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Dated: November 1, 2016

By: /Peter J. Gutierrez, III/
Peter J. Gutierrez, III, Reg. No. 56,732

US UTILITY APPLICATION TRANSMITTAL

Sir:

Transmitted herewith for filing is the patent application of

Inventor(s): **Jaldert Rombouts**
Borja Ibarz Gabardos
Jean-Baptiste Passot
Andrew Smith

For: **SYSTEMS AND METHODS FOR ROBOTIC MAPPING**

Included herewith are:

(X) Specification in forty-one (41) pages, including twenty (20) claims and abstract.

(X) Sixteen (16) figures on sixteen (16) sheet(s) of informal drawings.

(X) Application Data Sheet (8 pages).

(X) Applicant claims small entity status. (See 37 CFR 1.27)

[Continued on next page]

CLAIMS AS FILED

FOR	NUMBER FILED	NUMBER EXTRA	RATE	FEE
Basic Filing Fee			$ 70	$ 70
Utility Search Fee			$300	$300
Utility Examination Fee			$360	$360
Total Claims	20 - 20 =	0 ×	$ 40	$0
Independent Claims	3 - 3 =	0 ×	$210	$0
If application contains any multiple dependent claims(s), then add			$390	$0
			TOTAL FILING FEE:	**$730.00**

(X) The Commissioner is hereby authorized to charge any fees under 37 CFR 1.16 and 1.17 which may be required to Deposit Account No. 501423.

Respectfully Submitted,

GAZDZINSKI & ASSOCIATES, PC

Dated: November 1, 2016

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	BRAIN.133A/BC201608A
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR ROBOTIC MAPPING	

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

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	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR ROBOTIC MAPPING	

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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	132059		
Email Address	Docket@gazpat.com	Add Email	Remove Email

Application Information:

Title of the Invention	SYSTEMS AND METHODS FOR ROBOTIC MAPPING		
Attorney Docket Number	BRAIN.133A/BC201608A	Small Entity Status Claimed	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	16	Suggested Figure for Publication (if any)	

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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

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	132059		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim 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" field blank.

Prior Application Status			Remove
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)

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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. 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(i)(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).

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

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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.

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Title of Invention	SYSTEMS AND METHODS FOR ROBOTIC MAPPING	

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is 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 State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

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☐ A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	BRAIN.133A/BC201608A
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR ROBOTIC MAPPING	

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.

Applicant 1

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. ☒

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Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button.

Assignee Information including Non-Applicant Assignee Information:

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	BRAIN.133A/BC201608A
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR ROBOTIC MAPPING	

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.

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		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.

Signature:

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This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Peter J. Gutierrez, III/			Date (YYYY-MM-DD)	2016-11-01
First Name	Peter	Last Name	Gutierrez	Registration Number	56,732

Additional Signature may be generated within this form by selecting the Add button.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	BRAIN.133A/BC201608A
	Application Number	
Title of Invention	SYSTEMS AND METHODS FOR ROBOTIC MAPPING	

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.**

SYSTEMS AND METHODS FOR ROBOTIC MAPPING

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Background

Technological Field

[0002] The present application relates generally to robotics, and more specifically to systems and methods for robotic mapping.

Background

[0003] In some cases, robots map an environment. These maps enable the robot to navigate autonomously. As the robot maps its environment, it relies on its senses (e.g., using sensors) to detect features of the environment and remember those features for later reference. However, mapping can be a slow and difficult process due to, among other things, environmental noise, sensor noise and inaccuracy, ambiguities in the environment (e.g., substantially similar features), sensor drift, and other issues.

[0004] Inaccuracies in mapping can cause a robot to get lost during navigation or become unable to navigate an environment at all. In some cases, mapping issues can cause a robot to collide with objects or people in an environment, or fail to accomplish the objective the robot was tasked to do. As a result, there is need in the art to develop systems and methods that can correct for inaccuracies in mapping and generate a map that represents the environment and/or the route traveled by the robot.

[0005] As a further challenge, it is often desirable for robots to be affordable, lightweight, and as small as possible. Accordingly, it is desirable for systems and methods to be computationally efficient and capable of running on low cost (e.g., possibly less accurate) hardware, including sensors and processors.

Summary

[0006] The foregoing needs are satisfied by the present disclosure, which provides for, *inter alia*, apparatus and methods for mapping in autonomous navigation. Example implementations described herein have innovative features, no single one of which is indispensable or solely responsible for their desirable attributes. Without limiting the scope of the claims, some of the advantageous features will now be summarized.

[0007] In a first aspect, a method of generating a map by a robot is disclosed. In one exemplary implementation, the method includes: traveling, by the robot in an environment; creating a graph comprising a plurality of nodes, wherein each node corresponds to a scan taken by a sensor of the robot at a location in the environment; constraining the graph to start and end at a substantially similar location; performing scan matching on extended scan groups determined at least in part from groups of the plurality of nodes; associating a range of possible locations with each of the plurality of nodes based at least in part on the scan matching; determining confidences associated with each range of possible locations; optimizing the graph to find the likely location of the plurality of nodes based at least in part on the confidences; and rendering the map from the optimized graph.

[0008] In one variant, the generation of the map comprises ray tracing with the scans taken by the sensor, the scans associated with the plurality of nodes. In another variant, optimizing the graph comprises: generating a cost function based at least in part on: (1) relative locations of each of the plurality of nodes and (2) the confidences associated with each of the plurality of nodes, and solving the cost function for a minimum.

[0009] In another variant, constraining the graph to start and end at the substantially similar location further comprises constraining the graph to start and end in view of a home locator. In another variant, traveling in an environment comprises navigating under user control.

[0010] In another variant, the associated confidences further comprise using a probability distribution indicative at least in part of a probability that a given node is in a given location.

[0011] In another variant, the extended scan groups determined at least in part from groups of the plurality of nodes further comprise: selecting a root node as a reference location, finding possible overlaps in measurements of distinct features in scans taken at

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other nodes, and grouping the other nodes into extended scan groups based at least in part on overlapping distinct features of the scans at those respective other nodes.

[0012] In a second aspect, a robot is disclosed. In one exemplary implementation, the robot includes: a sensor configured to take scans of an environment at nodes, wherein each node is associated with a location; and a mapping and localization unit configured to: create a graph of the nodes based at least in part on the taken scans, determine extended scan groups based at least in part on groups of the plurality of nodes, and perform scan matching on the extended scan groups.

[0013] In one variant, the mapping and localization unit is further configured to constrain the graph to start and end at a substantially similar location. In another variant, the mapping and localization unit is further configured to determine confidences associated with the location of each node.

[0014] In another variant, the mapping and localization unit is further configured to generate a cost function based at least in part on the confidences and locations of each node, wherein the mapping and localization unit determines the location of each node in the graph based on solving the cost function for a minimum.

[0015] In another variant, the processor is further configured to render a map from the graph, the map rendered based at least in part on ray tracings of the scans.

[0016] In another variant, the robot further includes an actuator configured to move the robot between locations. In another variant, the robot further includes a user interface configured for user control of the robot.

[0017] In another variant, the robot further includes a navigation unit configured to navigate the robot autonomously.

In a third aspect, a non-transitory computer-readable storage apparatus is disclosed. In one embodiment, the non-transitory computer-readable storage apparatus has a plurality of instructions stored thereon, the instructions being executable by a processing apparatus to operate a robot. The instructions are configured to, when executed by the processing apparatus, cause a sensor to generate scans of an environment at a plurality of nodes, wherein each node of the plurality is associated with a location; create a graph of the plurality of nodes based on the generated scans; determine extended scan groups based at least in part from scans associated with groups of the plurality of nodes; and perform scan matching on

the extended scan groups.

[0018] In one variant, the instructions further cause the processing apparatus to constrain the graph to start and end at a substantially similar location.

[0019] In another variant, each extended scan group comprises three or more scans.

[0020] In another variant, the instructions further cause the processing apparatus to determine a cost function based at least in part on confidences of the location of each node.

[0021] In another variant, the instructions further cause the processing apparatus to generate a map based at least in part on minimizing the cost function.

[0022] These and other objects, features, and characteristics of the present disclosure, as well as the methods of operation and functions of the related elements of structure and the combination of parts and economies of manufacture, will become more apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of the disclosure. As used in the specification and in the claims, the singular form of "a", "an", and "the" include plural referents unless the context clearly dictates otherwise.

Brief Description of the Drawings

[0023] The disclosed aspects will hereinafter be described in conjunction with the appended drawings, provided to illustrate and not to limit the disclosed aspects, wherein like designations denote like elements.

[0024] FIG. 1 illustrates various side elevation views of exemplary body forms for a robot in accordance with principles of the present disclosure.

[0025] FIG. 2 is a diagram of an overhead view of a robot as an operator demonstrated a path in accordance with some implementations of this disclosure.

[0026] FIG. 3 illustrates a functional block diagram of an example robot in some implementations.

[0027] FIG. 4A is a top view map and route generated by a robot as it travels in an environment in accordance with some implementations of this disclosure.

[0028] FIG. 4B is a map that does not accurately reflect the surrounding and traveled route of a robot in accordance with some implementations of this disclosure.

[0029] FIG. 5 is a process flow diagram of an exemplary method for creating a map in accordance with some implementations of the present disclosure.

[0030] FIG. 6A is a top view of a diagram comprising discretized measurements of a robot along a route in a graph in accordance to some implementations of the present disclosure.

[0031] FIG. 6B is a top view of a diagram of a graph, which includes a continuation of the route illustrated in FIG. 6A in accordance with some implementations of this disclosure.

[0032] FIG. 6C illustrates a constraint for the graph from FIG. 6B in accordance with some implementations of the present disclosure, wherein the starting and ending locations are at the same and/or substantially the same location.

[0033] FIG. 7A is a process flow diagram of an exemplary method for creating an extended scan group in accordance with some implementations of this disclosure.

[0034] FIG. 7B is a conceptual diagram of a scan matching transformation in accordance with some implementations of the present disclosure.

[0035] FIG. 8 illustrates an example result of a scan matching of an extended scan group on the graph illustrated in FIG. 6C in accordance with some implementations of the present disclosure.

[0036] FIG. 9 illustrates springs to/from a node from the graph illustrated in FIG. 6A in accordance with some implementations of the present disclosure.

[0037] FIG. 10 is a diagram of the pixels of a map being constructed from scans in accordance to some implementations of this disclosure.

[0038] FIG. 11 is a process flow diagram of an exemplary method for generating a map by a robot in accordance with some implementations of the present disclosure.

[0039] FIG. 12 is a process flow diagram of an exemplary method for operating a robot in accordance with some implementations of the present disclosure.

[0040] All Figures disclosed herein are © Copyright 2016 Brain Corporation. All rights reserved.

Detailed Description

[0041] Various aspects of the novel systems, apparatuses, and methods disclosed herein are described more fully hereinafter with reference to the accompanying drawings. This disclosure can, however, be embodied in many different forms and should not be construed as limited to any specific structure or function presented throughout this disclosure. Rather, these aspects are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art. Based on the teachings herein, one skilled in the art should appreciate that the scope of the disclosure is intended to cover any aspect of the novel systems, apparatuses, and methods disclosed herein, whether implemented independently of, or combined with, any other aspect of the disclosure. For example, an apparatus can be implemented or a method can be practiced using any number of the aspects set forth herein. In addition, the scope of the disclosure is intended to cover such an apparatus or method that is practiced using other structure, functionality, or structure and functionality in addition to or other than the various aspects of the disclosure set forth herein. It should be understood that any aspect disclosed herein can be implemented by one or more elements of a claim.

[0042] Although particular aspects are described herein, many variations and permutations of these aspects fall within the scope of the disclosure. Although some benefits and advantages of the preferred aspects are mentioned, the scope of the disclosure is not intended to be limited to particular benefits, uses, and/or objectives. The detailed description and drawings are merely illustrative of the disclosure rather than limiting, the scope of the disclosure being defined by the appended claims and equivalents thereof.

[0043] The present disclosure provides for improved systems and methods for robotic mapping. As used herein, a robot can include mechanical or virtual entities configured to carry out complex series of actions automatically. In some cases, robots can be machines that are guided by computer programs or electronic circuitry. In some cases, robots can include electro-mechanical components that are configured for navigation, where the robot can move from one location to another. Such navigating robots can include autonomous cars, floor cleaners, rovers, drones, carts, and the like.

[0044] As referred to herein, floor cleaners can include floor cleaners that are manually controlled (e.g., driven or remote control) and/or autonomous (e.g., using little to

no user control). For example, floor cleaners can include floor scrubbers that a janitor, custodian, or other person operates and/or robotic floor scrubbers that autonomously navigate and/or clean an environment. Similarly, floor cleaners can also include vacuums, steamers, buffers, mop, polishers, sweepers, burnishers, etc.

[0045] A person having ordinary skill in the art would appreciate that a robot, as referred to herein, can have a number of different appearances/forms. FIG. 1 illustrates various side elevation views of exemplary body forms for a robot in accordance with principles of the present disclosure. These are non-limiting examples meant to further illustrate the variety of body forms, but not to restrict robots described herein to any particular body form. For example, body form 100 illustrates an example where the robot is a stand-up shop vacuum. Body form 102 illustrates an example where the robot is a humanoid robot having an appearance substantially similar to a human body. Body form 104 illustrates an example where the robot is a drone having propellers. Body form 106 illustrates an example where the robot has a vehicle shape having wheels and a passenger cabin. Body form 108 illustrates an example where the robot is a rover.

[0046] Body form 110 can be an example where the robot is a motorized floor scrubber. Body form 112 can be a motorized floor scrubber having a seat, pedals, and a steering wheel, where a user can drive body form 112 like a vehicle as body form 112 cleans, however, body form 112 can also operate autonomously. Other body forms are further contemplated, including industrial machines that can be robotized, such as forklifts, tugs, boats, planes, etc.

[0047] Detailed descriptions of the various implementations and variants of the system and methods of the disclosure are now provided. While many examples discussed herein are in the context of robotic floor cleaners, it will be appreciated that the described systems and methods contained herein can be used in other robots. Myriad other example implementations or uses for the technology described herein would be readily envisaged by those having ordinary skill in the art, given the contents of the present disclosure.

[0048] Advantageously, the systems and methods of this disclosure at least: (i) provide for accurate route and/or environment mapping by a robot; (ii) provide computational efficiency which can reduce consumption of processing power, energy, and/or other resources in navigating robots; and (iii) allow use of lower-cost hardware in

construction of robots. Other advantages are readily discernable by one having ordinary skill given the contents of the present disclosure.

[0049] For example, many current robots that can autonomously navigate are programmed to navigate routes and/or paths to goals. In order to navigate these routes and/or paths, these robots can create maps, which can sometimes be referred to as a global solution in that the maps identify one or more portions of the environment beyond what a robot can directly observe with its sensors at a point in time. These robots generate maps, and their relationship to the environment along routes, using localized detection in a small area around the robot (e.g., in the order of a few meters), where the robot can determine obstacles and/or other features detected by its sensors. When navigating autonomously, robots can then utilize both the global solution and localized detection of objects to avoid collisions and/or reach its goal.

[0050] By way of illustration, a robot (e.g., a floor cleaner, autonomous vehicle, or other robot) can be programmed by demonstration. In the example of a floor cleaner, an operator can control the robot along a desired route in a desired environment. Accordingly, the robot can generate a map, documenting its location (e.g., place on the global map and/or pose relative to features of the environment) while the operator controls it. The robot can generate the map using odometry and its sensors (e.g., scans by a Light Detecting and Ranging ("LIDAR") sensor and/or any other sensor that is described in this disclosure). Subsequently, the robot can navigate the route autonomously, e.g., with little to no operator control.

[0051] A challenge for the robot in this illustration is constructing an accurate map that the robot can utilize to autonomously navigate the route after demonstration. The demonstration process can include complex sets of movements and actions (e.g., turning, stopping, parking, turning on and off blinkers and other signals, lifting and dropping brushes, turning off and on water flow, turning off and on vacuums, etc.) associated with particular poses and/or trajectories, as well as identification of objects. During the demonstration, the robot's mapping may not be perfectly accurate (e.g., subject to drift, noise, and/or error), and the robot may need to determine how the map should have appeared to accurately reflect the true state of the environment.

[0052] FIG. 2 is a diagram of an overhead view of robot 202 as an operator demonstrated a path in accordance with some implementations of this disclosure. In this way, FIG. 2 can illustrate the path robot 202 actually travels in an environment 200 while it is mapping. Robot 202 can be any robot described in this disclosure. By way of illustration, robot 202 can be a robotic floor cleaner, such as a robotic floor scrubber, vacuums, steamers, buffers, mop, polishers, sweepers, burnishers, and the like. Environment 200 can be the space in which robot 202 navigates. In the example of a robotic floor cleaner, environment 200 can be a space having floors desired to be cleaned. For example, environment 200 can be a store, warehouse, office building, home, storage facility, etc. One or more of objects 208, 210, 212, 218 can be shelves, displays, objects, items, people, animals, or any other entity or thing that may be on the floor or otherwise impede the ability of robot 202 to navigate through environment 200. As such, route 206 can be the cleaning path traveled by robot 202. Route 206 can follow a path that weaves between objects 208, 210, 212, and 218 as illustrated in example route 206. For example, where objects 208, 210, 212, and 218 are shelves in a store, robot 202 can go along the aisles of the store and clean the floors of the aisles. However, other routes are also contemplated, such as, without limitation, weaving back and forth along open floor areas and/or any cleaning path a user could use to clean the floor (e.g., if the user is manually operating a floor cleaner). Accordingly, route 206 is meant merely as illustrative examples and can appear differently as illustrated. Also, as illustrated, one example of environment 200 is shown, however, it should be appreciated that environment 200 can take on any number of forms and arrangements (e.g., of any size, configuration, and/or layout of a room and/or building) and is not limited by the example illustrations of this disclosure.

[0053] In route 206, robot 202 can begin at the initial location 222, which can be the starting point/location of robot 202. In some cases, home locator 220 can be positioned near, substantially near, and/or at the initial location 222. For example, home locator 220 can be positioned adjacent to initial location 222, or be within the range of at least one sensor of robot 202 such that a sensor of robot 202 can detect home locator 220 from initial location 222. The operator can then demonstrate route 206 to robot 202 until robot 202 reaches an end location, where the operator can stop operating robot 202. The end location can be designated by a user and/or determined by robot 202. In some cases, the end location can be the location in route 206 after which robot 202 has cleaned the desired area of a floor. As

previously described, route 206 can be a closed loop or an open loop. By way of illustrative example, an end location can be a location for storage for robot 202, such as a temporary parking spot, storage room/closet, and the like. In some cases, the end location can be the point where a user training and/or programming tasks for robot 202. In some cases, the end location can be the same and/or substantially similar as initial location 222. For example, robot 202 can detect a return to a position that is the same and/or substantially similar to initial location 222 by detecting home locator 220.

[0054] In the context of floor cleaners (e.g., floor scrubbers, vacuum cleaners, etc.), robot 202 may or may not clean at every point along route 206. By way of illustration, where robot 202 is a robotic floor scrubber, the cleaning system (e.g., water flow, cleaning brushes, etc.) of robot 202 may only be operating in some portions of route 206 and not others. For example, robot 202 may associate certain actions (e.g., turning, turning on/off water, spraying water, turning on/off vacuums, moving vacuum hose positions, gesticulating an arm, raising/lowering a lift, moving a sensor, turning on/off a sensor, etc.) with particular positions and/or trajectories (e.g., while moving in a certain direction or in a particular sequence along route 206) along the demonstrated route. In the context of floor cleaners, such association may be desirable when only some areas of the floor are to be cleaned but not others and/or in some trajectories. In such cases, robot 202 can turn on a cleaning system in areas where a user demonstrated for robot 202 to clean, and turn off the cleaning system otherwise.

[0055] FIG. 3 illustrates a functional block diagram of example robot 202 in some implementations. As illustrated, robot 202 includes controller 254, memory 252, power supply 256, and operative units 250, each of which can be operatively and/or communicatively coupled to each other and each other's components and/or subcomponents. Controller 254 controls the various operations performed by robot 202. Although a specific implementation is illustrated in FIG. 3, the architecture may be varied in certain implementations as would be readily apparent to one of ordinary skill given the contents of the present disclosure.

[0056] Controller 254 can include one or more processors (e.g., microprocessors) and other peripherals. As used herein, the terms processor, microprocessor, and digital processor can include any type of digital processing devices such as, without limitation, digital signal

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processors ("DSPs"), reduced instruction set computers ("RISC"), general-purpose ("CISC") processors, microprocessors, gate arrays (e.g., field programmable gate arrays ("FPGAs")), programmable logic device ("PLDs"), reconfigurable computer fabrics ("RCFs"), array processors, secure microprocessors, and application-specific integrated circuits ("ASICs"). Such digital processors may be contained on a single unitary integrated circuit die, or distributed across multiple components.

[0057] Controller 254 can be operatively and/or communicatively coupled to memory 252. Memory 252 can include any type of integrated circuit or other storage device adapted for storing digital data including, without limitation, read-only memory ("ROM"), random access memory ("RAM"), non-volatile random access memory ("NVRAM"), programmable read-only memory ("PROM"), electrically erasable programmable read-only memory ("EEPROM"), dynamic random-access memory ("DRAM"), Mobile DRAM, synchronous DRAM ("SDRAM"), double data rate SDRAM ("DDR/2 SDRAM"), extended data output RAM ("EDO"), fast page mode ("FPM") RAM, reduced latency DRAM ("RLDRAM"), static RAM ("SRAM"), flash memory (e.g., NAND/NOR), memristor memory, pseudostatic RAM ("PSRAM"), etc. Memory 252 can provide instructions and data to controller 254. For example, memory 252 can be a non-transitory, computer-readable storage medium having a plurality of instructions stored thereon, the instructions being executable by a processing apparatus (e.g., controller 254) to operate robot 202. In some cases, the instructions can be configured to, when executed by the processing apparatus, cause the processing apparatus to perform the various methods, features, and/or functionality described in this disclosure. Accordingly, controller 254 can perform logical and arithmetic operations based on program instructions stored within memory 252.

