|

**Mailing Address of Inventor:**

| Address 1 | Zurichbergstrasse 46 A | | |
|---|---|---|---|
| Address 2 | | | |
| City | Zurich | State/Province | |
| Postal Code | 8044 | Country i | CH |

**Inventor 3** Remove

**Legal Name**

| Prefix | Given Name | Middle Name | Family Name | Suffix |
|---|---|---|---|---|
| | Sean | T. | Trott | |

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 10637-0013P01 |
|---|---|---|
| | Application Number | |
| Title of Invention | Natural Language Interface with Autonomous Systems | |

| **Residence Information (Select One)** | ◉ US Residency | ○ Non US Residency | ○ Active US Military Service | | |
|---|---|---|---|---|---|
| **City** | Albany | **State/Province** | CA | **Country of Residence** i | US |

**Mailing Address of Inventor:**

| | | | |
|---|---|---|---|
| **Address 1** | 1235 Solano Avenue | | |
| **Address 2** | Apartment 8 | | |
| **City** | Albany | **State/Province** | CA |
| **Postal Code** | 94706 | **Country** i | US |

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

## Correspondence Information:

**Enter either Customer Number or complete the Correspondence Information section below.**
**For further information see 37 CFR 1.33(a).**

☐ **An Address is being provided for the correspondence Information of this application.**

| | | | |
|---|---|---|---|
| **Customer Number** | 26181 | | |
| **Email Address** | | Add Email | Remove Email |

## Application Information:

| | | | |
|---|---|---|---|
| **Title of the Invention** | Natural Language Interface with Autonomous Systems | | |
| **Attorney Docket Number** | 10637-0013P01 | **Small Entity Status Claimed** | ☒ |
| **Application Type** | Provisional | | |
| **Subject Matter** | Utility | | |
| **Total Number of Drawing Sheets (if any)** | | **Suggested Figure for Publication (if any)** | |

## Filing By Reference :

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

| Application number of the previously filed application | Filing date (YYYY-MM-DD) | Intellectual Property Authority or Country i |
|---|---|---|
| | | |

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 10637-0013P01 |
|---|---|---|
| | Application Number | |
| Title of Invention | Natural Language Interface with Autonomous Systems | |

## Publication Information:

| | |
|---|---|
| ☐ | Request Early Publication (Fee required at time of Request 37 CFR 1.219) |
| ☐ | **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing. |

## Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

| | | | |
|---|---|---|---|
| Please Select One: | ◉ Customer Number | ○ US Patent Practitioner | ○ Limited Recognition (37 CFR 11.9) |
| Customer Number | 26181 | | |

## Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the application number blank.

| Prior Application Status | | | Remove |
|---|---|---|---|
| Application Number | Continuity Type | Prior Application Number | Filing Date (YYYY-MM-DD) |
| | | | |

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button. Add

## Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) [i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

| | | | Remove |
|---|---|---|---|
| Application Number | Country [i] | Filing Date (YYYY-MM-DD) | Access Code [i] (if applicable) |
| | | | |

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 10637-0013P01 |
|---|---|---|
| | Application Number | |
| Title of Invention | Natural Language Interface with Autonomous Systems | |

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button. Add

## Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

## Authorization to Permit Access:

☐ Authorization to Permit Access to the Instant Application by the Participating Offices

If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the instant patent application is filed access to the instant patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the instant patent application is filed to have access to the instant patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing this Authorization.

## Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 10637-0013P01 |
|---|---|---|
| | Application Number | |
| Title of Invention | Natural Language Interface with Autonomous Systems | |

**Applicant 1** Remove

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

| ◯ Assignee | ◯ Legal Representative under 35 U.S.C. 117 | ◯ Joint Inventor |
|---|---|---|
| ◯ Person to whom the inventor is obligated to assign. | ◯ Person who shows sufficient proprietary interest | |

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor :

If the Applicant is an Organization check here. ☐

| Prefix | **Given Name** | Middle Name | **Family Name** | Suffix |
|---|---|---|---|---|
| | | | | |

**Mailing Address Information:**

| | | | |
|---|---|---|---|
| **Address 1** | | | |
| Address 2 | | | |
| **City** | | **State/Province** | |
| **Country** [i] | | Postal Code | |
| Phone Number | | Fax Number | |
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## Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not subsitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

**Assignee 1**

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication . An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