[0058] Operative units 250 can be coupled to controller 254, or any other controller, to perform the various operations described in this disclosure. One or more, or none, of the modules in operative units 250 can be included in some implementations. Throughout this disclosure, reference may be made to various controllers and/or processors. In some implementations, a single controller (e.g., controller 254) can serve as the various controllers and/or processors described. In other implementations, different controllers and/or processors can be used, such as controllers and/or processors used particularly for, and/or as part of, one or more of operative units 250. Controller 254 can send and/or receive signals, such as power

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signals, control signals, sensor signals, interrogatory signals, status signals, data signals, electrical signals and/or any other desirable signals, including discrete and analog signals to operative units 250. Controller 254 can coordinate and/or manage operative units 250, and/or set timings (e.g., synchronously or asynchronously), turn on/off, control power budgets, receive/send network instructions and/or updates, update firmware, send interrogatory signals, receive and/or send statuses, and/or perform any operations for running features of robot 202.

[0059] Operative units 250 can include various units that perform functions for robot 202. For example, units of operative units 250 can include mapping and localization units 262, sensor units 264, actuator units 268, communication units 266, navigation units 276, and user interface units 272. Operative units 250 can also comprise other units that provide the various functionality of robot 202. In some cases, the units of operative units 250 can be instantiated in software or hardware and/or both software and hardware. For example, in some cases, units of operative units 250 can comprise computer-implemented instructions executed by a controller. In some cases, units of operative units 250 can comprise hardcoded logic. In some cases, units of operative units 250 can comprise both computer-implemented instructions executed by a controller and hardcoded logic. Where operative units 250 are implemented at least in part in software, operative units 250 can include units/modules of code configured to provide one or more functionalities.

[0060] In some implementations, sensor units 264 can comprise systems that can detect characteristics within and/or around robot 202. Sensor units 264 can include sensors that are internal to robot 202 or external, and/or have components that are partially internal and/or partially external. Sensors unit 314 can include exteroceptive sensors such as sonar, LIDAR, radar, lasers, video cameras, infrared cameras, 3D sensors, 3D cameras, and/or any other sensor known in the art. Sensor units 264 can also include proprioceptive sensors, such as accelerometers, inertial measurement units, odometers, gyroscopes, speedometers, and/or the like. In some implementations, sensor units 264 can collect raw measurements (e.g., currents, voltages, resistances gate logic, etc.) and/or transformed measurements (e.g., distances, angles, detected points in obstacles, etc.).

[0061] In some implementations, mapping and localization units 262 can include systems and methods that can computationally construct and update maps (e.g., maps 300,

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and 400 as will be described with reference to FIGS. 4A and 4B, and/or any other map created by robot 202) of an environment and/or routes as robot 202 navigates the environment. By way of illustrative example, mapping and localization units 262 can map environment 200 and localize robot 202 (e.g., find the position and/or pose) in map 300 at one or more points in time. At the same time, mapping and localization units 262 can record a demonstrated route in map 300 (e.g., mapped route 306).

[0062] Mapping and localization units 262 can also receive sensor data from sensor units 264 to localize robot 202 in a map. In some implementations, mapping and localization units 262 can include localization systems and methods that allow robot 202 to localize itself in the coordinates of a map. As will be described further in this disclosure, mapping and localization units 262 can also process measurements taken by robot 202, such as by generating a graph and/or map.

[0063] In some implementations, communication units 266 can include one or more receivers, transmitters, and/or transceivers. Communication units 266 can be configured to send/receive a transmission protocol, such as BLUETOOTH®, ZIGBEE®, Wi-Fi, induction wireless data transmission, radio frequencies, radio transmission, radio-frequency identification ("RFID"), near-field communication ("NFC"), infrared, network interfaces, cellular technologies such as 3G (3GPP/3GPP2), high-speed downlink packet access ("HSDPA"), high-speed uplink packet access ("HSUPA"), time division multiple access ("TDMA"), code division multiple access ("CDMA") (e.g., IS-95A, wideband code division multiple access ("WCDMA"), etc.), frequency hopping spread spectrum ("FHSS"), direct sequence spread spectrum ("DSSS"), global system for mobile communication ("GSM"), Personal Area Network ("PAN") (e.g., PAN/802.15), worldwide interoperability for microwave access ("WiMAX"), 802.20, long term evolution ("LTE") (e.g., LTE/LTE-A), time division LTE ("TD-LTE"), global system for mobile communication ("GSM"), narrowband/frequency-division multiple access ("FDMA"), orthogonal frequency-division multiplexing ("OFDM"), analog cellular, cellular digital packet data ("CDPD"), satellite systems, millimeter wave or microwave systems, acoustic, infrared (e.g., infrared data association ("IrDA")),and/or any other form of wireless data transmission.

[0064] As used herein, network interfaces can include any signal, data, or software interface with a component, network, or process including, without limitation, those of the

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FireWire (e.g., FW400, FW800, FWS800T, FWS1600, FWS3200, etc.), universal serial bus ("USB") (e.g., USB 1.X, USB 2.0, USB 3.0, USB Type-C, etc.), Ethernet (e.g., 10/100, 10/100/1000 (Gigabit Ethernet), 10-Gig-E, etc.), multimedia over coax alliance technology ("MoCA"), Coaxsys (e.g., TVNET™), radio frequency tuner (e.g., in-band or OOB, cable modem, etc.), Wi-Fi (802.11), WiMAX (e.g., WiMAX (802.16)), PAN (e.g., PAN/802.15), cellular (e.g., 3G, LTE/LTE-A/TD-LTE/TD-LTE, GSM, etc.), IrDA families, etc. As used herein, Wi-Fi can include one or more of IEEE-Std. 802.11, variants of IEEE-Std. 802.11, standards related to IEEE-Std. 802.11 (e.g., 802.11 a/b/g/n/ac/ad/af/ah/ai/aj/aq/ax/ay), and/or other wireless standards.

[0065] Communication units 266 can also be configured to send/receive a transmission protocol over wired connections, such as any cable that has a signal line and ground. For example, such cables can include Ethernet cables, coaxial cables, Universal Serial Bus ("USB"), FireWire, and/or any connection known in the art. Such protocols can be used by communication units 266 to communicate to external systems, such as computers, smart phones, tablets, data capture systems, mobile telecommunications networks, clouds, servers, or the like. Communication units 266 can be configured to send and receive signals comprising of numbers, letters, alphanumeric characters, and/or symbols. In some cases, signals can be encrypted, using algorithms such as 128-bit or 256-bit keys and/or other encryption algorithms complying with standards such as the Advanced Encryption Standard ("AES"), RSA, Data Encryption Standard ("DES"), Triple DES, and the like. Communication units 266 can be configured to send and receive statuses, commands, and other data/information. For example, communication units 266 can communicate with a user controller to allow the user to control robot 202. Communication units 266 can communicate with a server/network in order to allow robot 202 to send data, statuses, commands, and other communications to the server. The server can also be communicatively coupled to computer(s) and/or device(s) that can be used to monitor and/or control robot 202 remotely. Communication units 266 can also receive updates (e.g., firmware or data updates), data, statuses, commands, and other communications from a server for robot 202 and/or its operative units 250.

[0066] In some implementations, one or more of operative units 250 may be instantiated remotely from robot 202. For example, mapping and localization units 262, may

be located in a cloud and/or connected to robot 202 through communication units 266. Connections can be direct and/or through a server and/or network. Accordingly, implementations of the functionality of this disclosure should also be understood to include remote interactions where data can be transferred using communication units 266, and one or more portions of processes can be completed remotely.

[0067] In some implementations, actuator units 268 can include actuators such as electric motors, gas motors, driven magnet systems, solenoid/ratchet systems, piezoelectric systems (e.g., inchworm motors), magnetostrictive elements, gesticulation, and/or any way of driving an actuator known in the art. By way of illustration, such actuators can actuate wheels or other displacement enabling drivers (e.g., mechanical legs, jet engines, propellers, hydraulics, etc.). For example, actuator units 268 can allow robot 202 to move and/or navigate through environment 200 and/or any other environment. In some cases, actuator units 268 can include actuators configured for actions and/or action-specific tasks, such as mobilizing brushes for floor cleaning, moving (e.g., moving up, down, left, right, forward, back) squeegees, turning on/off water, spraying water, turning on/off vacuums, moving vacuum hose positions, gesticulating an arm, raising/lowering a lift, turning a camera and/or any sensor of sensor units 264, and/or any movement desired for robot 202 to perform an action.

[0068] In some implementations, user interface units 272 can be configured to enable a user (e.g., user 604 or any other user) to interact with robot 202. For example, user interface units 272 can include touch panels, buttons, keypads/keyboards, ports (e.g., USB, Digital Visual Interface ("DVI"), Display Port, E-Sata, Firewire, PS/2, Serial, video graphics array ("VGA"), Small Computer System Interface ("SCSI"), audioport, High-Definition Multimedia Interface ("HDMI"), Personal Computer Memory Card International Association ("PCMCIA") ports, memory card ports (e.g., SD and miniSD), and/or ports for computer-readable media), mice, rollerballs, consoles, vibrators, audio transducers, and/or any interface for a user to input and/or receive data and/or commands, whether coupled wirelessly or through wires (including, without limitation, any of the wireless or wired connections described in this disclosure, such as with reference to communication units 266). User interface units 272 can include a display, such as, without limitation, Liquid Crystal Display ("LCDs"), Light-emitting Diode ("LED") displays, LED LCD displays, In-Plane Switching

("IPSs"), cathode ray tubes, plasma displays, High Definition ("HD") panels, 4K displays, retina displays, organic LED displays, touchscreens, surfaces, canvases, and/or any displays, televisions, monitors, panels, screens, and/or devices known in the art for visual presentation. In some implementations, user interface units 272 can be positioned on the body of robot 202. In some implementations, user interface units 272 can be positioned away from the body of robot 202, but can be communicatively coupled to robot 202 (e.g., via communication units 266) directly or indirectly (e.g., through a network or a cloud).

[0069] In some implementations, navigation units 276 can include components and/or software configured to provide directional instructions for robot 202 to navigate. Navigation units 276 can process maps and localization information generated by mapping and localization units 262, sensor data from sensor units 264, and/or other operative units 250. For example, navigation units 276 can receive map 300 from mapping and localization units 262. Navigation units 276 can also receive localization information from mapping and localization units 262, which can be indicative at least in part of the location of robot 202 within map 300, including route 306. Navigation units 276 can also receive sensor data from sensor units 264 which can be indicative at least in part of objects around robot 202. Using one or more of the map, location, and sensor data, navigation units 276 can instruct robot 202 where to navigate (e.g., go forward, left, right, back, and/or any other direction).

[0070] Navigation units 276 can also implement actions and/or action-specific tasks, such as mobilizing brushes for floor cleaning, moving (e.g., moving up, down, left, right, forward, back) squeegees, turning on/off water, spraying water, turning on/off vacuums, moving vacuum hose positions, gesticulating an arm, raising/lowering a lift, turning a camera and/or any sensor of sensor units 264, and/or any action taken by robot 202. In some cases, such actions and/or action-specific tasks can be indicated in a map and be executed by actuator units 268.

[0071] In some implementations, power supply 256 can include one or more batteries, including, without limitation, lithium, lithium ion, nickel-cadmium, nickel-metal hydride, nickel-hydrogen, carbon-zinc, silver-oxide, zinc-carbon, zinc-air, mercury oxide, alkaline, or any other type of battery known in the art. Certain batteries can be rechargeable, such as wirelessly (e.g., by a resonant circuit and/or a resonant tank circuit) and/or by plugging into an external power source. Power supply 256 can also be any supplier of

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energy, including wall sockets and electronic devices that convert solar, wind, water, nuclear, hydrogen, gasoline, natural gas, fossil fuels, mechanical energy, steam, and/or any power source into electricity.

[0072] In some implementations, operating system 270 can be configured to manage memory 252, controller 254, power supply 256, modules in operative units 250, and/or any software, hardware and/or features of robot 202. For example, and without limitation, operating system 270 can include device drivers to manage hardware resources for robot 202.

[0073] As previously mentioned, any of the aforementioned components of robot 202 can be instantiated in software and/or hardware. For example, a unit/module can be a piece of hardware and/or a piece of code run on a computer.

[0074] FIG. 4A is a top view map 300 and route 306 generated by robot 202 as it travels in environment 200 in accordance with some implementations of this disclosure. In some implementations, the generation of map 300 can be performed by mapping and localization units 262. Map 300 can comprise pixels, wherein each pixel corresponds to a mapped area of environment 200. The number of pixels in map 300 can be determined based on the resolution of map 300. Map 300 can be substantially similar in layout as environment 200, where each pixel in map 300 can approximate a location in environment 200. Robot 202 can appear on map 300 as robot indicator 302. Each pixel can represent an area, which can be uniform or non-uniform. For example, a pixel could represent one area unit, a nxm or nxn area unit, or a non-uniform unit of area.

[0075] The mapping can be performed by imposing data obtained at least in part by sensor units 264 into a two-dimensional ("2D"), three-dimensional ("3D"), and/or four-dimensional ("4D") map representative at least in part of environment 200. For example, map 300 can include depictions representative at least in part of obstacles and/or objects detected by robot 202. Map 300 can also record demonstrated routes, such as routes robot 202 learned while under user control. For example, mapped route 322 can include coordinates (e.g., x and y in a 2D map and x, y, and z in a 3D map) based at least in part on the relative position, orientation, and/or pose of robot 202 (e.g., including one or more of location, displacement, and orientation) to a reference, such as initialization location 222. For example, pose can have (x, y, theta) coordinates. As used herein, the term position has its ordinary and customary meaning. For example, in some cases, position can include a location

in terms of displacement, coordinates, etc. of an object, robot 202, etc. In some cases, position can also include an orientation of an object, robot 202, etc. Accordingly, in some cases, the terms position and pose may be used interchangeably to include one or more of location, displacement, and orientation. Map 300, created through the demonstration process, can record part of and/or substantially the whole of the environment that robot 202 sensed in one or more demonstrations/trainings. For this reason, some may call map 300 a global map. In some cases, map 300 can be static in that after a demonstration/training, map 300 may not be substantially updated. In some implementations, map 300 and mapped route 306 can also be generated separately (e.g., by a user using a computer) and uploaded onto robot 202.

[0076] In some implementations, pixels (and/or voxels in 3D) of map 300 can have one or more states, where the pixel state is indicative at least in part of a characteristic of the position/location in environment 200 represented by that pixel. For example, pixels of map 300 can be binary, where a first pixel state (e.g., pixel value) is indicative at least in part of a clear (e.g., navigable) location, and a second pixel state is indicative at least in part of a blocked (e.g., not navigable) location. By way of illustration, a pixel value of zero (0) can be indicative at least in part of a clear location and a pixel value of one (1) can be indicative at least in part of a blocked location.

[0077] In some implementations, instead of or in addition to the aforementioned binary states, pixels of map 300 can have other pixels states such as one or more of: a pixel state indicative at least in part of an unknown location (e.g., a position/location with no information); a pixel state indicative at least in part of a position/location that should not be traveled to; a pixel state indicative at least in part of being part of a navigable route; a pixel state indicative at least in part of an area in which robot 202 has traveled; a pixel state indicative at least in part of an area to which robot 202 has not traveled; a pixel state indicative at least in part of an object; a pixel state indicative at least in part of standing water; and/or any other categorization of a position/location on map 300. In some implementations, a pixel state, and/or data associated with a pixel, can be indicative at least in part of actions and/or action-specific tasks, such as mobilizing brushes for floor cleaning, moving (e.g., moving up, down, left, right, forward, back) squeegees, turning on/off water, spraying water, turning on/off vacuums, moving vacuum hose positions, gesticulating an arm, raising/lowering a lift, turning a camera and/or any sensor of sensor units 264, and/or

any other action by robot 202.

[0078] Pixels of map 300 can also store more than a single value or pixel state. For example, each pixel of map 300 can store a plurality of values such as values stored in a vector and/or matrix. These values can include values indicative at least in part of the position/pose (e.g., including location and/or orientation) of robot 202 when the position is measured at a point (e.g., pixel) along route 306. These values can also include whether robot 202 should clean or not clean a position/location, and/or other actions/action-specific tasks that should be taken by robot 202.

[0079] Robot 202 can travel along a route (e.g., 206 pictured in FIG. 2), which can be reflected in map 300 as route 306. At each location robot 202 travels along the route, robot 202 can determine its position and/or orientation, in some cases relative to an initialization location (e.g., initialization location 222), home locator (e.g., home locator 220), and/or another reference point. These mapping and localization functions can be performed by mapping and localization units 262. The initialization location can be represented on map 300 as mapped position 322. In some cases, mapped position 322 can be determined relative to a home locator (which in some implementations can also be a pinpoint on map 300 and/or otherwise represented therein).

[0080] For example, robot 202 can measure or approximate its distance from initialization location 204 (or another reference point) using odometry, where it uses proprioceptive sensors of sensor units 264 (e.g., wheel encoders (e.g., rotary encoders), visual odometry, Inertial Measurement Units ("IMUs") (including accelerometers, magnetometers, angular rate sensors), and the like), to track the movements of robot 202 since starting at initialization location 202. By way of illustrative example, one or more of the proprioceptive sensors can be wheel encoders that measure and/or estimate distance based on the revolution of the wheels of robot 202. As another illustrative example, visual odometers can be used to measure or estimate the distance travelled and/or orientation of robot 202 through sequential images taken by a camera. The visual odometers can construct an optical flow field (e.g., using Lucas-Kanade methods or other methods) and/or estimate camera motion, such as by using Kalman filters or projection. As another non-limiting example, IMUs can be used to measure and/or estimate the position and/or orientation of robot 202.

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[0081] Robot 202 can record route 306 in map 300, as robot indicator 302 (e.g., as seen in FIG. 6A and elsewhere) progresses along map 300 in a substantially similar way as robot 202 navigates through environment 200. Advantageously, in some implementations map 300 and route 306 can be created together, wherein robot 202 maps the environment 200 and records route 306 at substantially similar times. Accordingly, in some implementations, map 300 and route 306 can be paired together wherein each recorded route is stored only with a particular map.

[0082] Each location that is part of route 206 can correspond to a pixel on route 306 in map 300, where the pixel state of route 306 indicates the pixel is part of a navigable route. As robot 202 travels, robot 202 can also measure robot's 202 position and/or orientation relative to objects using one or more sensors units 264. These measures can be taken at discrete times and/or locations, represented as nodes. Robot 202 can also take scans using one or more of sensor units 264 to detect its environment. In this way, robot 202 can detect and/or measure the position and/or orientation of robot 202 relative to objects, such as shelves or walls.

[0083] In the case where robot 202 detects objects, robot 202 can use sensors units 264 to detect and/or measure the position and/or orientation of those objects in a plurality of directions relative to robot 202. At the same time, robot 202 can use sensors units 264 to estimate robot's 202 position and/or orientation. As robot 202 moves in the environment, different objects can come within the range of sensors of sensor units 264. For example, sensors can be positioned on front side of robot 202 and can have a predetermined range. For example, robot 202 can detect objects at a front side up to the predetermined range. Similarly, other sensors can each have ranges and detect objects within those ranges. These sensors can be positioned on the front, back, left side, right, side, bottom, top, and/or any combination of the foregoing.

[0084] In some cases, sensors units 264 may not sense certain areas. For example, an object can impede the availability of robot 202 to sense an area, or the area may appear in a blind spot (e.g., place not covered by the measuring range of the sensors).

[0085] The environment mapped in map 300 is a larger set than that illustrated in FIG. 2 as environment 200. Route 306 includes traversals of the aisles and other movements, including horizontally illustrated traversals through paths between aisles. As illustrated in

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map 300, robot 202 can clean a floor while traversing the aisles, driving over each aisle a plurality of times.

[0086] In some cases, FIG. 4A can be a completed top view map 300 in accordance with some implementations of this disclosure. Robot 202 can begin and end at mapped position 322. The completed map 300 of FIG. 4A illustrates a completed, accurate map. However, it is not straight-forward to create a map substantially similar to the ground truth simply by plotting data collected by sensor units 264 on a map. Sensors of sensor units 264 have noise, measurement drift, etc. As a result, sensors of sensor units 264 may not always unambiguously identify features in the environment. Sensors of sensor units 264 may also not always unambiguously identify the position and/or pose of robot 202.

[0087] Because identification by sensor units 264 may not be unambiguous, robot 202 can probabilistically determine its position and/or the position of features of the environment 200. As robot 202 moves through environment 200 while mapping, it can record sensor data from sensor units 264 as well as internal robot commands (e.g., move forward, left, right, back, rotate, etc.). The sensor data from sensor units 264 can also be compared to itself or other data, such as through scan matching to determine the relative positions. As a result, robot 202 (e.g., using mapping and localization units 262) can build a posterior probability distribution function of a map given at least sensor data, scan matching, and the internal robot commands. Other factors may also be considered.

[0088] Because of the ambiguity in measurements, robot 202 can generate maps that do not reflect its surrounding and traveled routes if not corrected. FIG. 4B is a map 400 that does not accurately reflect the surrounding and traveled route of robot 202 in accordance with some implementations of this disclosure. Because of noise, sensor drift, and other factors, map 400 appears distorted. As a result, route 406 appears to go all over the place. The mapped environment around route 406 appears to spread out and overlap upon itself, with features that do not reflect the ground truth. By comparison, map 400 can be corrected into map 300, where map 400 is actually a map of the same environment and route as map 300; however, map 400 is distorted and map 300 more accurately reflects reality. As can be observed, environment actually comprises a series of aisles (e.g., appearing as columns).

[0089] FIG. 5 is a process flow diagram of an exemplary method 550 for creating a map in accordance with some implementations of the present disclosure. For example, block

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552 includes creating a graph containing nodes. Block 554 includes constraining the graph to start and end at substantially the same location. Block 556 includes performing scan matching on extended scan groups determined from the scans at the nodes. Block 558 includes determining confidence in the location of each node. Block 560 includes creating and solving a cost function to determine the location of each node. Block 562 includes rendering a map from the scans from the located nodes. This process flow diagram is provided for illustrative purposes only. In some cases, one or more blocks can be omitted in the process. Moreover, as described in this disclosure, various other blocks may be added and/or or used in the alternative.

[0090] The creating a graph containing nodes of block 522 of FIG. 5 can be performed, in some cases, by mapping and localization unit 262 and/or controller 254 as robot 202 travels in an environment. By way of further illustration, FIG. 6A is a top view of a diagram comprising discretized measurements of robot 202 (illustrated in FIG. 2) along route 622 in graph 600 in accordance to some implementations of the present disclosure. Route 622 is used for illustrative purposes. In some cases, route 622 can be representative of a route and/or trajectory connecting nodes determined by robot 202, which is illustrated in the graph space of graph 600 as robot indicator 302, from the discrete nodes 602A – 602D. Accordingly, as illustrated in figures herein, routes are drawn for ease of reference, however, systems and methods described herein may be applied prior to and/or after routes are determined.

[0091] As robot 202 navigates along the route represented by route 622 illustrated in graph 600, it can take measurements at nodes 602A – 602D (again illustrated in the map space of graph 600), such as by using sensor units 264. A person having ordinary skill the art would appreciate that there can be a plurality of nodes, the number of which can be determined based at least in part on the resolution of sensors of sensor units 264, the speed of robot 202 (e.g., represented by robot indicator 302), the noise and/or error of the sensors of sensor units 264, predetermined tuning of robot 202 (e.g., setting node distance or time between establishing nodes), etc. FIG. 6A only illustrates one example configuration of example route 622. For example, the distance between nodes can be set as a predefined parameter in standard units (e.g., millimeters, centimeters, meters, inches, feet, etc.) or relative units (clicks, pixels, lengths, etc.). The distance can be determined based on the

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resolution desired, which can be dependent on considerations of desired accuracy, storage size, noise, etc. For example, fewer nodes can take up less storage space, but provide less information than more nodes. The gathering of information from nodes 602A – 602D, and the one or more systems and methods used for mapping, can be performed by mapping and localization units 262 and/or controller 254.

[0092] Each of nodes 602A – 602D can represent positions of measurements (e.g., scans) by robot 202. Each of nodes 602A – 602D can be associated with a pose (e.g., including measurements such as (x, y, θ) of robot 202). The pose of robot 202 can be relative to a location and/or orientation (e.g., initialization location 222 and/or home locator 220) and/or features of environment 200. The pose can be determined from data obtained by laser scans, LIDAR, odometry, and/or any other sensor of sensor units 264. Moreover, in some cases, nodes can be positioned on substantially similar spots, such as, for example, when robot 202 passes by the same location a plurality of times.

[0093] Each of edges between nodes 602A – 602D can have an associated probabilistic function and/or probabilistic distribution, illustrated for each of nodes 602A – 602D as ranges 604A – 604D, respectively. In some cases, ranges 604A – 604D can be computed using a posterior probability distribution. In some cases, ranges 604A – 604D can be derived from the mean computed position plus the covariance. In some cases, the probability distribution can be computed using a Bayesian framework, where the uncertainties of the nodes can be stored in one or more data structures, such as matrices (e.g., covariance matrices). A person having ordinary skill in the art would appreciate that ranges 604A – 604D can also be computed using other statistical methods, such as the cross-variance, variance, chi-square distribution, and/or any other statistical methods used in, for example, Simultaneous Localization and Mapping ("SLAM") and/or other techniques for determining pose known in the art. In some cases, ranges 604A – 604D can be representative, at least in part, of areas around each node 602A – 602D, wherein the actual location of robot 202 relative to graph 600 (e.g., illustrated as robot indicator 302) can be within the areas. For example, instead of node 602B being located as illustrated, node 602B can actually be located anywhere within range 604B, and with different poses, including positions and/or orientations, within range 604B. In some cases, each position within any one of ranges 604A–604D can have associated probabilities, wherein some positions are more

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likely than other. In some cases, due to compounding noise, sensor drift, and other factors, subsequent ones of ranges 604A – 604D can become larger as seen from the position of robot indicator 302 as illustrated, representing more uncertainty of the positioning of nodes 602A – 602D. However, some factors, such as the identification of distinct features, scan matching, calibration, external identification, etc., can actually reduce the size of one or more ranges 604A – 604D as compared to preceding ones of ranges 604A – 604D.

[0094] FIG. 6B is a top view of a diagram of graph 650, which includes a continuation of route 622 of FIG. 6A in accordance with some implementations of this disclosure. As illustrated, robot 202 can begin, as represented on graph 650, at node 602A. Node 602A can be positioned relative to indicator 620, which can be the mapped/graphed position of a home locator. As described with reference to FIG. 6, robot 202 can map nodes 602A – 602D. However, one challenge that can occur is that errors can accumulate as robot continues on route 622. For example, ranges can continue to expand throughout as viewed from the location of node 622A (whose position may be determined relative to a home locator, such as indicator 620). By way of illustration, range 628 can be larger than range 604D, and range 624, associated with node 622B, can be even larger. Accordingly, with the larger ranges, there can be more ambiguity in the locations of those nodes. As a result, optimizing graph 650 using conventional SLAM and/or any other algorithm can be computationally expensive and/or inaccurate. The computation, time, and processing costs can be high in trying to find the optimization.

[0095] In some implementation, the constraining of the graph to start and end at substantially the same location of block 554 of FIG. 5 can be performed by mapping and localization unit 262 and/or controller 254. FIG. 6C illustrates a constraint for graph 690 from FIG. 6B in accordance with some implementations of the present disclosure, wherein the starting and ending locations are at the same and/or substantially the same location. Graph 690 illustrates the nodes from graph 650, where nodes 622A and 622B are now constrained to be in substantially the same location. In some implementations nodes 622A and 622B can be in the same and/or substantially the same location in order to constrain graph 690, and the nodes therein, to graphs that start and end at the same and/or substantially similar location. In some cases, graphs that end at the same and/or substantially the same can be determined by detection of a home locator as illustrated by indicator 620. In these cases,

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where robot 202 detects the same home locator (e.g., represented by indicator 620 on graph 690) at the beginning and/or end of route 622, such detection can be indicative at least in part that nodes 622A and 622B are in the same and/or substantially the same location.

[0096] In some implementations, substantially similar can be predetermined, such as based on one or more thresholds relating to x-distances, y-distances, z-distances, angles, etc. For example, there can be distance and/or angle thresholds, such as those based on standard units (e.g., inches, meters, degrees, and/or other standard units) or relative units (e.g., clicks, pixels, lengths, etc.). The threshold can be determined based at least in part on the resolution of sensors of sensor units 264, noise from sensors of sensor units 264, sensor drift from sensors of sensor units 264, acceptable errors in graphing/mapping, empirical evidence of performance, view of a reference feature (e.g., home locator and/or other objects) and/or other factors.

[0097] Advantageously, this constraint can reduce ambiguity. Working from the known (and/or assumed) positions of nodes 622A and 622B, which are the start and end positions respectively, error propagation can then be taken in both directions. Accordingly, by way of illustration, range 626 is markedly reduced from the analogous node form FIG. 6B, and the largest range is elsewhere, such as range 628. Noticeably, this reduction of ambiguity of node locations can further reduce computation, time, and processing costs in optimizing graph 690 as compared to graph 650. Ranges 804A, 804B, and 804C will be discussed in further detail with reference to FIG. 8.

[0098] In some cases, confidence in a location can be determined through other methods, such as scan matching. By way of illustration, robot 202 can use scan matching, which can include registering a plurality of scans (e.g., laser scans) from sets of nodes to determine their relative positions. In some cases, scan matching can be used to determine the rigid-body transformation (e.g., using translations and/or rotations) that aligns best a scan and a graph/map, a scan and a scan, and/or a graph/map and a graph/map.

[0099] By way of illustration, a robot sensing an environment from two nodes, x_0 and x_1, can obtain LIDAR scans z_0 and z_1. These LIDAR scans can capture a scan of the environment. For example, provided some parts of the environment are visible from both x_0 and x_1, scan matching can be used to find a rigid transform that will project the points z_1 so

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that they align with z_0. Scan matching, in some forms, has been used in mapping algorithms such as SLAM and others.

[00100] In some cases, the performing of scan matching on extended scan groups determined from the scans at the nodes of block 556 can be performed by mapping and localization unit 262 and/or controller 254. FIG. 7A is a process flow diagram of an exemplary method 700 for creating an extended scan group in accordance with some implementations of this disclosure. Block 720 includes selecting a root node. The root node can include a node from which other nodes are viewed (e.g., the position, distances, poses, angles, etc. and/or certainty relative to the root node). Block 722 includes finding possible overlaps in measurements from nodes. Overlaps of measurements from nodes can include overlaps where scans have features in common and/or are in close proximity. For example, overlap can include scans from nodes that have captured the same feature. By way of illustration, as robot 202 navigates, it can use sensor units 264 to take measurements in its environment. In some cases, such measurements can be done using a scan LIDAR. Accordingly, the scan LIDAR can take measurements of an object within its range as robot 202 navigates. Based on the proximity of the nodes where robot 202 takes scans, individual scans can capture the same object, but at different points in time and/or space (e.g., a first scan can include an object as robot 202 approaches it, a second scan can include the object as robot 202 is near it, a third scan can include the object as robot 202 passes it, a fourth scan can include the object as robot 202 moves further away, etc.). In this way, these overlapping measurements can capture different aspects of a same feature in an environment. Moreover, these measurements can also be substantially proximate in time and/or space. For example, proximity can include nodes that are sequentially next to each other, or within a predetermined number of nodes. Proximity can also include times that are within a predetermined threshold time, such as threshold times determined based at least in part on sensor resolution, capture times, the speed of robot 202, etc.

[00101] Block 724 includes creating groups of nodes based at least in part on overlaps to form extended scan groups. Each extended scan group can include a predetermined number of nodes, such as 2, 3, 4, 5, or more nodes. The number of nodes can be chosen based at least in part on the desired accuracy of scan matching, the data size of each scan, computational resources, etc. In many cases, three nodes can be used to balance the amount

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of information provided by having more scans and the complexity of performing the scan matching.

[00102] In some cases, not every node may be in a group. Finding groups can further include only grouping nodes that include and/or are proximal to distinct features. Distinct features can include features that can be distinctive and/or identifiable. For example, hallways with nearly identical walls throughout may not include distinct features. By way of illustration, distinct features can include objects, obstacles, fixtures, and/or any aspect that can make a location distinguishable from at least some other locations. Advantageously, where only groups with distinct features are used, robot 202 can further reduce consumption of system resources by focusing on scan matches that will provide useful and/or less ambiguous information. Advantageously, reliance on the distinct features can reduce false positives.

[00103] In some cases, the same nodes may be used in multiple extended scan groups. In some cases, different extended scan groups can include the same nodes. However, in some cases, each node can be restricted to only being in one extended scan group. Accordingly, determining whether a node belongs in a particular group depends on one or more factors, included in various implementations. The relative weights of each of these factors as implemented can be adjusted between implementations based at least in part on the environment, distinct features (and/or lack thereof), empirical performance measures, etc. A first factor can include the amount of a distinct feature captured in a scan from a node. For example, if more measurements of a distinct feature are captured in a scan from a node, that scan from that node would be more likely to be included in an extended scan group with similarly more measurements of a distinct feature instead of other scans from other nodes that had fewer measures of the distinct feature. A second factor can include proximity to other nodes. Nodes that are in proximity to each other would be more likely to be included together in an extended scan group. Proximity can be based at least in part on distance and/or angle thresholds, determined based at least in part on sensor resolution, density of nodes (e.g., how many nodes are in a space, where proximity may be defined as closer in the situation where there are more nodes in a given space as compared to when there are fewer nodes in a given space), empirical results, etc. A third factor can include the presence of other distinct features within a scan. For example, a scan at a node can have measurements of

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a plurality of distinct features. In order to optimize matches, having more extended scan groups can be favorable. Accordingly, where more scans are desired to complete extended scan groups, having scans with multiple distinct features assigned to sets of scans that would otherwise be too few to create an extended scan group would be preferable. In such a situation, robot 202 can be calibrated so it is more likely that more extended scan groups are produced. On the other hand, in other cases, having larger extended scan groups could be advantageous for the speed of computation. A fourth factor can include the size of the extended scan groups. As aforementioned, each extended scan group can be a predetermined sized. Accordingly, determining whether a particular scan from a node belongs with other scans from nodes is dependent on the size of the extended scan groups.

[00104] In some cases, recursive and/or iterative grouping algorithms can be used to match scans into extended scan groups. In some cases, based on one or more performance criteria, each set of extended scan groups can be evaluated. The performance criteria can be based on one or more of the above factors. In some cases, algorithms, such as the minimal cut, graph theory, and/or other grouping algorithms can be implemented to divide the nodes of a graph, and associated scans, into extended scan groups.

[00105] Once groups have been identified, a scan matcher (e.g., as part of mapping and localization units 262) can be used to determine locations and/or orientations of scans. FIG. 7B is a conceptual diagram of a scan matching transformation in accordance with some implementations of the present disclosure. In some cases, a plurality of nodes can be used in a scan matcher, forming an extended scan group. The extended scan group can be compared to other extended scan groups to determine relative translations (and as a result, locations) and/or rotations. Advantageously, the extended scan groups can provide more context (e.g., information, data, etc.) and/or improve one or more of: the speed of graph/map optimization, the accuracy of graphs/maps relative to the ground truth, and the computational and other resource costs of optimization. If a larger scan group has been matched to a location, robot 202 can have relatively high confidence in the location of the nodes involved in the scan matching. In some cases, such as the matching of an extended scan group to previous scans, the confidence can at least match that of the previous scan. In some cases, there can be greater confidence if the extended scan groups and the previous scans were recorded by robot 202 having substantially similar locations and/or orientations. Moreover, in some cases,

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known information can be included, wherein the location of features in a graph are known a priori. Accordingly, such information can further increase confidence.

[00106] Scan matching can identify locations based at least in part on overlap of an extended scan group to another extended scan group. Overlap can be determined by algorithms known in the art, such as correlation, iterative comparisons, area of intersection, associations (e.g., point-to-point, point-to-feature, feature-to-feature, etc.), regression algorithms, closest point algorithms (e.g., Iterative Closest Point ("ICP")), nearest neighbor searching algorithms, and others.

[00107] By way of illustration, frame 702A illustrates nodes 708A, 710A, and 712A, as well as detected features 704A and 706A based on scans at nodes 708A, 710A, and 712A. Transform function 714 illustrates a rigid body transform, which can perform scan matching of frame 702A. Transform function 714 can perform translational and/or rotational movements of scans/nodes in frame 702A. As a result, frame 702B illustrates translated and rotated versions as nodes 708A, 710A, and 712A as nodes 708B, 710B, and 712, as well as translated and rotated versions of detected features 704A and 706A as detected features 704B and 706B. In some implementations, transform function 714 may not be a rigid body transform, wherein the relative positions of one or more of nodes 708A, 710A, and 712A and/or detected features 704A and 704B can change relative to one another.

[00108] In some cases, determining the confidence in the location of each node under block 558 of FIG. 5 can be performed by mapping and localization unit 262 and/or controller 254. FIG. 8 illustrates an example result of a scan matching of an extended scan group on the graph illustrated in FIG. 6C in accordance with some implementations of the present disclosure. Extended scan group 800 includes nodes 802A, 802B, and 802C. Because the scan matcher identified the positioning of nodes 802A, 802B, and 802C, their positions are determined with increased confidence. As a result, ranges 804A, 804B, and 804C may narrow, reflecting greater confidence. Accordingly, robot 202 can determine confidence based at least in part on scan matching, the propagation of errors (e.g., as reflected by ranges 602A, 602B, 602C, 602D, 626, and/or 628, and/or other ranges computed by robot 202), and/or other factors.

[00109] With the confidences determined, creating and solving a cost function to determine the location of each node under block 560 of FIG. 5 can be performed by mapping

and localization unit 262 and/or controller 254. In some cases, one or more nodes of a graph can have conceptual springs (e.g., connections) that characterize the spatial relationship between the nodes and the confidence in that relationship (e.g., in a covariance and/or other statistical categorization). The confidence can be based at least in part on the ranges illustrated in FIGS. 6A–6C and 8.

[00110] FIG. 9 illustrates springs to/from node 602A from graph 600 from FIG. 6A in accordance with some implementations of the present disclosure. As illustrated node 602A is connected to a plurality of nodes, including nodes 602B, 602C, and 602D by springs 650AB, 650AC, and 650AD. Node 602A can also be connected to any and/or all of the other nodes in the respective graph 600. However, in some cases, not all nodes of a map may be connected. Optionally, some nodes may be disconnected to prevent and/or mitigate the generation of unrealistic maps. For example, in some implementations, nodes can be selectively disconnected based at least in part on errors, exceeding a predetermined threshold uncertainty, being less than a predetermined threshold uncertainty, and/or any other predetermined constraints and/or restrictions.

[00111] Each of springs 950AB, 950AC, and 950AD can comprise one or more of: (1) a relative location between node 602A and the corresponding node at the other end (e.g., node 602D for spring 950AD, node 602C for spring 950AC, and node 602B for spring 950AB) and/or (2) a confidence of the relative positioning.

[00112] By way of illustration, the relative location can comprise a plurality of relative descriptions. In two-dimensions (e.g., such as those taken by a 2D scan), the relative location can comprise a horizontal direction, vertical direction, and/or an angle, such as in the form one or more of Δx, Δy, and $\Delta\theta$. Other ways of representing relative location are also contemplated, such as those with different coordinate systems and/or dimensions. For example, in three dimensions, relative location can be described in one or more of Δx, Δy, Δz, $\Delta\theta$, Δr, $\Delta\theta$, $\Delta\varphi$, etc. A person having ordinary skill in the art would appreciate that there are many ways to describe relative position and/or orientation in two, three, four, and/or any dimension. The confidence can be represented as a covariance matrix. By way of illustration, the covariance matrix can comprise the covariances between the elements of the location of the nodes (e.g., between node 602A and node 602D for spring 650AD, between node 602A and node 602C for spring 650AC, and between node 602A and node 602B for spring

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650AB). In some implementations, confidence can also be represented with other statistical indicia known in the art, such as variances, sample variances, correlations, etc. The confidence can be dependent in part on ranges, such as ranges calculated with respect to FIGS. 6A–6C and 8.

[00113] In some cases, the springs can define a cost function, wherein optimizing a graph includes minimizing the potential energy of the system defined by the springs. In this way, finding the optimal map can also be described as minimizing the cost function and/or finding substantially the maximum likelihood position of each node (e.g., based on the probability distributions). Solving the cost function can utilize least-squares regression methods, non-linear least squares optimization, perturbation theory, weighted-least squares methods, Kalman Filters, and/or any other methods known in the art for solving the cost function. Substantially similar to physical springs, the equilibrium configuration is one where the net force on each node is equal to substantially zero and/or a local minimum. The springs can be represented as weights and/or orientations.

[00114] Once the position of the nodes in the graph (e.g., graph 600, 650, and/or 690, and/or any graph generated by robot 202), robot 202 can construct a map (e.g., map 300, 500A, and/or 500B, and/or any map generated by robot 202), such as by processing the graph with mapping and localization units 262.

[00115] The rendering of a map from scans from the located nodes of block 562 of FIG. 5 can be performed by mapping and localization unit 262 and/or controller 254. For example, FIG. 10 is a diagram of the pixels of a map being constructed from scans in accordance to some implementations of this disclosure. By way of illustration, matrix 1000 comprises cells that correspond to locations on a map. In some cases, each cell can correspond to a pixel. Nodes 1004A and 1004B in cells in matrix 1000, indicative at least in part of the relative location of Nodes 1004A and 1004B. The locations can be based on standard units from a reference point and/or coordinate system (e.g., centimeters, meters, and/or any other standard measurement) and/or relative units (e.g., pixels, clicks, and/or any other relative measurement). Nodes 1004A and 1004B are provided for illustrative purposes. The positioning, number, and/or spacing of nodes can be dependent on the scans taken by robot 202 as it traversed an environment.

[00116] Each scan can provide information indicative at least in part of the relative

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location of objects around robot 202 at the nodes. In some cases, scans (e.g., scans from a scan LIDAR) can provide measurements to objects. For example, in some cases, ray tracing can be used, wherein the location of objects along rays extending from robot 202 across space can be used to identify the locations and/or orientations of objects. In matrix 1000, dotted lines such as line 1006 are indicative at least in part of rays. When an object is detected along a ray, the cell, such as cell 1002, can be marked. For visual illustration, mark 1008 is an "X" indicative at least in part that an object has been detected at the location corresponding to cell 1002.

[00117] In contrast, where a ray passes through a location with no object, the corresponding cell can be marked with an "O", such as illustrated with mark 1010. The cells corresponding to locations that rays have not passed through can have no mark. Other designations are contemplated. A person having ordinary skill in the art would appreciate that cells can be marked in any way desired. Additionally, more information can be associated with each cell, such as by associating each cell to another data structure and/or using a data structure with more dimensions. For example, additional information such as the location of the route by robot 202, performance of actions and/or action-specific tasks, characteristics of an environment (e.g., water, carpet, reflective, and/or any other description), prohibited areas, and/or others can also be associated with one or more cells. Such additional information can be derived from scans (e.g., from sensors of sensor units 264) and/or derived separately and inserted into the map. Such additional information can be added in at this stage and/or later after map construction.

[00118] Accordingly, through the plurality of ray tracings that can be observed from scans, the location of objects seen by robot 202 at various nodes can be mapped. Together, the accumulation of scans from nodes can create the map. In some cases, there can be overlap between scans at nodes. In some cases, such overlapping scans can agree on the positioning of objects. However, in some cases, overlapping scans can disagree and provide conflicting information. In some cases, these can be due in errors in measurements and/or moving objects. Accordingly, probabilities can be assigned to an identified cell. In some cases, the probability can be computed as the number of scans that detected an object (or in some cases, the scans that did not detect an object) divided by the total number of scans. In this way Other statistics can be used as well, such as weighted averages, statistical tests, variances,

and/or any other statistical method that reflects the uncertainty of conflicting information. In some cases, based on a predetermined statistical threshold, the presence and/or absence of objects can be determined in the map. For example, if the predetermined statistical threshold is met (either exceeded or not exceeded depending on how it is set), the location of the object will be filled in the generated map (e.g., maps 300, 500A, or 500B, and/or any other map generated by robot 202). By way of illustration, where the predetermined statistical threshold is a percentage, if the percentage of scans that identify an object in a location exceeds a predetermined percentage (e.g., 60, 70, 80, 90, and/or any other percentage based on the certainty desired), then the location will be identified as corresponding to an object in the map. As another illustration, in the case of identifying the absence of an object, if the percentage of scans that identify no object in a location exceeds a predetermined percentage (e.g., 60, 70, 80, 90, and/or any other percentage), then the location will be identified as no corresponding to an object (e.g., an empty space) in the map. A similar statistical analysis can be used in identifying any of the other/additional information described in this disclosure. A person having ordinary skill in the art would appreciate that the predetermined statistical thresholds can be defined in a number of ways, either in the positive (e.g., the presence of an object and/or characteristic) and/or the negative (e.g., the absence of an object and/or characteristic). Advantageously, taking a statistical approach can filter out moving objects, which may only appear in some scans but not others.