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| **Application Data Sheet 37 CFR 1.76** | Attorney Docket Number | 10637-0013P01 |
|---|---|---|
| | Application Number | |
| Title of Invention | Natural Language Interface with Autonomous Systems | |

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

| Prefix | **Given Name** | Middle Name | **Family Name** | Suffix |
|---|---|---|---|---|
| | | | | |

**Mailing Address Information For Assignee including Non-Applicant Assignee:**

| | | | |
|---|---|---|---|
| **Address 1** | | | |
| Address 2 | | | |
| **City** | | **State/Province** | |
| **Country** i | | Postal Code | |
| Phone Number | | Fax Number | |
| Email Address | | | |

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button. Add

## Signature:

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NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications

| **Signature** | /Hans R. Troesch,Reg.#36950/ | | | Date (YYYY-MM-DD) | 2015-02-27 |
|---|---|---|---|---|---|
| First Name | Hans | Last Name | Troesch | Registration Number | 36950 |

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This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

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# Electronic Patent Application Fee Transmittal

| | |
|---|---|
| **Application Number:** | |
| **Filing Date:** | |
| **Title of Invention:** | Natural Language Interface with Autonomous Systems |
| **First Named Inventor/Applicant Name:** | Jerome A. Feldman |
| **Filer:** | Hans R. Troesch/Christine Rogers |
| **Attorney Docket Number:** | 10637-0013P01 |

Filed as Small Entity

**Filing Fees for Provisional**

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Basic Filing:** | | | | |
| Provisional Application Filing Fee | 2005 | 1 | 130 | 130 |
| **Pages:** | | | | |
| **Claims:** | | | | |
| **Miscellaneous-Filing:** | | | | |
| **Petition:** | | | | |
| **Patent-Appeals-and-Interference:** | | | | |
| **Post-Allowance-and-Post-Issuance:** | | | | |

| Description | Fee Code | Quantity | Amount | Sub-Total in USD($) |
|---|---|---|---|---|
| **Extension-of-Time:** | | | | |
| **Miscellaneous:** | | | | |
| | | | **Total in USD ($)** | **130** |

# Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 21629760 |
| **Application Number:** | 62126378 |
| **International Application Number:** | |
| **Confirmation Number:** | 8024 |
| **Title of Invention:** | Natural Language Interface with Autonomous Systems |
| **First Named Inventor/Applicant Name:** | Jerome A. Feldman |
| **Customer Number:** | 26181 |
| **Filer:** | Hans R. Troesch/mary ann reed |
| **Filer Authorized By:** | Hans R. Troesch |
| **Attorney Docket Number:** | 10637-0013P01 |
| **Receipt Date:** | 27-FEB-2015 |
| **Filing Date:** | |
| **Time Stamp:** | 20:25:17 |
| **Application Type:** | Provisional |

## Payment information:

| | |
|---|---|
| Submitted with Payment | yes |
| Payment Type | Deposit Account |
| Payment was successfully received in RAM | $130 |
| RAM confirmation Number | 7146 |
| Deposit Account | 061050 |
| Authorized User | |

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## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | | 10637_0013P01_Specification.pdf | 867957<br>bad1dadf7d2e584e9a204cb6bd20f7a38a8c53ed | yes | 19 |

**Multipart Description/PDF files in .zip description**

| Document Description | Start | End |
|---|---|---|
| Specification | 1 | 13 |
| Claims | 14 | 15 |
| Appendix to the Specification | 16 | 16 |
| Appendix to the Specification | 17 | 18 |
| Appendix to the Specification | 19 | 19 |

**Warnings:**

**Information:**

| | | | | | |
|---|---|---|---|---|---|
| 2 | Application Data Sheet | 10637_0013P01_ADS.pdf | 1560845<br>9f6dcf177a42c4c1f44100722935e4c53eb81de3 | no | 7 |

**Warnings:**

**Information:**

| | | | | | |
|---|---|---|---|---|---|
| 3 | Provisional Cover Sheet (SB16) | 10637_0013P01_Transmittal.pdf | 109046<br>24343595595ce93e40884ea080fba07622a31890 | no | 1 |

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| 4 | Fee Worksheet (SB06) | fee-info.pdf | 29536<br>5be73bdc53fc9e5dad139f549eb181eaa298fb5a | no | 2 |

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**New Applications Under 35 U.S.C. 111**

**If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.**

**National Stage of an International Application under 35 U.S.C. 371**

**If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.**

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