[00119] In some implementations, additionally process can be performed on a map and/or graph. For example, in some cases, pixel states can be indicative at least in part of whether robot 202 can navigate through an area. In some cases, certain locations may not have been adequately observed during demonstration, objects in the environment may have moved, and/or there can be uncertainty in measurements. Using user interface units 272, a user can edit a map and/or graph in order to add additional information. For example, a user can edit a map to identify areas in which robot 202 can traverse and/or areas in which robot 202 cannot traverse.

[00120] Robot 202 can learn from the users input. For example, robot 202 can store in memory 252 a library comprising one or more of: (i) original maps and/or graphs, (ii) maps and/or graphs with user input, (iii) other maps and/or graphs. In some cases, the library can be can contain approximately 1, 5, 10, 100, 1000, 10,000, 100,000, 1,000,000, 10,000,000, or

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any number of mays and/or graphs. In some implementations, the library can be stored in a network (e.g., cloud, server, etc.) and may not be saved within memory 252. The library can be used (e.g., based on machine learning algorithms) to train robot 202 to determine one or more associations between original maps/graphs and maps/graphs with user input. In this way, robot 202 can learn what changes have been made due to user input in the library and make substantially similar changes when it comes across substantially similar scenarios.

[00121] In some implementations, robot 202 can also made changes to existing graphs and/or maps during subsequent navigations in an environment. For example, robot 202 can collect additional data and/or scans in a new graph and/or map and use that additional data and/or scans to supplement an existing graph and/or map.

[00122] By way of illustration, robot 202 can, in a first period of time, generate a first graph and/or map beginning at a first home locator and traveling along a first route. At a later, second period of time, robot 202 can travel along a substantially similar path to the first route beginning at the first home locator and generating a second graph and/or map thereto, except collecting data (e.g., scans) that was not collected in the first period of time. Advantageously, where robot 202 started at the first home locator in the first period and the second period of time, robot 202 can use its localization to tie scans together from the first graph and/or map and the second graph and/or map. In this way, robot 202 can add additional coverage to the first graph and/or map that was measured in the second graph and/or map, and/or vice versa.

[00123] In some implementations, where different home locators are used as beginning points for the first graph and/or map and the second graph and/or map, robot 202 can transform them into a common coordinate system in order to more easily combine scans from each.

[00124] FIG. 11 is a process flow diagram of an exemplary method 1100 for generating a map by a robot in accordance with some implementations of the present disclosure. Block 1102 includes traveling, bu the robot, in an environment. Block 1104 includes creating a graph comprising a plurality of nodes, wherein each node corresponds to a scan taken by a sensor of the robot at a location in the environment. Block 1106 includes constraining the graph to start and end at a substantially similar location. Block 1108 includes performing scan matching on extended scan groups determined at least in part from

groups of the plurality of nodes. Block 1110 includes associating a range of possible locations with each of the plurality of nodes based at least in part on the scan matching. Block 1112 includes determining confidences associated with each range of possible locations. Block 1114 includes optimizing the graph to find the likely location of the plurality of nodes based at least in part on the confidences. Block 1116 includes generating the map from the optimized graph.

[00125] FIG. 12 is a process flow diagram of an exemplary method 1200 for operating a robot in accordance with some implementations of the present disclosure. Block 1202 includes causing a sensor to generate scans of an environment at a plurality of nodes, wherein each node of the plurality is associated with a location. Block 1204 includes creating a graph of the plurality of nodes based on the generated scans. Block 1206 includes determining extended scan groups based at least in part from scans associated with groups of the plurality of nodes. Block 1208 includes performing scan matching on the extended scan groups.

[00126] As used herein, computer and/or computing device can include, but are not limited to, personal computers ("PCs") and minicomputers, whether desktop, laptop, or otherwise, mainframe computers, workstations, servers, personal digital assistants ("PDAs"), handheld computers, embedded computers, programmable logic devices, personal communicators, tablet computers, mobile devices, portable navigation aids, J2ME equipped devices, cellular telephones, smart phones, personal integrated communication or entertainment devices, and/or any other device capable of executing a set of instructions and processing an incoming data signal.

[00127] As used herein, computer program and/or software can include any sequence or human or machine cognizable steps which perform a function. Such computer program and/or software may be rendered in any programming language or environment including, for example, C/C++, C#, Fortran, COBOL, MATLAB™, PASCAL, Python, assembly language, markup languages (e.g., HTML, SGML, XML, VoXML), and the like, as well as object-oriented environments such as the Common Object Request Broker Architecture ("CORBA"), JAVA™ (including J2ME, Java Beans, etc.), Binary Runtime Environment (e.g., BREW), and the like.

[00128] As used herein, connection, link, transmission channel, delay line, and/or wireless can include a causal link between any two or more entities (whether physical or

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logical/virtual), which enables information exchange between the entities.

[00129] It will be recognized that while certain aspects of the disclosure are described in terms of a specific sequence of steps of a method, these descriptions are only illustrative of the broader methods of the disclosure, and may be modified as required by the particular application. Certain steps may be rendered unnecessary or optional under certain circumstances. Additionally, certain steps or functionality may be added to the disclosed implementations, or the order of performance of two or more steps permuted. All such variations are considered to be encompassed within the disclosure disclosed and claimed herein.

[00130] While the above detailed description has shown, described, and pointed out novel features of the disclosure as applied to various implementations, it will be understood that various omissions, substitutions, and changes in the form and details of the device or process illustrated may be made by those skilled in the art without departing from the disclosure. The foregoing description is of the best mode presently contemplated of carrying out the disclosure. This description is in no way meant to be limiting, but rather should be taken as illustrative of the general principles of the disclosure. The scope of the disclosure should be determined with reference to the claims.

[00131] While the disclosure has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive. The disclosure is not limited to the disclosed embodiments. Variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed disclosure, from a study of the drawings, the disclosure and the appended claims.

[00132] It should be noted that the use of particular terminology when describing certain features or aspects of the disclosure should not be taken to imply that the terminology is being re-defined herein to be restricted to include any specific characteristics of the features or aspects of the disclosure with which that terminology is associated. Terms and phrases used in this application, and variations thereof, especially in the appended claims, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing, the term “including” should be read to mean “including, without limitation,” “including but not limited to,” or the like; the term “comprising” as used

herein is synonymous with "including," "containing," or "characterized by," and is inclusive or open-ended and does not exclude additional, unrecited elements or method steps; the term "having" should be interpreted as "having at least;" the term "such as" should be interpreted as "such as, without limitation;" the term 'includes" should be interpreted as "includes but is not limited to;" the term "example" is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof, and should be interpreted as "example, but without limitation;" adjectives such as "known," "normal," "standard," and terms of similar meaning should not be construed as limiting the item described to a given time period or to an item available as of a given time, but instead should be read to encompass known, normal, or standard technologies that may be available or known now or at any time in the future; and use of terms like "preferably," "preferred," "desired," or "desirable," and words of similar meaning should not be understood as implying that certain features are critical, essential, or even important to the structure or function of the present disclosure, but instead as merely intended to highlight alternative or additional features that may or may not be utilized in a particular embodiment. Likewise, a group of items linked with the conjunction "and" should not be read as requiring that each and every one of those items be present in the grouping, but rather should be read as "and/or" unless expressly stated otherwise. Similarly, a group of items linked with the conjunction "or" should not be read as requiring mutual exclusivity among that group, but rather should be read as "and/or" unless expressly stated otherwise. The terms "about" or "approximate" and the like are synonymous and are used to indicate that the value modified by the term has an understood range associated with it, where the range can be ±20%, ±15%, ±10%, ±5%, or ±1%. The term "substantially" is used to indicate that a result (e.g., measurement value) is close to a targeted value, where close can mean, for example, the result is within 80% of the value, within 90% of the value, within 95% of the value, or within 99% of the value. Also, as used herein "defined" or "determined" can include "predefined" or "predetermined" and/or otherwise determined values, conditions, thresholds, measurements, and the like.

WHAT IS CLAIMED IS:

1. A method of generating a map by a robot, comprising:

traveling, by the robot, in an environment;

creating a graph comprising a plurality of nodes, wherein each node corresponds to a scan taken by a sensor of the robot at a location in the environment;

constraining the graph to start and end at a substantially similar location;

performing scan matching on extended scan groups determined at least in part from groups of the plurality of nodes;

associating a range of possible locations with each of the plurality of nodes based at least in part on the scan matching;

determining confidences associated with each range of possible locations;

optimizing the graph to find a likely location of the plurality of nodes based at least in part on the associated confidences; and

generating the map from the optimized graph.

2. The method of Claim 1, wherein the generation of the map comprises ray tracing with the scans taken by the sensor, the scans associated with the plurality of nodes.

3. The method of Claim 1, wherein optimizing the graph comprises:

generating a cost function based at least in part on: (1) relative locations of each of the plurality of nodes, and (2) the confidences associated with each of the plurality of nodes; and

solving the cost function for a minimum.

4. The method of Claim 1, wherein constraining the graph to start and end at the substantially similar location further comprises constraining the graph to start and end in view of a home locator.

5. The method of Claim 1, wherein the traveling, by the robot, in the environment further comprises navigating under user control.

6. The method of Claim 1, wherein the associated confidences further comprise using a probability distribution indicative at least in part of a probability that a given node is in a given location.

7. The method of Claim 1, wherein the extended scan groups determined at least in part from groups of the plurality of nodes, further comprises:

selecting a root node as a reference location;

finding possible overlaps in measurements of distinct features in scans taken at other nodes; and

grouping the other nodes into extended scan groups based at least in part on overlapping distinct features of the scans at those respective other nodes.

8. A robot, comprising:

a sensor configured to take scans of an environment at a plurality of nodes, wherein each node is associated with a location; and

a mapping and localization unit configured to:

create a graph of the nodes based at least in part on the taken scans;

determine extended scan groups based at least in part on groups of the plurality of nodes; and

perform scan matching on the extended scan groups.

9. The robot of Claim 8, wherein the mapping and localization unit is further configured to constrain the graph to start and end at a substantially similar location.

10. The robot of Claim 8, wherein the mapping and localization unit is further configured to determine confidences associated with the location of each node.

11. The robot of Claim 10, wherein the mapping and localization unit is further configured to generate a cost function based at least in part on the confidences and locations of each node, wherein the mapping and localization unit determines the location of each node in the graph based on solving the cost function for a minimum.

12. The robot of Claim 8, further comprising a processor that is further configured to render a map from the graph, the map rendered based at least in part on ray tracings of the scans.

13. The robot of Claim 8, further comprising an actuator configured to move the robot between locations.

14. The robot of Claim 8, further comprising a user interface configured for user control of the robot.

15. The robot of Claim 8, further comprising a navigation unit configured to navigate the robot autonomously.

16. A non-transitory computer-readable storage apparatus having a plurality of

instructions stored thereon, the instructions being executable by a processing apparatus to operate a robot, the instructions configured to, when executed by the processing apparatus, cause the processing apparatus to:

cause a sensor to generate scans of an environment at a plurality of nodes, wherein each node of the plurality is associated with a location;

create a graph of the plurality of nodes based on the generated scans;

determine extended scan groups based at least in part from scans associated with groups of the plurality of nodes; and

perform scan matching on the extended scan groups.

17. The non-transitory computer-readable storage apparatus of Claim 16, further comprising one or more instructions, when executed by the processing apparatus, that further cause the processing apparatus to constrain the graph to start and end at a substantially similar location.

18. The non-transitory computer-readable storage apparatus of Claim 16, wherein each extended scan group comprises three or more scans.

19. The non-transitory computer-readable storage apparatus of Claim 16, further comprising one or more instructions, when executed by the processing apparatus, that further cause the processing apparatus to determine a cost function based at least in part on confidences associated with the location of each node.

20. The non-transitory computer-readable storage apparatus of Claim 19, further comprising one or more instructions, when executed by the processing apparatus, that further cause the processing apparatus to generate a map based at least in part on minimizing the cost function.

SYSTEMS AND METHODS FOR ROBOTIC MAPPING

Abstract of the Disclosure

Systems and methods for robotic mapping are disclosed. In some exemplary implementations, a robot can travel in an environment. From travelling in the environment, the robot can create a graph comprising a plurality of nodes, wherein each node corresponds to a scan taken by a sensor of the robot at a location in the environment. In some exemplary implementations, the robot can generate a map of the environment from the graph. In some cases, to facilitate map generation, the robot can constrain the graph to start and end at a substantially similar location. The robot can also perform scan matching on extended scan groups, determined from identifying overlap between scans, to further determine the location of features in a map.

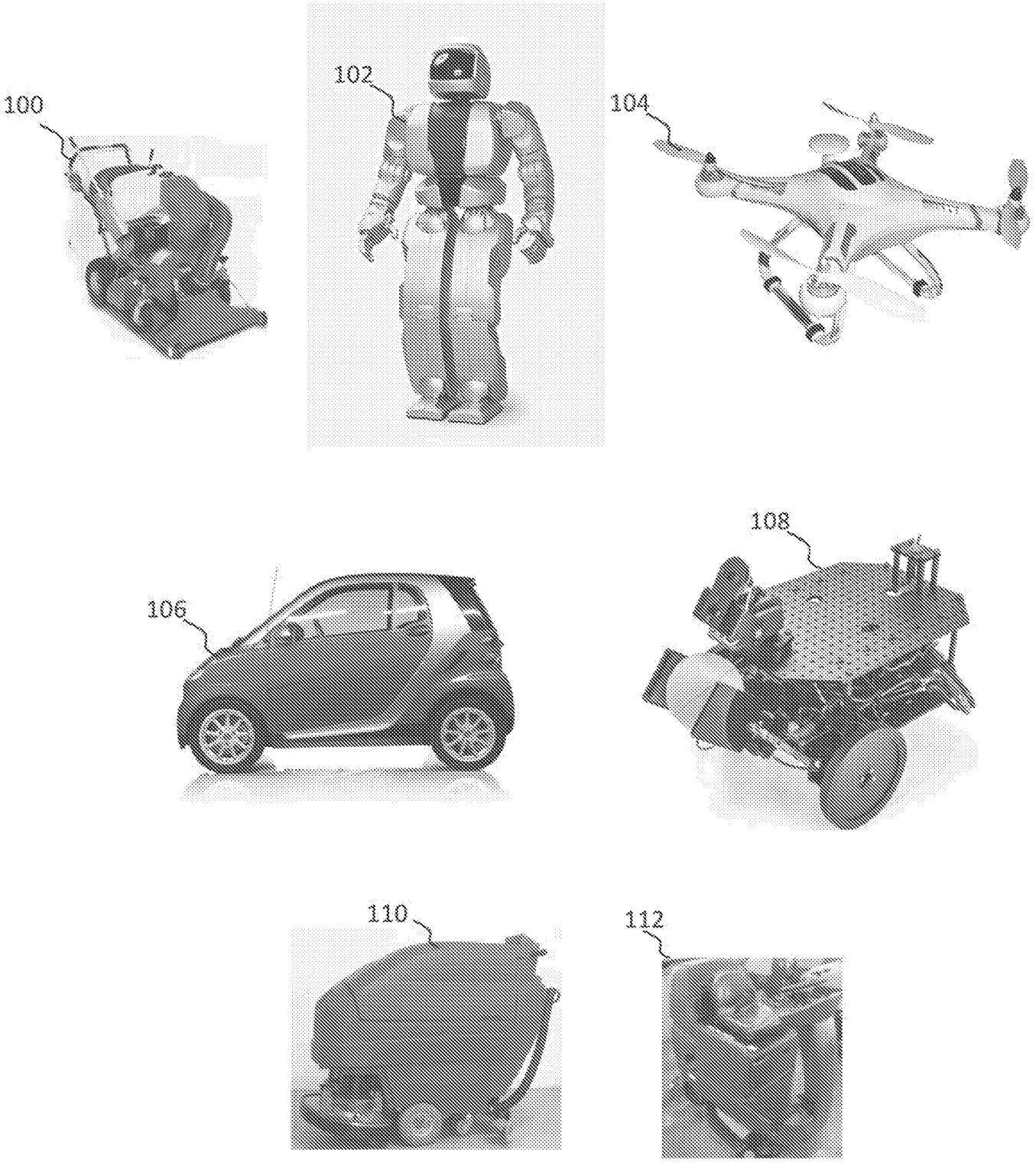


FIG. 1

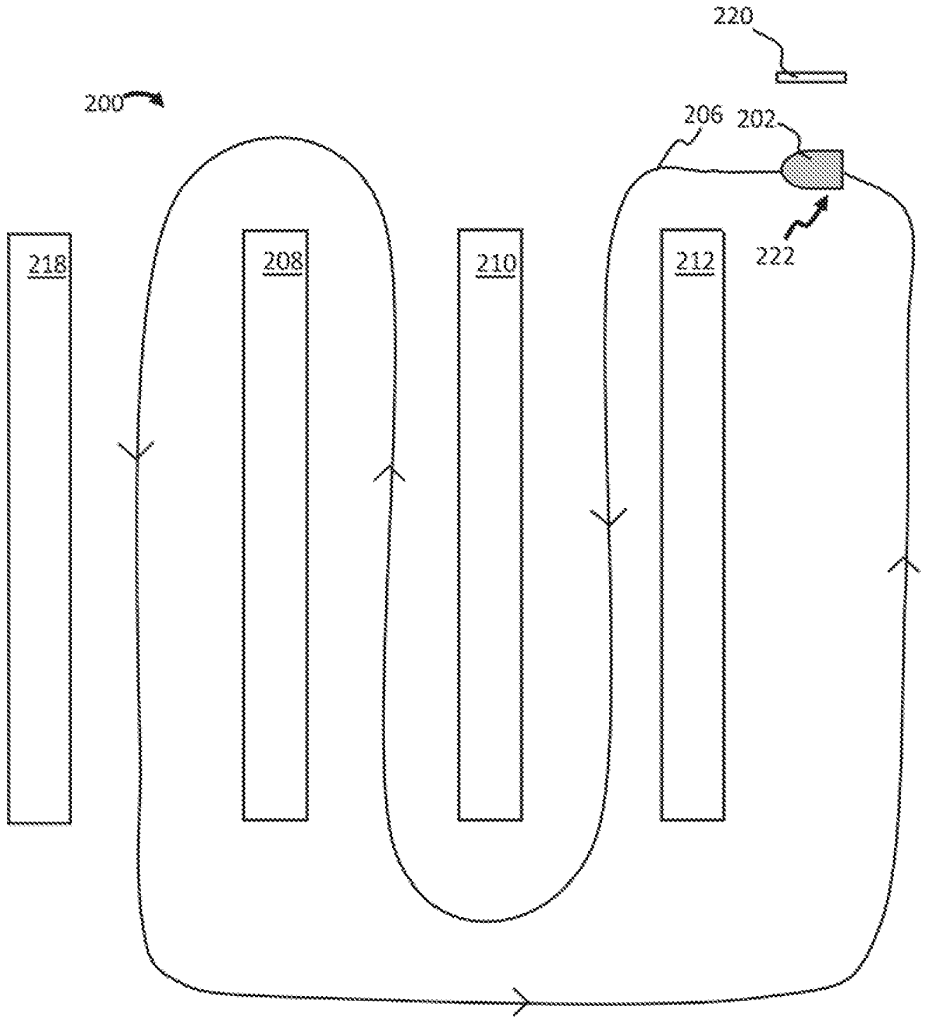


FIG. 2

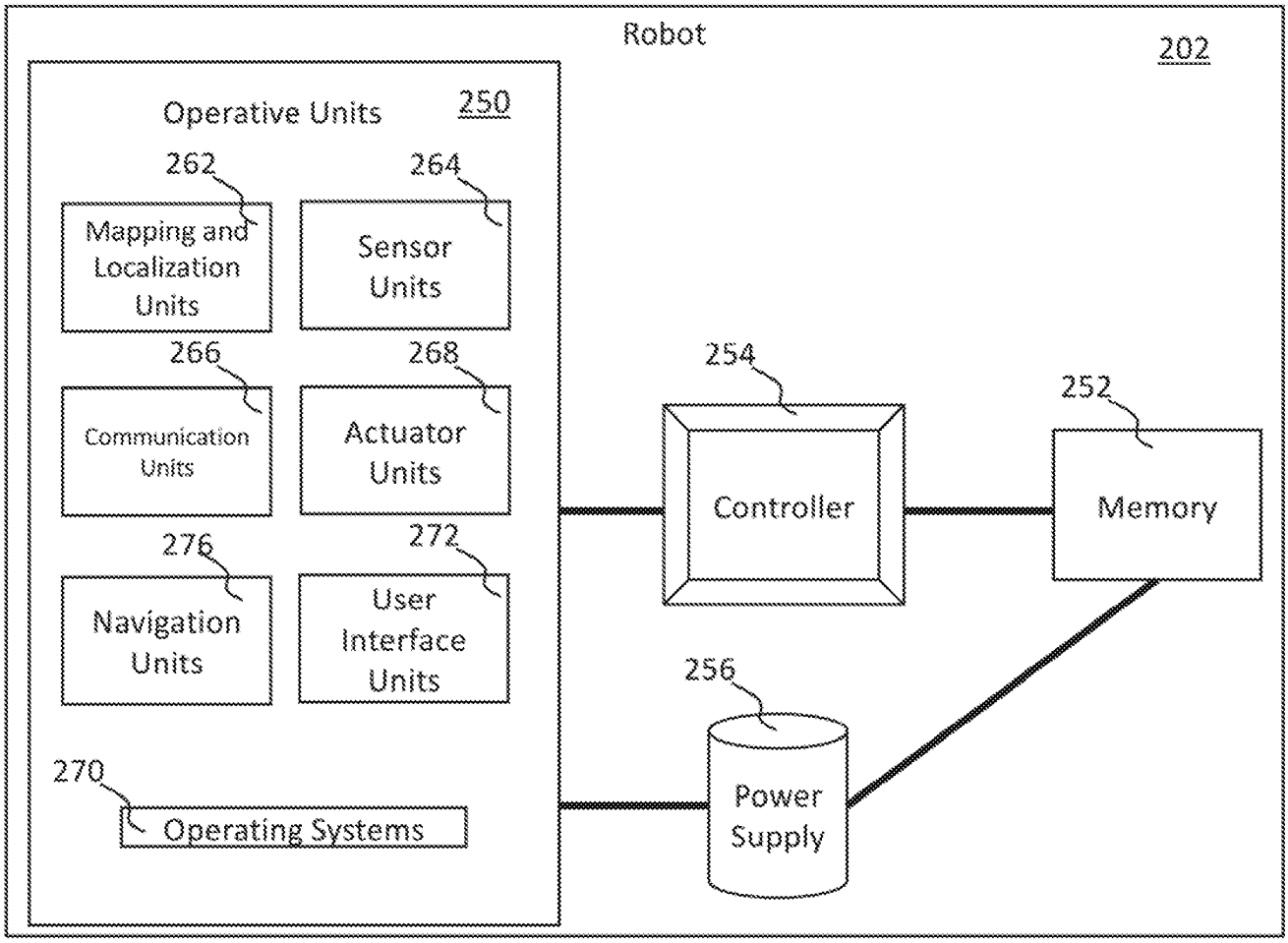

Robot
202
Operative Units
250
262
Mapping and Localization Units
264
Sensor Units
266
Communication Units
268
Actuator Units
276
Navigation Units
272
User Interface Units
270
Operating Systems
254
Controller
252
Memory
256
Power Supply

FIG. 3

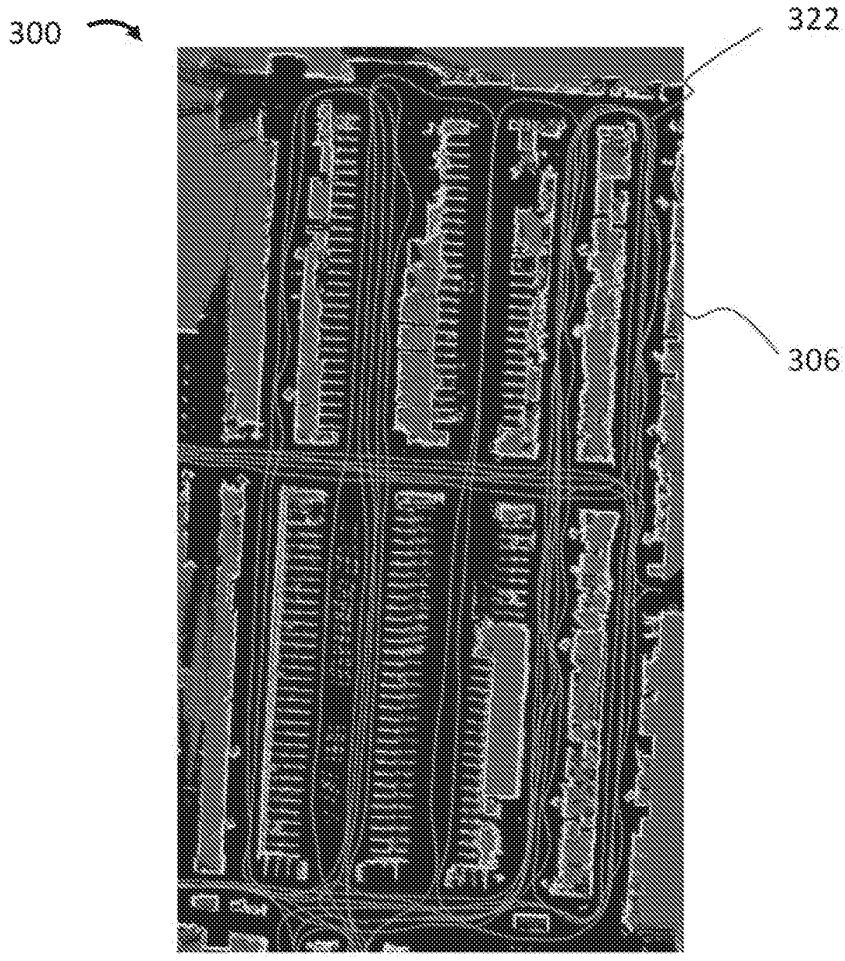


FIG. 4A

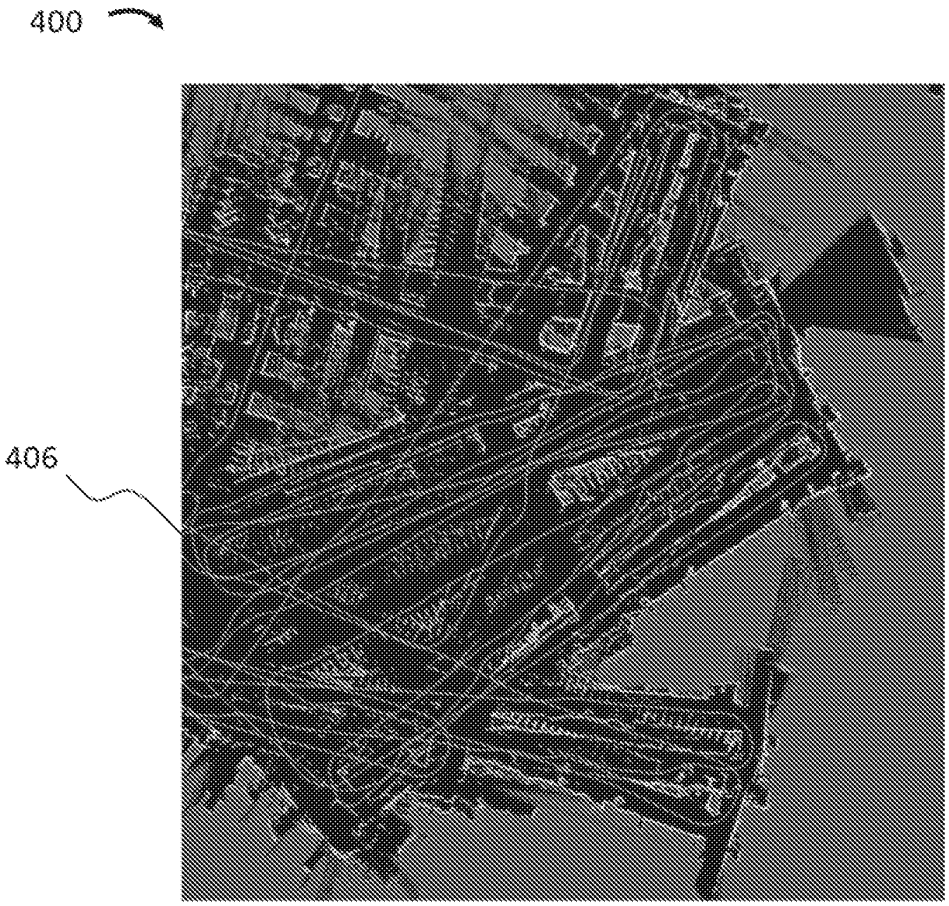


FIG. 4B

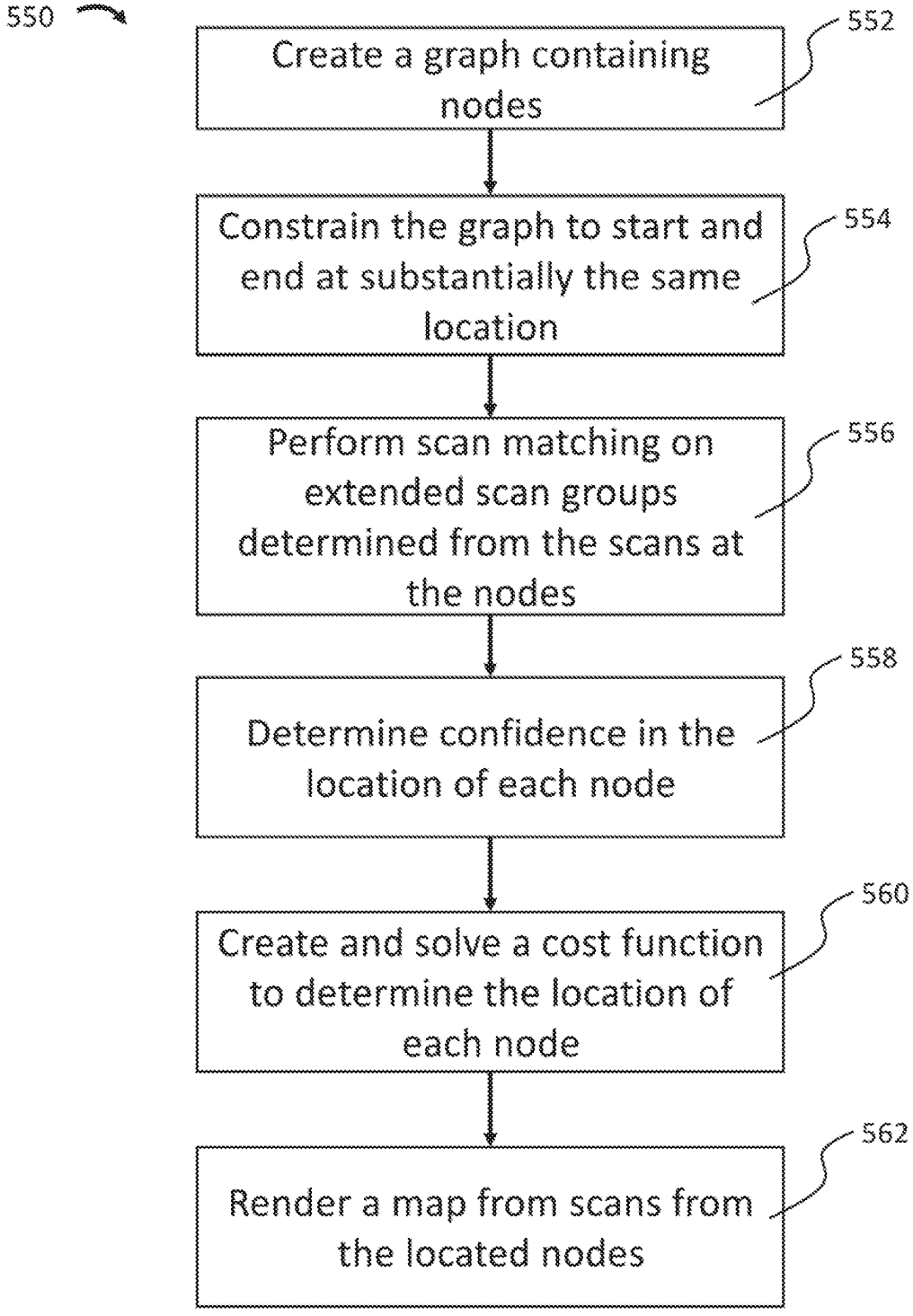

550
Create a graph containing nodes
552
Constrain the graph to start and end at substantially the same location
554
Perform scan matching on extended scan groups determined from the scans at the nodes
556
Determine confidence in the location of each node
558
Create and solve a cost function to determine the location of each node
560
Render a map from scans from the located nodes
562

FIG. 5

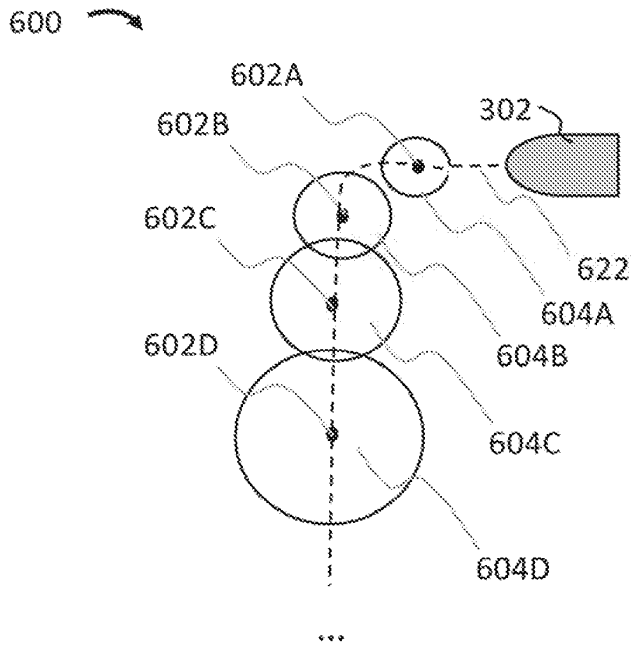


FIG. 6A

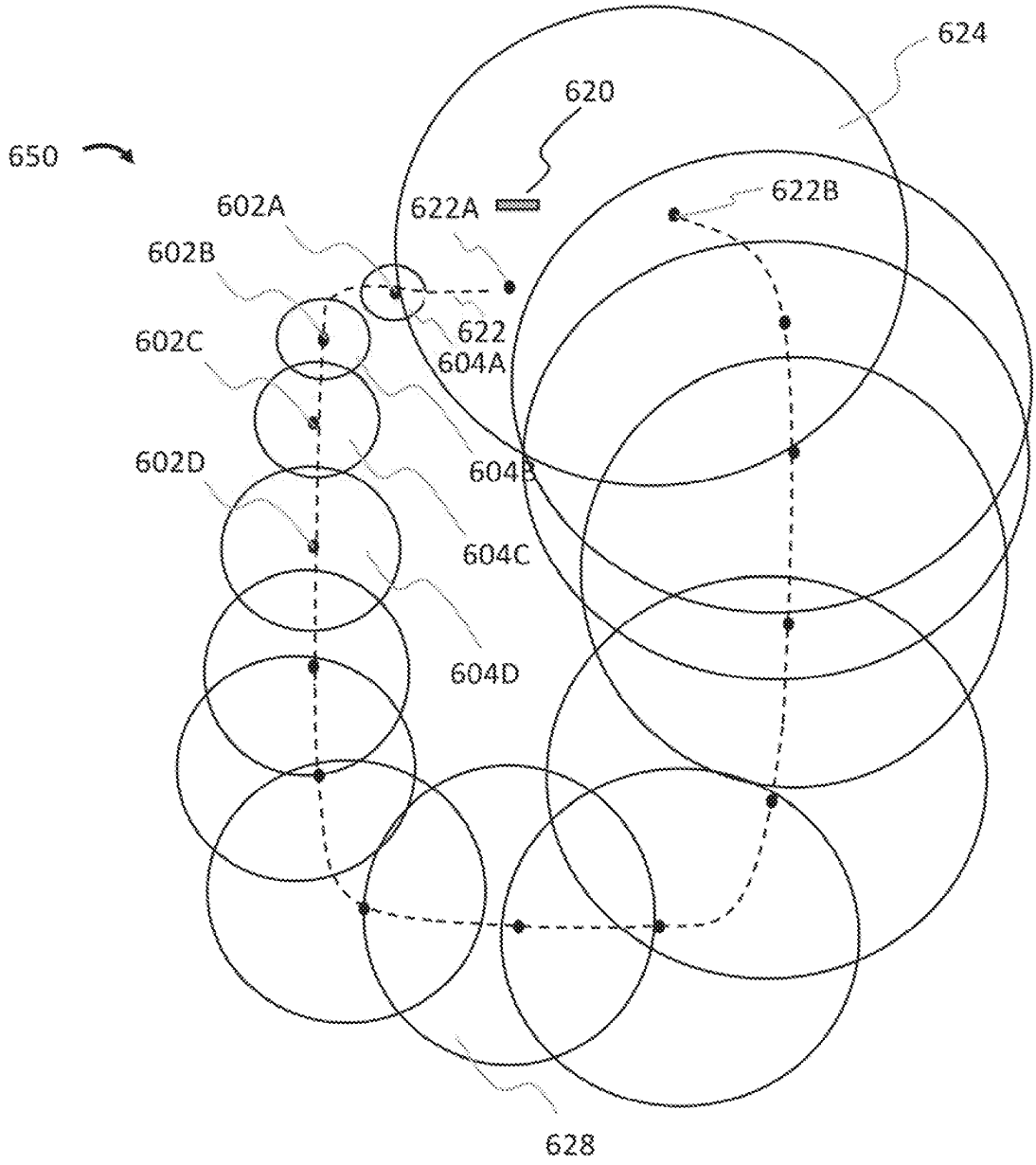

624
620
650
622B
602A
622A
602B
622
604A
602C
604B
602D
604C
604D
628

FIG. 6B

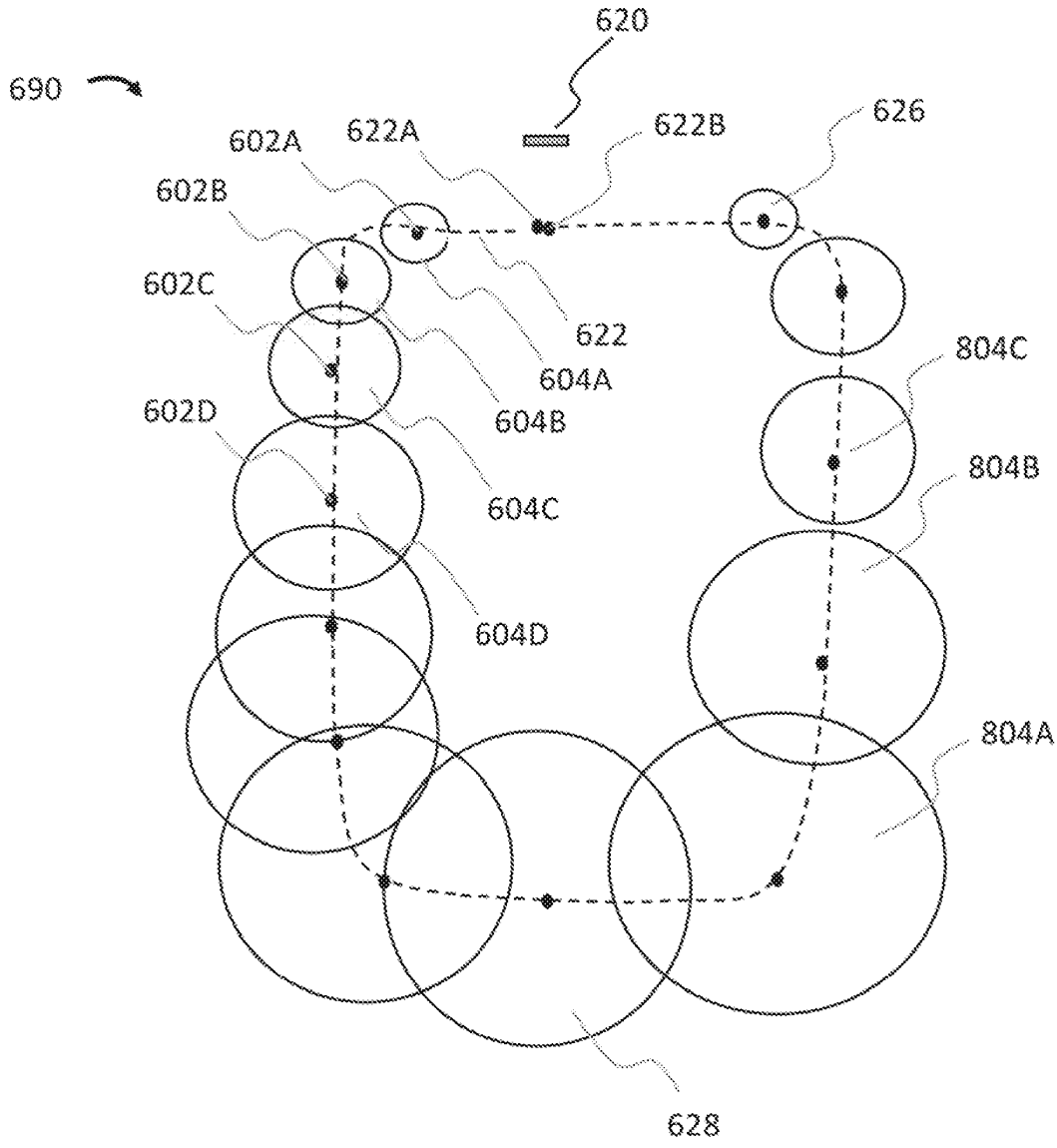

620
690
602A
622A
622B
626
602B
602C
622
604A
804C
602D
604B
804B
604C
604D
804A
628

FIG. 6C

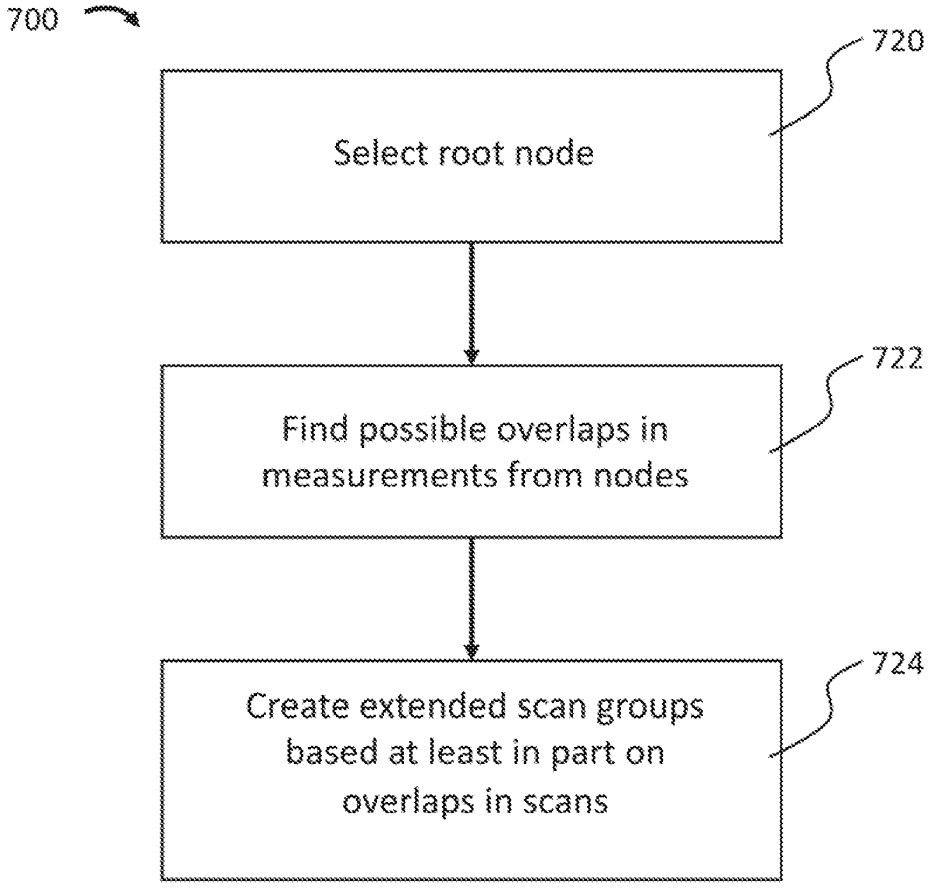

700
720
Select root node
722
Find possible overlaps in measurements from nodes
724
Create extended scan groups based at least in part on overlaps in scans

FIG. 7A

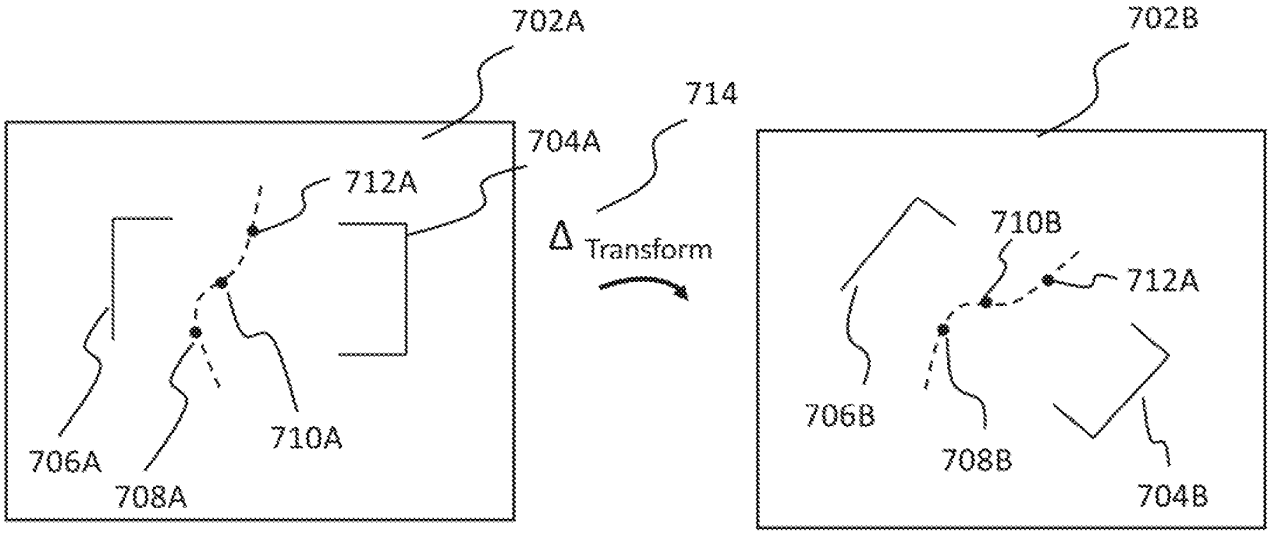

702A
714
704A
712A
Δ Transform
706A
708A
710A
702B
710B
712A
706B
708B
704B

FIG. 7B

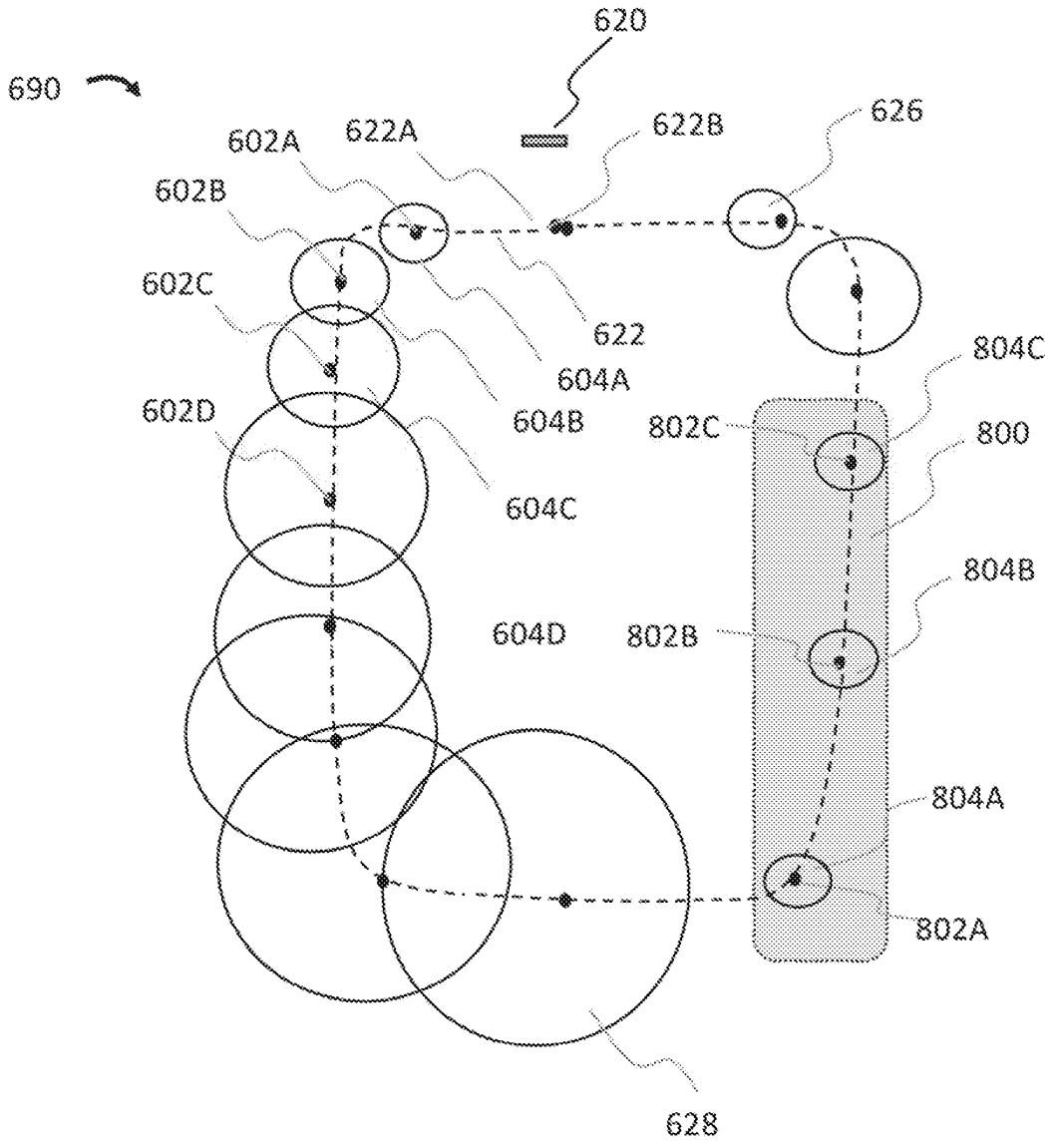

690
620
602A
622A
622B
626
602B
602C
622
604A
804C
602D
604B
802C
800
604C
804B
604D
802B
804A
802A
628

FIG. 8

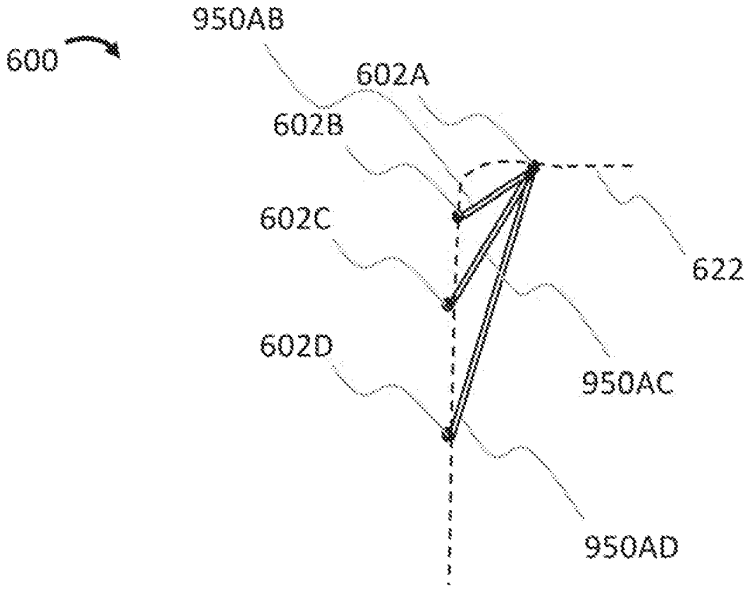


FIG. 9

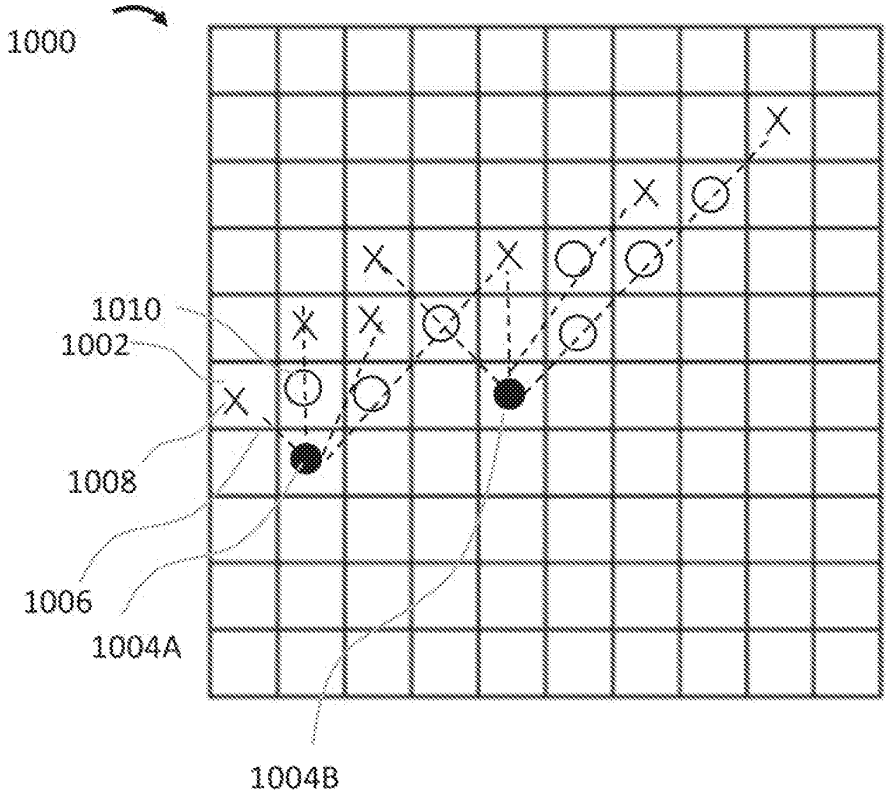


FIG. 10

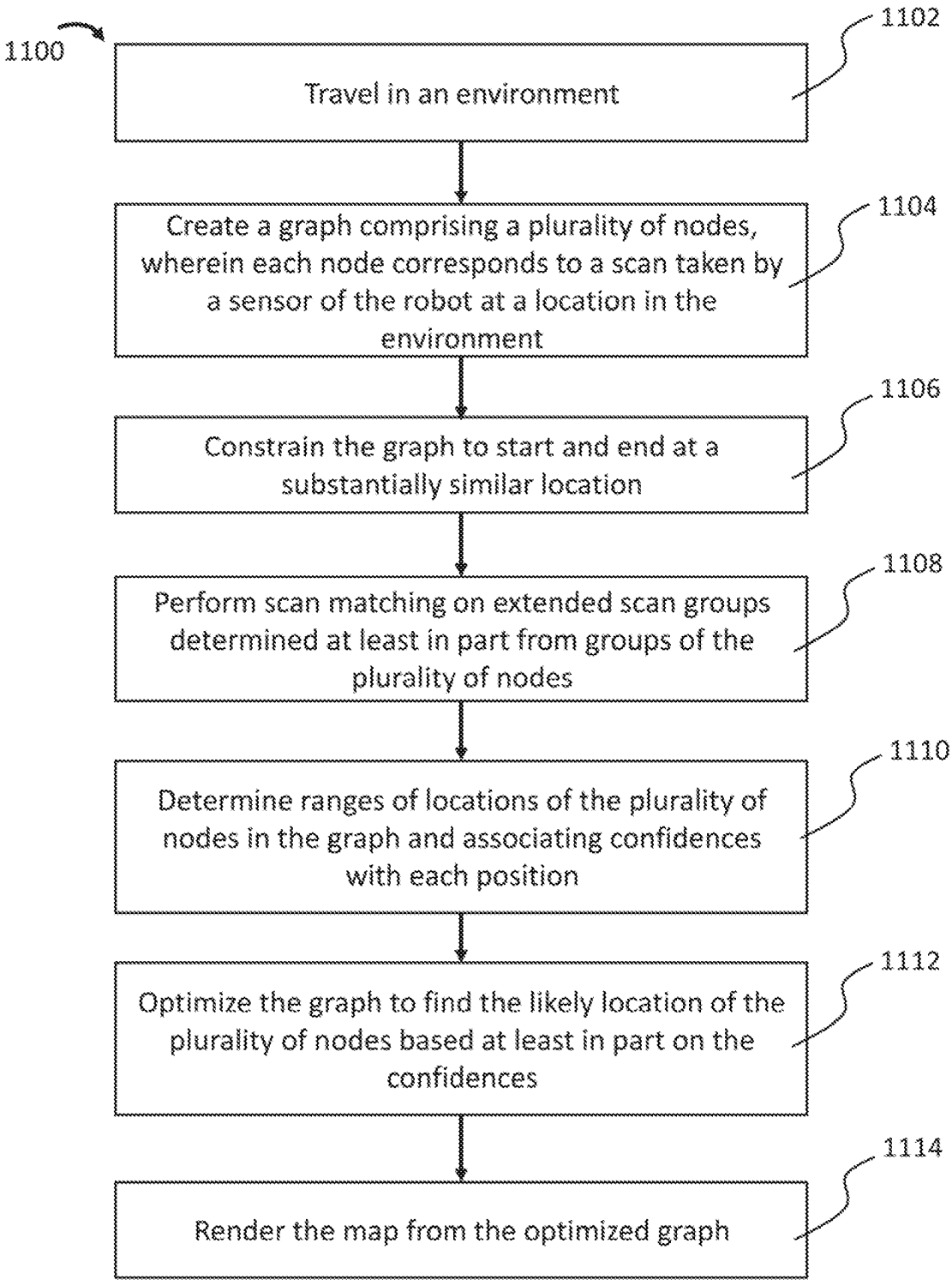

1100
1102
Travel in an environment
1104
Create a graph comprising a plurality of nodes, wherein each node corresponds to a scan taken by a sensor of the robot at a location in the environment
1106
Constrain the graph to start and end at a substantially similar location
1108
Perform scan matching on extended scan groups determined at least in part from groups of the plurality of nodes
1110
Determine ranges of locations of the plurality of nodes in the graph and associating confidences with each position
1112
Optimize the graph to find the likely location of the plurality of nodes based at least in part on the confidences
1114
Render the map from the optimized graph

FIG. 11

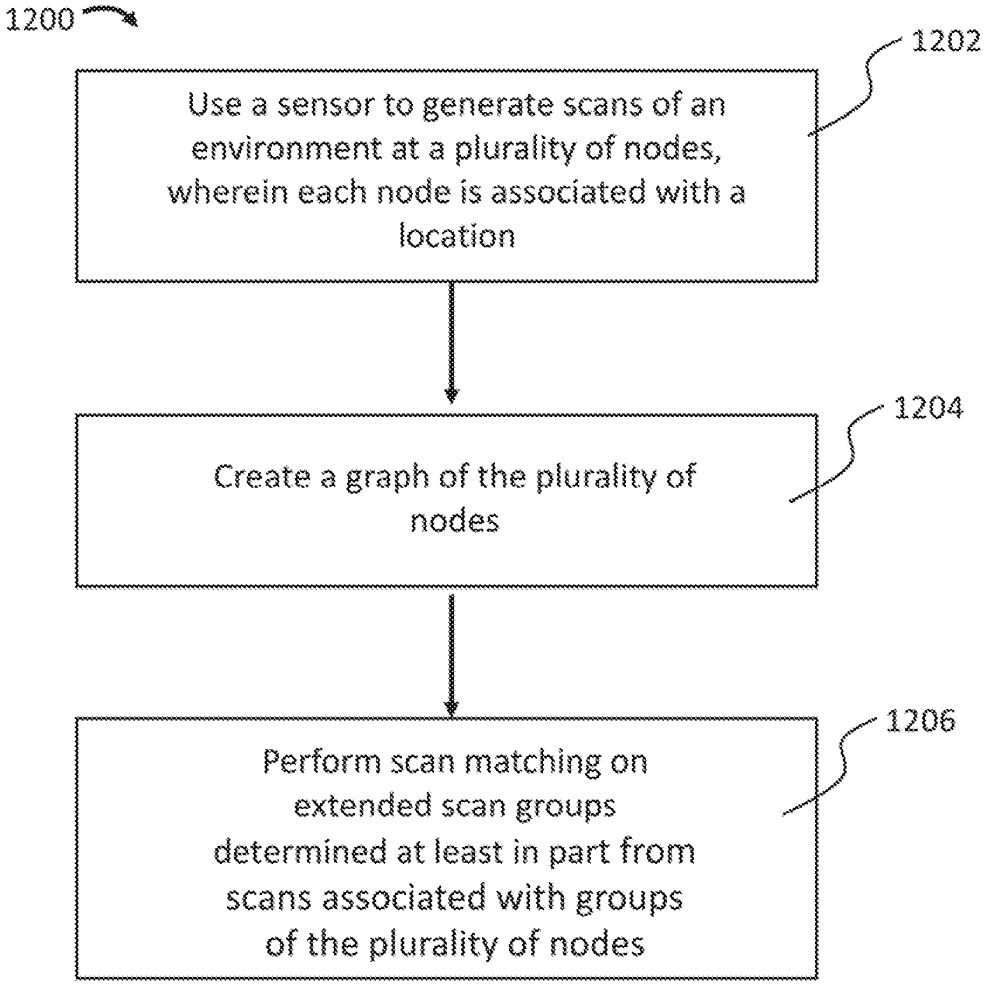

1200
1202
Use a sensor to generate scans of an environment at a plurality of nodes, wherein each node is associated with a location
1204
Create a graph of the plurality of nodes
1206
Perform scan matching on extended scan groups determined at least in part from scans associated with groups of the plurality of nodes

FIG. 12

Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Filer:	Peter John Gutierrez III/Carrie DeCoro
Attorney Docket Number:	BRAIN.133A/BC201608A

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
UTILITY FILING FEE (ELECTRONIC FILING)	4011	1	70	70
UTILITY SEARCH FEE	2111	1	300	300
UTILITY EXAMINATION FEE	2311	1	360	360
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**730**

Electronic Acknowledgement Receipt	
EFS ID:	27389875
Application Number:	15340807
International Application Number:	
Confirmation Number:	3030
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Customer Number:	132059
Filer:	Peter John Gutierrez III/Carrie DeCoro
Filer Authorized By:	Peter John Gutierrez III
Attorney Docket Number:	BRAIN.133A/BC201608A
Receipt Date:	01-NOV-2016
Filing Date:	
Time Stamp:	18:20:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	$730
RAM confirmation Number	110216INTEFSW00004885501423
Deposit Account	501423
Authorized User	Carrie DeCoro
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: 37 CFR 1.16 (National application filing, search, and examination fees) 37 CFR 1.17 (Patent application and reexamination processing fees)	

37 CFR 1.19 (Document supply fees)

37 CFR 1.20 (Post Issuance fees)

37 CFR 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal of New Application	BRAIN133A_Transmittal.pdf	94167 9939e3cd8f922887a0bffb88286a6af44cdeb509	no	2
Warnings:					
Information:					
2	Application Data Sheet	BRAIN133A_ADS.pdf	120853 ee4176025cfdf74378af79659e1a184b1cf67b84	no	8
Warnings:					
Information:					
This is not an USPTO supplied ADS fillable form					
3	Specification	BRAIN133A_SPEC.pdf	228890 c42b8c3573f72438396c357ab8adc111e2a5cd81	no	41
Warnings:					
Information:					
4	Drawings-other than black and white line drawings	BRAIN133A_FIGS.pdf	1226816 e332bf06ae17fcc1f1a28ccb5e4ef09f631b9a54	no	16
Warnings:					
Information:					
5	Fee Worksheet (SB06)	fee-info.pdf	34965 611b27a2d43db010e81e894f4e9365cb5e580618	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	1705691		

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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.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

DocCode – SCORE

SCORE Placeholder Sheet for IFW Content

Application Number: 15340807 Document Date: 11/01/2016

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

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Form Revision Date: August 26, 2013

Document code: WFEE

United States Patent and Trademark Office
Sales Receipt for Accounting Date: 11/10/2016

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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 15/340,807

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	70		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	300		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	360		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	20 minus 20 =	*	x 40 =	0.00	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*	x 210 =	0.00			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	730		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)	OR	RATE($)	ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

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www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/340,807	11/01/2016	Jaldert Rombouts	BRAIN.133A/BC201608A

CONFIRMATION NO. 3030

132059
Gazdzinski & Associates, PC
16644 West Bernardo Drive
Suite 201
San Diego, CA 92127

INFORMAL NOTICE

OC000000087158093

Date Mailed: 11/14/2016

INFORMATIONAL NOTICE TO APPLICANT

Applicant is notified that the above-identified application contains the deficiencies noted below. No period for reply is set forth in this notice for correction of these deficiencies. However, if a deficiency relates to the inventor's oath or declaration, the applicant must file an oath or declaration in compliance with 37 CFR 1.63, or a substitute statement in compliance with 37 CFR 1.64, executed by or with respect to each actual inventor no later than the expiration of the time period set in the "Notice of Allowability" to avoid abandonment. See 37 CFR 1.53(f).

The item(s) indicated below are also required and should be submitted with any reply to this notice to avoid further processing delays.

- A properly executed inventor's oath or declaration has not been received for the following inventor(s):
  Jaldert Rombouts
  Borja Ibarz Gabardos
  Jean-Baptiste Passot
  Andrew Smith

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/hchin/

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United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
15/340,807	11/01/2016		800	BRAIN.133A/BC201608A	20	3

CONFIRMATION NO. 3030

FILING RECEIPT

132059
Gazdzinski & Associates, PC
16644 West Bernardo Drive
Suite 201
San Diego, CA 92127

OC000000087138092

Date Mailed: 11/14/2016

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Jaldert Rombouts, San Diego, CA;
Borja Ibarz Gabardos, La Jolla, CA;
Jean-Baptiste Passot, Solana Beach, CA;
Andrew Smith, San Diego, CA;

Applicant(s)

BRAIN CORPORATION, San Diego, CA

Power of Attorney: None

Domestic Applications for which benefit is claimed - None.
A proper domestic benefit claim must be provided in an Application Data Sheet in order to constitute a claim for domestic benefit. See 37 CFR 1.76 and 1.78.

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access Application via Priority Document Exchange: Yes

Permission to Access Search Results: Yes

Applicant may provide or rescind an authorization for access using Form PTO/SB/39 or Form PTO/SB/69 as appropriate.

If Required, Foreign Filing License Granted: 11/10/2016

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 15/340,807**

Projected Publication Date: 05/03/2018

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****
Title

SYSTEMS AND METHODS FOR ROBOTIC MAPPING

Preliminary Class

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

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Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 1 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	001	US-4638445	01-20-1987	MATTABONI; Paul J.	
	002	US-4763276	08-09-1988	PERREIRRA; Noel D. et al.	
	003	US-4852018	07-25-1989	GROSSBERG; Stephen et al.	
	004	US-5121497	06-09-1992	KERR; Randal H. et al.	
	005	US-5280179	01-18-1994	PRYOR; Timothy R. et al.	
	006	US-5446356	08-29-1995	KIM; Sang-Gwon	
	007	US-5602761	02-11-1997	SPOERRE; Julie K. et al.	
	008	US-5612883	03-18-1997	SHAFFER; Gary K. et al.	
	009	US-5673367	09-30-1997	BUCKLEY; Theresa M.	
	010	US-5719480	02-17-1998	BOCK; Otmar et al.	
	011	US-5841959	11-24-1998	GUIREMAND; Harry A.	
	012	US-5994864	11-30-1999	INOUE; Yasuyuki et al.	
	013	US-6124694	09-26-2000	BANCROFT; Allen J. et al.	
	014	US-6169981	01-02-2001	WERBOS; Paul J.	
	015	US-6243622	06-05-2001	YIM; Mark H. et al.	
	016	US-6366293	04-02-2002	HAMILTON; Jeffrey L. et al.	
	017	US-6442451	08-27-2002	LAPHAM; John R.	
	018	US-6560511	05-06-2003	YOKOO; Naohiro et al.	
	019	US-6584375	06-24-2003	BANCROFT; Allen et al.	
	020	US-6636781	10-21-2003	SHEN; Wei-Min et al.	
	021	US-6697711	02-24-2004	YOKONO; Jun et al.	

Examiner Signature		Date Considered	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Sheet 2 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	022	US-6760645	07-06-2004	KAPLAN; Frederic et al.	
	023	US-6812846	11-02-2004	GUTTA; Srinivas et al.	
	024	US-6961060	11-01-2005	MOCHIZUKI; Yoshiyuki et al.	
	025	US-7002585	02-21-2006	WATANABE; Atsushi et al.	
	026	US-7148644	12-12-2006	YOURLO; Zhenya Alexander et al.	
	027	US-7243334	07-10-2007	BERGER; Kenneth A. et al.	
	028	US-7342589	03-11-2008	MISEROCCHI; Nathan P.	
	029	US-7668605	02-23-2010	BRAUN; Scott D. et al.	
	030	US-8145492	03-27-2012	FUJITA; Masahiro	
	031	US-8364314	01-29-2013	ABDALLAH; Muhammad E. et al.	
	032	US-8380348	02-19-2013	NEKI; Norio et al.	
	033	US-8380652	02-19-2013	FRANCIS Jr.; Anthony G.	
	034	US-8419804	04-16-2013	HERR; Hugh M. et al.	
	035	US-8423225	04-16-2013	HILLMAN Jr.; Henry L. et al.	
	036	US-8452448	05-28-2013	PACK; Robert T. et al.	
	037	US-8515162	08-20-2013	CHENG; Ting-Yuan	
	038	US-8639035	01-28-2014	SHIBA; Hisashi	
	039	US-8639644	01-28-2014	HICKMAN; Ryan et al.	
	040	US-8679260	03-25-2014	HILLMAN Jr.; Henry L. et al.	
	041	US-8793205	07-29-2014	FISHER; Dimitry et al.	

Examiner Signature		Date Considered	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Sheet 3 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	042	US-8924021	12-30-2014	DARIUSH; Behzad et al.	
	043	US-8958911	02-17-2015	WONG; Cheuk Wah et al.	
	044	US-8958912	02-17-2015	BLUMBERG; Bruce et al.	
	045	US-8958937	02-17-2015	HILLMAN Jr.; Henry L. et al.	
	046	US-9008840	04-14-2015	PONULAK; Filip et al.	
	047	US-9015093	04-21-2015	COMMONS; Michael Lamport	
	048	US-9144907	09-29-2015	SUMMER; Matthew D. et al.	
	049	US-9242372	01-26-2016	LAURENT; Patryk et al.	
	050	US-20020158599	10-31-2002	FUJITA; Masahiro et al.	
	051	US-20020175894	11-28-2002	GRILLO; Vince	
	052	US-20020198854	12-26-2002	BERENJI; Hamid R. et al.	
	053	US-20030023347	01-30-2003	KONNO; Reizo et al.	
	054	US-20030025082	02-06-2003	BREWINGTON; James Gabriel et al.	
	055	US-20030108415	06-12-2003	HOSEK; Martin et al.	
	056	US-20030144764	07-31-2003	YOKONO; Jun et al.	
	057	US-20030220714	11-27-2003	NAKAMURA; Yoshihiko et al.	
	058	US-20040030449	02-12-2004	SOLOMON; Neal	
	059	US-20040036437	02-26-2004	ITO; Masato	
	060	US-20040051493	03-18-2004	FURUTA; Takayuki et al.	
	061	US-20040167641	08-26-2004	KAWAI; Masakazu et al.	

Examiner Signature		Date Considered	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 4 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	062	US-20040172166	09-02-2004	LAPSTUN; Paul et al.	
	063	US-20040172168	09-02-2004	WATANABE; Atsushi et al.	
	064	US-20040267404	12-30-2004	DANKO; George	
	065	US-20050008227	01-13-2005	DUAN; Baofu et al.	
	066	US-20050065651	03-24-2005	AYERS; Joseph et al.	
	067	US-20050069207	03-31-2005	ZAKRZEWSKI; Radoslaw Romuald et al.	
	068	US-20050125099	06-09-2005	MIKAMI; Tatsuo et al.	
	069	US-20060207419	09-21-2006	OKAZAKI; Yasunao et al.	
	070	US-20060250101	11-09-2006	KHATIB; Oussama et al.	
	071	US-20070074177	03-29-2007	KURITA; Shigeru et al.	
	072	US-20070151389	07-05-2007	PRISCO; Giuseppe et al.	
	073	US-20070200525	08-30-2007	KANAOKA; Katsuya	
	074	US-20070255454	11-01-2007	DARIUSH; Behzad et al.	
	075	US-20070260356	11-08-2007	KOCK; Sonke et al.	
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	082	US-20090231359	09-17-2009	BASS II; Robert Leon et al.	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Sheet 5 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	083	US-20090234501	09-17-2009	ISHIZAKI; Takehiro	
	084	US-20090265036	10-22-2009	JAMIESON; Josef et al.	
	085	US-20090272585	11-05-2009	NAGASAKA; Kenichiro	
	086	US-20100114372	05-06-2010	KNUTH Jr.; David M. et al.	
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Sheet 6 of 14

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Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

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Sheet 7 of 14

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Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

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	124	US-20130173060	07-04-2013	YOO; Su Jung et al.	
	125	US-20130206170	08-15-2013	SVENDSEN; Selma et al.	
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	141	US-20140358828	12-04-2014	PHILLIPPS; Kelly D. et al.	
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Sheet 8 of 14

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Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

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	144	US-20150032258	01-29-2015	PASSOT; Jean-Baptiste et al.	
	145	US-20150094850	04-02-2015	PASSOT; Jean-Baptiste et al.	
	146	US-20150094852	04-02-2015	LAURENT; Patryk et al.	
	147	US-20150120128	04-30-2015	ROSENSTEIN; Michael T. et al.	
	148	US-20150127155	05-07-2015	PASSOT; Jean-Baptiste et al.	
	149	US-20150185027	07-02-2015	KIKKERI; Harshavardhana et al.	
	150	US-20150204559	07-23-2015	HOFFBERG; Steven M. et al.	
	151	US-20150213299	07-30-2015	SOLANO; Ferrández José Vicente et al.	
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Sheet 9 of 14

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Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

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	001	WO-0167749-A2	09-13-2001	SARNOFF CORP [US]		☐
	002	WO-2014196925-A1	12-11-2014	CTRLWORKS PTE LTD [SG]		☐
	003	WO-2015047195-A1	04-02-2015	CTRLWORKS PTE LTD [SG]		☐

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Sheet 10 of 14

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First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No.[1]	Include name of the author(in CAPITAL LETTERS),title of the article(when appropriate), title of the item (book,magazine,journal,serial,symposium,catalog,etc.),date,page(s),volume-issue number(s),publisher, city and/or country where published.	T[2]
	001	ASENSIO et al., "Robot Learning Control Based on Neural Network Prediction" ASME 8th Annual Dynamic Systems and Control Conference joint with the JSME 11th Motion and Vibration Conference 2012 [Retrieved on: Jun. 24, 2014]. Retrieved fro internet:http://msc.berkeley.edu/wjchen/publications/DSC12.sub.--8726.sub.--FI-.pdf<http: />.	☐
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Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author(in CAPITAL LETTERS),title of the article(when appropriate), title of the item (book,magazine,journal,serial,symposium,catalog,etc.),date,page(s),volume-issue number(s),publisher, city and/or country where published.	T[2]
	009	Hopkins, Chasing Water with Thermal Imaging, Infrared Training Center, 2011.	☐
	010	HUNT, et al., "Detection of Changes in Leaf Water Content Using Near-and Middle-Infrared Reflectance, " Journal of Remote Sensing of Environment, 1989, Vol. 30 (1), pp.43-54.	☐
	011	JAIN, Learning Trajectory Preferences for Manipulators via Iterative Improvement, 2013, Advances in Neural Information Processing Systems 26 (NIPS 2013).	☐
	012	JOSHI, Blog Post from Perpetual Enigma Website, "Understanding Camera Calibration" posted 5-31-14, accessed 6-20-16 at the following Web address: https://prateekvjoshi.com/2014/05/31/understanding-camera-calibration/.	☐
	013	Kalman Filter; wikipedia.	☐
	014	KASABOV, "Evolving Spiking Neural Networks for Spatio-and Spectro-Temporal Pattern Recognition", IEEE 6th International Conference Intelligent Systems 2012 [Retrieved on Jun 24, 2014], Retrieved from the Internet: http://ncs.ethz.ch/projects/evospike/publications/evolving-spiking-neural-networks-for-spatio-and-spectro-temporal-pattern-recognition-plenary-talk-ieee-is/view.	☐
	015	MAESEN, et al., "Tile Tracker: A Practical and Inexpensive Positioning System for Mobile AR Applications" pp.1-8.	☐
	016	PR2 User Manual, October 5, 2012.	☐
	017	RAHMAN, et al., "An Image Based Approach to Compute Object Distance, "International Journal of Computational Intelligence Systems, 2008, Vol. 1 (4), pp. 304-315.	☐

Examiner Signature		Date Considered	

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(Use as many sheets as necessary)

Sheet 12 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author(in CAPITAL LETTERS),title of the article(when appropriate), title of the item (book,magazine,journal,serial,symposium,catalog,etc.),date,page(s),volume-issue number(s),publisher, city and/or country where published.	T[2]
	018	ROSEBROCK,Tutorial "Find Distance from Camera to Object/marker using Python and OpenCV" 1-19-15, accessed 6-20-16 at the following Web address:http://www.pyimagesearch.com/2015/01/19/find-distance-camera-objectmarker-using-python-opencv/.	☐
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	023	TRIGGS, "Camera Pose and Calibration from 4 or 5 known 3D Points," 7th International Conference on Computer Vision (ICCV '99), IEEE Computer Society, 1999, Vol. 1, pp.278–284.	☐
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	025	Video "TECNALIA-Limaccio Autonomous Cleaning Robot", published 2-22-13, available at the following Web address: http://www.youtube.com/watch?v=4GJ00EBbBfQ&sns=em.	☐
	026	WAN, et al., "Automatic Navigation System with Multiple Sensors," IFIP International Federation for Information Processing, Volume 259, Computer and Computing Technologies in Agriculture, 2008, Vol. 2, pp. 769-776.	☐

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Sheet 13 of 14

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Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

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	027	Wikipedia Page "Pose (Computer Vision)" accessed 6-20-16, available at the following Web address: https://en.wikipedia.org/wiki/Pose_(computer_vision).	☐
	028	ZHANG, A Flexible New Technique for Camera Calibration, last updated 12-5-9, Technical Report MSR-TR-98-71, December 2, 1998.	☐

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application 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, 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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Sheet 14 of 14

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Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☒ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☐ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Mark I. Wang/	Date (YYYY-MM-DD)	2017-03-02
Name/Print	Mark I. Wang	Registration Number	65,282

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	:	Jaldert Rombouts, et al.
Appl. No.	:	15/340,807
Filed	:	November 1, 2016
For	:	**SYSTEMS AND METHODS FOR ROBOTIC MAPPING**
Examiner	:	Unknown
Group Art Unit:		Unknown

CUSTOMER NO. 132059

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I hereby certify that this correspondence is being transmitted via the Office electronic filing system in accordance with 37 C.F.R. § 1.8(a)(i)(C) from the Pacific Time Zone of the United States on the local date shown below.

March 2, 2017
(Date)

/Mark I. Wang/
Mark I. Wang, Reg. No. 65,282

INFORMATION DISCLOSURE STATEMENT

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P.O. Box 1450
Alexandria, VA 22313-1450

Dear Examiner:

Applicant submits herewith an IDS citing one hundred and eighty-seven (187) references for consideration by the Office.

This Information Disclosure Statement is being filed before the mailing date of a first Office Action on the merits, and presumably no fee is required in accordance with 37 C.F.R. § 1.97(b)(3). If a first Office Action on the merits was mailed before the mailing date of this Statement, it is requested that the Commissioner charge any fees under 37 C.F.R. § 1.16 and § 1.17 to Deposit Account No. 501423.

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art in this application. Further, Applicant makes no representation regarding the completeness of this list or that better art does not exist.

Respectfully submitted,

GAZDZINSKI & ASSOCIATES, PC

Dated: March 2, 2017

By: /Mark I. Wang/
Mark I. Wang
Registration No. 65,282
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Electronic Acknowledgement Receipt	
EFS ID:	28521106
Application Number:	15340807
International Application Number:	
Confirmation Number:	3030
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Customer Number:	132059
Filer:	Peter John Gutierrez III/Chrissie McGaw
Filer Authorized By:	Peter John Gutierrez III
Attorney Docket Number:	BRAIN.133A/BC201608A
Receipt Date:	02-MAR-2017
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Time Stamp:	18:26:28
Application Type:	Utility under 35 USC 111(a)

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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(71) Applicant: SARNOFF CORPORATION [US/US]; 201 Washington Road, CN 5300, Princeton, NJ 08543-5300 (US).

(72) Inventors: SAWHNEY, Harpreet, Singh; 17 Melville Road, West Windsor, NJ 08550 (US). KUMAR, Rakesh; 966 Ridge Road, Monmouth Junction, NJ 08852 (US). HSU, Steve; 1134 Country Mill Drive, Cranbury, NJ 08512 (US). SAMARASEKERA, Supun; 24 Blackstone Drive, Princeton, NJ 08540 (US).

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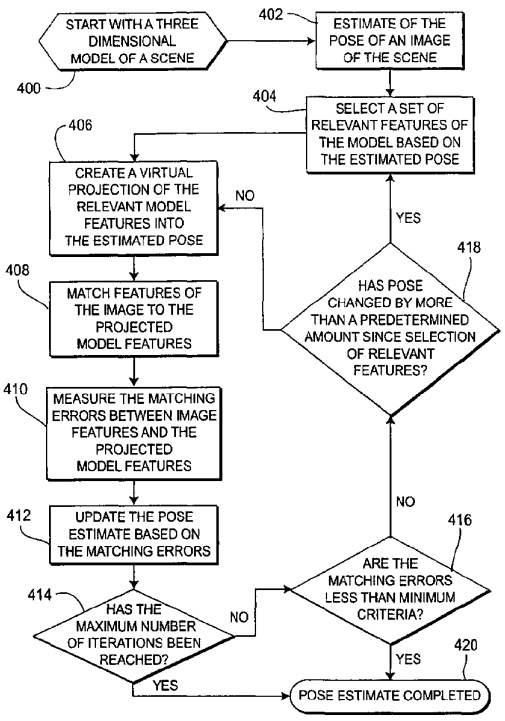
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZW.

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[Continued on next page]

WO 01/67749 A2

(54) Title: A METHOD OF POSE ESTIMATION AND MODEL REFINEMENT FOR VIDEO REPRESENTATION OF A THREE DIMENSIONAL SCENE



(57) Abstract: The present invention is embodied in a video flashlight method. This method creates virtual images of a scene using a dynamically updated three-dimensional model of the scene and at least one video sequence of images. An estimate of the camera pose is generated by comparing a present image to the three-dimensional model. Next, relevant features of the model are selected based on the estimated pose. The relevant features are then virtually projected onto the estimated pose and matched to features of the image. Matching errors are measured between the relevant features of the virtual projection and the features of the image. The estimated pose is then updated to reduce these matching errors. The model is also refined with updated information from the image. Meanwhile, a viewpoint for a virtual image is selected. The virtual image is then created by projecting the dynamically updated three-dimensional model onto the selected virtual viewpoint.

patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

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A METHOD OF POSE ESTIMATION AND MODEL REFINEMENT FOR VIDEO REPRESENTATION OF A THREE DIMENSIONAL SCENE

[0001] This application claims the benefit of the filing date of the Provisional application 60/187,557 filed March 7, 2000, the contents of which are incorporated herein by reference.

[0002] The present invention is directed toward the domain of image processing, in particular toward the creation and manipulation of three dimensional scene models and virtual images of the scene seen from arbitrary viewpoints.

BACKGROUND OF THE INVENTION

[0003] Tremendous progress in the computational capability of integrated electronics and increasing sophistication in the algorithms for smart video processing has lead to special effects wizardry, which creates spectacular images and otherworldly fantasies. It is also bringing advanced video and image analysis applications into the mainstream. Furthermore, video cameras are becoming ubiquitous. Video CMOS cameras costing only a few dollars are already being built into cars, portable computers and even toys. Cameras are being embedded everywhere, in all variety of products and systems just as microprocessors are.

[0004] At the same time, increasing bandwidth on the Internet and other delivery media has brought widespread use of camera systems to provide live video imagery of remote locations. In order to provide coverage of live video imagery of a remote site, it is often desirable to create representations of the environment to allow realistic viewer movement through the site. The environment consists of static parts (building, roads, trees, etc.) and dynamic parts (people, cars, etc.). The geometry of the static parts of the environment can be modeled offline using a number of well-established techniques. None of these techniques has yet provided a completely automatic solution for modeling relatively complex environments, but because the static parts do not change, offline, non-real time, interactive modeling may suffice for some applications. A number of commercially available systems (GLMX, PhotoModeler, etc.) provide interactive tools for modeling environments and objects.

[0005] For arbitrary 3D scenes, various modeling approaches have been proposed, such as image-based rendering, light fields, volume rendering, and superquadrics plus

shape variations. For general modeling of static scenes, site models are known to provide a viable option. In the traditional graphics pipeline based rendering, scene and object models stored as polygonal models and scene graphs are rendered using Z-buffering and texture mapping. The complexity of such rendering is dependent on the complexity of the scene. Standard graphics pipeline hardware has been optimized for high performance rendering.

[0006] However, current site models do not include appearance representations that capture the changing appearance of the scene. Also these methods generally seek to create a high quality model from scratch, which in practice necessitates constrained motion, instrumented cameras, or interactive techniques to obtain accurate pose and structure. The pose of the camera defines both its position and orientation. The dynamic components of a scene cannot, by definition, be modeled once and for all. Even for the static parts, the appearance of the scene changes due to varying illumination and shadows, and through modifications to the environment. For maintaining up-to-date appearance of the static parts of the scene, videos provide a cost-effective and viable source of current information about the scene, but unless the cameras are fixed, the issue of obtaining accurate pose information remains.

[0007] Between a pair of real cameras, virtual viewpoints may be created by tweening images from the two nearest cameras. Optical flow methods are commonly used by themselves to create tweened images. Unfortunately, the use of only traditional optical flow methods can lead to several problems in creating a tweened image. Particularly difficult are the resolution of large motions, especially of thin structures, for example the swing of a baseball bat; and occlusion/deocclusions, for example between a person's hands and body.The body of work on structure from motion may be pertinent to 3D-scene modeling. Purely image-driven methods, however, tend to drift away from metric accuracy over extended image sequences, because there is no constraint to tie down the estimated structure to the coordinate system of the real world. That constraint must come from physical measurements like GPS, or surveyed landmarks, or from a prior scene model with shape and/or texture information. The problem of loss of metric accuracy is particularly acute for analysis and control of a remote scene in which use of such

constraint indicia is not practical, for example to control a remote vehicle on Mars or underground.

SUMMARY OF THE INVENTION

[0009] The present invention is embodied in a method of accurately estimating a pose of a camera within a scene using a three dimensional model of the scene. The exemplary method begins by generating an initial estimate of the camera pose. Next, a set of relevant features of the three-dimensional model based on the estimate of the pose is selected. A virtual projection of this set of relevant features as seen from the estimated pose is then created. The virtual projection of the set of relevant features is matched to features of the received image and matching errors between the features of the image and the features of the projection are measured. The estimate of the pose is then updated to reduce the matching errors.

[0010] A second embodiment of the present invention is method of refining a three dimensional model of a scene using an image of the scene taken by a camera, which may have an unknown pose. First the image is compared to the three dimensional model of the scene to generate an estimate of the camera pose. The three dimensional model of the scene is then updated based on data from the image and the estimated pose.

[0011] Another embodiment of the present invention is a method of accurately estimating a position of remote vehicle using a three dimensional model and an image from a camera having a known orientation relative to the remote vehicle. The image is compared to the three dimensional model of the scene to generate an initial estimate of the pose. A set of relevant features of the three dimensional model are selected and matched to features of the image. Matching errors are then measured and used to update the estimate of the pose. The position of the remote vehicle is determined using the estimated pose and the orientation of the camera. The three dimensional model may then be updated based on data from the image and the estimate of the pose.

[0012] Yet another embodiment of the present invention is a method of refining a three dimensional model of a scene containing an object using a plurality of images of the scene. First, a first image and a second image are compared to the three dimensional model of the scene to generate first and second pose estimates. Then, the first image and the second image are compared to one another to generate relative pose constraints. The

first pose and the second pose are updated based on these relative pose constraints. Two sets of relevant features of the three-dimensional model corresponding to the first pose and the second pose are selected. These sets of relevant features are then matched to features in the first and second images, and two sets of matching errors are measured. The position estimate of the object within the three-dimensional model is then updated to reduce the two sets of matching errors.

[0013] The present invention is also embodied in a method of creating a textured three-dimensional model of a scene using a plurality of images of the scene. First a polyhedral model the scene including a plurality of polygonal surfaces is created. Each polygonal surface in the polyhedral model is larger than a predetermined size. One polygonal surface is then separated into a plurality of portions. For a selected portion, a subset of images containing that portion of the polygonal surface is identified. The corresponding section of the selected image is then projected onto the selected portion of the polygonal surface in the textured three-dimensional model as a local color map.

[0014] The present invention is also embodied in a video flashlight method of creating a dynamic sequence of virtual images of a scene using a dynamically updated three dimensional model of the scene. The three dimensional model is updated using a video sequence of images of the scene as described with regard to the second embodiment of the present invention. Meanwhile a viewpoint of a virtual image is selected. The virtual image is then created by projecting the dynamic three-dimensional model onto the virtual viewpoint.

BRIEF DESCRIPTION OF THE FIGURES

[0015] Figure 1 is a top plan drawing of several cameras viewing a scene.

[0016] Figure 2 is a perspective drawing of a polyhedral model of the scene in Figure 1.

[0017] Figure 3 is a drawing illustrating selection of relevant features from the polyhedral model of Figure 2.

[0018] Figure 4 is a flowchart illustrating an embodiment of the present invention to accurately estimate the pose of an image of a scene using a three dimensional model of the scene.

[0019] Figure 5 is a flowchart illustrating an embodiment of the present invention to update a three dimensional model of a scene using an image of the scene with an unknown pose.

[0020] Figure 6 is a perspective drawing illustrating the use of epipolar geometry to determine the relative pose of two images.

[0021] Figure 7 is a flowchart illustrating an embodiment of the present invention to update a three dimensional model of a scene using a pair of images of the scene with unknown poses.

[0022] Figure 8 is a top plan drawing illustrating a remote vehicle with a mounted camera viewing the scene from Figure 1.

[0023] Figure 9 is a flowchart illustrating an embodiment of the present invention to accurately estimate the position of a remote vehicle within a scene using a three dimensional model of the scene and an image of the scene.

[0024] Figure 10 is a perspective drawing of a surface from Figure 2 illustrating the separation of the surface into approximately equal sized portions used in an exemplary hybrid three dimensional model according to the present invention.

[0025] Figure 11 is a flowchart illustrating an embodiment of the present invention to create a hybrid three-dimensional model of a scene.

[0026] Figure 12 is a perspective drawing of a scene illustrating an exemplary video flashlight method of the present invention.

[0027] Figure 13 is a flowchart illustrating an embodiment of the present invention to create virtual images of a scene and a dynamic three-dimensional model of the scene using a video flashlight method.

DETAILED DESCRIPTION OF THE INVENTION

[0028] The present invention embodies systems and methods for processing one or more video streams, for the purposes of progressively constructing and refining a 3D-scene model, geolocating objects, and enhanced visualization of dynamic scenes. One embodiment of the present invention is a progressive strategy to model construction and refinement, starting with a coarse model and incrementally refining it with information

derived from freely moving video cameras, thereby increasing the spatial fidelity and temporal currentness of the model.

[0029] Figure 1 is a top plan drawing showing several cameras **108**, which may be stationary or may be in motion. The cameras view an exemplary scene **100**, containing three objects, cube **102**, star prism **104**, and cylinder **106**.

[0030] Figure 2 is a perspective drawing of an exemplary polyhedral model of scene **100** from Figure 1. All objects in this model are all represented as polyhedra composed of planar polygonal surfaces **200**, even a curved object, such as cylinder **106**. To accomplish such a polyhedral representation, the modeled representation of cylinder **106** contains artificial edge boundaries **204**. Also shown in Figure 2 are dotted lines **202**, which represent edge boundaries that are hidden in the illustrated view of the model. While this model is shown as an image of a physical scene, it is contemplated that the model may be a mathematical representation of the scene, stored in a data file.

[0031] A first exemplary embodiment of the present invention is a method of automatic pose estimation and registration of video to an existing polyhedral scene model, which may or may not have texture information suitable for registration. The method of this embodiment may be used to estimate camera pose with respect to textured or untextured models, by optimizing the fit between line segments projected from model to image and the gradients of image intensity. This method may be combined with interframe prediction to continuously track a video stream.

[0032] Figure 4 is a flowchart illustrating this exemplary embodiment of the present invention. The method begins with a three dimensional model of the scene, **400**, such as that shown in Figure 2. The first step, **402**, is to generate an initial, rough estimate of the pose of an image by comparing the image to the three dimension model of the scene. Numerous methods may be used to obtain this initial estimate. In an interactive system, a user can set the pose for the first frame. Physical measurements from position/attitude sensors mounted on the camera platform may be another source. Alternatively, when processing a sequence of frames, the estimated pose of the previous frame may be used as the initial pose, or the pose can be predicted from the previous frame's estimated pose based on assumed motion. Interframe alignment may also be used to assist with prediction and with overcoming ambiguity. One method for determining an

initial pose estimate may be to extract corresponding 2D feature points from a pair of successive images using an optical flow technique. In order to support large displacements, flow estimation may be initialized with the 2D projective motion field estimated by a global parametric motion algorithm. Methods for flow estimation of this type are described in U.S. Patent number 5,629,988, entitled "SYSTEM AND METHOD FOR ELECTRONIC IMAGE STABILIZATION". Next, each selected feature point is mapped into its corresponding 3D point in the world view by using the current estimated pose and the current shape model. The initial pose estimate is then determined from the set of 3D and 2D correspondences. This may be done, for example, using the Random Sample Consensus (RANSAC) method of robust least squares fitting. Even though the current pose and shape model may include significant errors, these errors should be reduced in the process of refining the image to model alignment.

[0033] Next a set of relevant features is selected from the three dimensional model based on the estimate of the pose, step **404**. The existing model may be considered a collection of untextured polygonal faces. Face edges in the model imply discontinuities in surface normal and/or material properties in the actual 3D scene, which generally induce brightness edges in an image. Although the subject invention is described in terms of brightness edges, it is contemplated that other types of edges may be used such as those defined by changes in color or texture on an appropriately colored and/or textured model. Because they are relatively easy to identify, an exemplary alignment method selects 3D line segments from the model as relevant features.

[0034] Figure 3 is a drawing illustrating selection of relevant features **302** from the polyhedral model of Figure 2. Figure 3 is drawn to have the same pose as that used for the perspective drawing of Figure 2. Given an initial pose estimate, occluded fragments of model features, dotted lines **202** in Figure 2, may be deleted by known methods, such as a Z-buffer hidden line removal process.

[0035] Because many models of objects, such as buildings, may be constructed for various applications besides pose estimation (e.g. architecture), many model edges will not induce brightness edges in the image. Even after occluded edge fragments are suppressed, a model may contain clutter such as edges occluded by unmodeled objects, edges of structures that are semantically but not geometrically significant, edges between

faces meeting at a shallow angle. Pose estimation may be adversely affected if too much model clutter happens to fall close to image edges. Therefore, it is important to cull the edges of the polyhedral model to keep those most likely to induce brightness edges.

[0036] Additionally, multiple local minima in pose estimation may be caused by closely spaced edges in either the model or the image even if they correspond to brightness edges in the image. Therefore, once the possible relevant features of the model have been identified, a projection of these features as they appear in the estimated pose is created, step **406** in Figure 4, and projected model features are culled out if any similarly oriented projected model edge lies near it. Projected model features may also be culled if image texture analysis reveals the presence of multiple image edges within a predetermined distance. This culling may be dynamically adapted to the current level of uncertainty, so that as pose becomes better known, more edges can be included for increased pose estimation accuracy.

[0037] Application-dependent heuristics for this culling may be applied, for example, keeping only model edges common to exactly two faces, keeping edges only at large dihedral angles, ignoring edges which are too close together, and ignoring edges near and on the ground (terrain faces may be annotated in the given model). In Figure 3 the dotted lines **300** represent features which have been ignored in this exemplary pose as too close to other lines. Also missing are the artificial edge boundaries **204** from the model shown in Figure 2, as the their dihedral angles have been determined to be too small.

[0038] While the pose, and hence occlusions, may change during the optimization process, it may suffice to cull model edges once when initializing the optimization and afterwards only if the pose changes significantly. This determination, based on the change in the estimated pose in the exemplary method of Figure 4, is shown as step **418**. If the pose of the camera has changed by more than a threshold amount since the features were selected from the model, step **418** jumps to step **404** to select a new set of features. The process of pose refinement desirably leads toward smaller changes in the estimated pose. Therefore, often the estimate of pose will quickly become approximately correct. In this instance, step **418** branches to step **406** and same set of relevant features will be used throughout the remaining pose refinement.

[0039] It is noted that, though the embodiments of the present invention mostly disclose the measurement and reduction of matching errors, one of skill in the art may easily practice the present invention by, instead, measuring and increasing matching scores without substantially altering the invention.

[0040] Next, the virtual projection of the relevant features is matched to brightness features in the image, step **408**. Additionally, color and/or texture edges may be used to generate image features, not just brightness edges. Matching errors are generated to indicate the goodness of the fit, step **410**. The estimated pose is then updated based on these matching errors, step **412**. The matching error calculation may be accomplished by many methods, including a number of image processing methods used for image warping and mosaic construction.

[0041] In the case of an already-textured model, constructed from a previous set of images, the matching of image intensity patterns in the image to the textured model may be accomplished following the teachings of U.S. Patent Application number 09/075462, entitled "METHOD AND APPARATUS FOR PERFORMING GEO-SPATIAL REGISTRATION" and U.S. Provisional Application number 60/141460, entitled "GEO-SPATIAL REGISTRATION USING EUCLIDEAN REPRESENTATION".

[0042] One difficulty that may arise is that an image may have brightness edges that are close together, causing local minima in the objective function. Also, if the given polyhedral model does not agree with veridical scene structure, no pose can simultaneously align all edge features well. Projected model features may get stuck at the wrong image edge, preventing progress towards the correct pose.

[0043] Several approaches to mitigate this problem exist. One exemplary method is to use any of a number of discrete search schemes. Perturbing the pose estimate, either at the initial estimate, step **402**, or during refinement, step **412**, is one method that may increase the likelihood of finding the global minimum. These perturbations in pose estimate may be generated by explicitly perturbing the pose parameters. Alternatively, they may be generated in a data-driven fashion, as in RANSAC, wherein pose hypotheses are estimated from many randomly chosen subsets of the model features.

[0044] For video sequences, interframe registration may be used to yield constraints on relative poses of neighboring frames, which, in turn, may allow poses of a

collection of frames to be determined unambiguously. If a set of nearby frames collectively views a larger set of edges than any single frame, simultaneously exploiting image-to-model constraints in multiple frames may help to disambiguate pose. An exemplary embodiment of the present invention aligns the three dimensional model to a mosaic, virtual wide-angle image, from a virtual rigid rig of cameras. Suppose that a pose estimate has been predicted for one frame, but that this pose estimate is ambiguous due to a paucity of relevant model edges. For each of the remaining frames, interframe prediction may be used to obtain pose estimates. These pose estimates may then be treated as a virtual rigid rig of cameras. The total image-to-model error of the mosaic, virtual wide-angle image, created from these frames is then minimized. This method is particularly useful for scenes in which the features are relatively static.

[0045] Mismatched features may also occur because the attributes being measured are not sufficiently discriminating. For example, a projected model feature may be matched equally well to an image edge of equal length, an image edge of longer length, or a series of short image edges. Many different methods for matching image features tuned to scale and orientation are known in the art. One method that may be used is pyramid processing. Both the image and the model may be processed into a pyramid of resolution levels. As the estimated pose becomes more accurate (i.e. the matching errors decrease), the resolution level, and number of features retained, may be increased.

[0046] The matching errors may also be optimized with respect to the estimated pose via steepest descent. The natural representation of an infinitesimal change in the pose parameters as a translation and a cross product for small rotation, however, unweighted steepest descent tends to work slowly when the energy surface is highly anisotropic, and may get stuck in local minima. To solve this problem, the current pose estimate may be iteratively incremented by moving in the gradient direction in the space of an orthogonalized incremental pose parameter. In that space, a unit step in any direction causes the RMS change in line segment points of image features to be 1 pixel.

[0047] One of the properties that may be desirable for the matching errors is a degree of robustness against outliers. Desirably this robustness includes both poorly fitting lines and model clutter, i.e. a spurious model feature that has no true matching image feature. If the projected feature lies far from any image feature, it contributes little

to the calculation of the gradient of estimated pose. To reduce the chance that a projected model line segment, whether an artifact of model clutter or a valid feature, would be attracted to a falsely matching image feature, dissimilarly oriented model and image edges may be ignored by using an oriented energy image tuned to the angle of the model line.

[0048] Many different methods for generating a measure of local edge strength within an image tuned to scale and orientation are known. In an embodiment of the present invention, an oriented energy image including the oriented energy at a selected angle may be computed as follows. The source image is differentiated in the selected direction and smoothed in a perpendicular direction. The magnitude of the latter is smoothed in the selected direction. This method responds to both step edges and impulses. For computational efficiency, the orientation may be quantized to multiples of 45° and scaled to powers of 2, as in a pyramid.

[0049] Unfortunately, the robustness of this method may mean that, if the error in initial estimate of pose causes many model line segments to be projected far from their corresponding image features, the steepest descent may not move towards the true pose. An exemplary method to increase the capture range and speed convergence is to vary the scale of the energy image from coarse to fine resolution during the optimization process. The scale may desirably be tuned for each model line, commensurate with the expected amount of uncertainty in the location of predicted feature with respect to the actual corresponding image edge.

[0050] It has been found that the capture range of coarse-to-fine pose estimation may be reasonably large for low complexity images, and limited only by the presence of multiple local minima in matching errors when the image has lots of edges. Thus, it may be desirable to exploit interframe constraints to ensure stable tracking over a sequence, such as by using prediction to initialize estimated pose in the correct minimum basin, or by multiframe alignment. Intelligent selection of a subset of model features is also critical.

[0051] Also, the orientation tuning may be very broad in the oriented energy pyramid described above. The solution may be to add more discriminating feature attributes to the representation. The measure of the matching errors may be improved, for example, by using sharper orientation tuning.

[0052] Alternatively, in an outdoor site modeling application, the camera may only see a small part of the model at a time. Thus, there may be individual images that contain little texture or few model edges, so that matching features may be difficult and the pose may be undtermined. One method to overcome this difficulty is to combine several images to form a mosaic that is warped to the coordinate system of the current image. This composite image may be used in the algorithm, in place of the individual image, to determine the pose of the camera at the position of the current image.

[0053] The process of pose refinement shown in steps **406**, **408**, **410**, and **412** may be repeated until a set number of iterations have occurred, step **414**, or until the matching errors fall below a set criteria, step **416** (alternatively, the matching score, if used, may exceed a predetermined level).

[0054] Figure 5 is a flowchart illustrating an embodiment of the present invention to update a three dimensional model of a scene using an image of the scene with an unknown pose. This method begins with several steps that are similar to those described above with regard to Figure 4. As in the exemplary embodiments described with regard to Figure 4, the embodiment illustrating in Figure 5 begins with a three dimensional model of the scene, **500**. This starting model may be very rudimentary and limited in its scope. As images are aligned and information from these images used to update the model, the detail and range of the model may both be increased.

[0055] Still following the outline of Figure 4, the image is compared to the three dimensional model of the scene to generate an initial estimate of the pose, step **502**. A set of relevant features are selected from the three dimensional model based on this pose estimate, step **504**. The relevant features of the model are then projected and matched to features in the image to generate matching errors, step **506**. Next, the estimated pose is updated based on the matching errors, step **508**. Once again as previously described, the pose refinement process, shown in Figure 5 as steps **504**, **506**, and **508**, may be repeated until a set number of iterations have occurred, step **510**, or until the matching errors fall below a set criteria, step **512** (alternatively, if an embodiment employing a matching score is used, step **512** may query if the matching score exceeds a predetermined level). Step **514** determines whether the pose estimate indicates that the pose of the camera has changed so much from the initial pose in which the current relevant features were selected

that it may be desirable to reselect a new set of relevant model features to be used for continued pose refinement.

[0056] Once the pose estimate is completed, as evidenced by a '*yes*' answer to the query of either step **510** or step **512**, the data from the image is used to update the three dimensional model, step **516**. This update may include: the refinement of object placement within the scene; the additions of textural or fine structural detail to surfaces of objects; temporal updating of dynamic processes, such as changing illumination, or objects in motion; and the spatial extension of the scene being modeled. A number of methods to project image data onto a corresponding three dimensional model, such as a simple ray tracing method, are known in the art and may be used in step **516**. For many of these methods it is desirable to use two, or more, images simultaneously, particularly to assist with refining object placement and identifying objects in motion. Figure 6 is a perspective drawing illustrating a plane in the scene, **600**, and the poses of two images, **602** and **604**, of the scene, both of which include object **606**. Significant work has been done using the epipolar geometry shown in Figure 6 for image processing and mosaic construction. In this Figure, the epipole is shown as the line O – O'. The epipolar geometry of a scene may also be used to place constraints on the relative pose of images **602** and **604** even if the location of object **606** within the scene is not known. Additionally, plane plus parallax methods may be used to generate relative pose constraints between images. A detailed discussion of some of these methods is provided in U.S. Patent number 6,192,145, entitled "METHOD AND APPARATUS FOR THREE-DIMENSIONAL SCENE PROCESSING USING PARALLAX GEOMETRY OF PAIRS OF POINTS".

[0058] Figure 7 is a flowchart illustrating another exemplary embodiment of the present invention. This exemplary method is similar to that previously described with regard to Figure 5, but uses multiple images of the scene with unknown poses to update a three dimensional model of a scene. Although the exemplary method shown in Figure 7 only employs two images at a time, it is contemplated that three or more images may be simultaneously used in this embodiment. The images may be successive images from a moving source, or they may be concurrently generated images from multiple sources. The parallel paths in Figure 7, such as steps **702** and **704**, represent parallel processes,

which may occurs as multi-threaded tasks within the image processing hardware of the present invention. It may be desirable for these tasks to be performed concurrently by parallel processors to increase processing speed.

[0059] As in previously described embodiments of the present invention, this embodiment begins with a three dimension model of a scene, **700**, and the first and second images are compared to the three dimensional model of the scene, steps **702** and **704** respectively, to generate pose estimates. These pose estimates may be initial pose estimates, or may be refined as described in previous embodiments of the present invention. If the pose estimated are refined, it may be desirable for the matching error criteria to be less precise than in previous embodiments.

[0060] Next, the first and second image are compared to one another, step **706**, to generate constraints on the relative poses of the two images. A number of methods exist to generate relative pose constraints as described above with respect to Figure 6, such as optical flow, RANSAC, epipolar geometry calculations, and plane plus parallax. Relative pose constraints can also be generated due to the known motion of a single camera, or known spatial relationships between multiple cameras. The pose estimates are then updated to accommodate the relative pose constraints, step **708**. While it is often desirable to minimize the individual image to model mismatches when the pose estimates are being updated, this update should result in pose estimates that fit within the relative pose constraints generated in step **706**.

[0061] Next, sets of relevant features from the three dimensional model, corresponding to the first image and the second image, are selected based on the updated poses, steps **710** and **712** respectively. These sets of relevant features may be selected by any of the previously disclosed methods. The corresponding set of relevant features is next projected to the estimated pose of the first image, matched to the first image and first image matching errors are measured, step **714**. The same procedure is followed for the second image in step **716**.

[0062] The three dimensional model is updated using the matching errors from both images to improve the position estimate of objects within the model, step **718**. The matching errors are jointly minimized with respect to position estimate for both images to refine the placement of known objects in the scene model. Further iterations may be used

to improve the model refinement, and possibly the estimated camera poses as well. These iterations may start by once again estimating the image poses, steps **702** and **704**, or with the selection of sets of relevant model features, steps **710** and **712**.

[0063] The use of more than two images at a time may also increase the accuracy of object placement. To help overcome errors in estimating object placement when the estimates of camera pose are inaccurate, or vice versa, parameters may be estimated jointly in multiple frames, akin to bundle adjustment in structure from motion. For further stability, inconsistency of poses with respect to interframe alignments should also be penalized, e.g. uncertainties in the relative pose constraints of corresponding points in frame pairs may be used to weight the importance of matching errors for various images.

[0064] This is a 3D generalization of the method disclosed in U.S. Patent number 6,078,701, entitled "METHOD AND APPARATUS FOR PERFORMING LOCAL TO GLOBAL MULTI-FRAME ALIGNMENT TO CONSTRUCT MOSAIC IMAGES".

[0065] In addition, refinement of object placement may be extended to more general deformations by using an additional set of parameters to describe known sizes and relationships of parts of objects.

[0066] One possible use of the present invention is illustrated in Figures 8 and 9. This application of the present invention involves using current video from a camera mounted on a remote vehicle to locate the vehicle relative to objects in a three dimensional model. An additional application for the present invention may be to extend and refine a three dimensional model of an area as the area is explored by the remote vehicle possibly beyond the range of the scene originally covered by the model. Numerous applications in robotics exist for such methods. These methods may be particularly useful for the exploration of places in which other location techniques, such as GPS, are not practical, including underground, deep-sea, and interplanetary exploration.

[0067] Figure 8 is a top plan drawing of remote vehicle **800**, with mounted camera **802**, viewing the scene from Figure 1. In this exemplary sketch, the camera is turned so that at least a portion of each object in the scene, cube **102**, star prism **104**, and cylinder **106**, is visible (shown as surfaces **804**). Although both the remote vehicle and the camera may be independently moveable, the position and angular orientation of camera **802** relative to remote vehicle **800** are assumed to be known, or at least measurable.

[0068] Figure 9 is a flowchart illustrating an exemplary embodiment of the present invention to accurately estimate the position of a remote vehicle within a scene using a three dimensional model of the scene and an image of the scene. As previously described, the method begins with a three dimension model and an image from a camera having an orientation relative to the remote vehicle, **900** that can be determined. The next seven steps, **902**, **904**, **906**, **908**, **910**, **912**, and **914**, involve estimating and refining the camera pose with respect to the three dimensional model. These steps are the same as steps **502**, **504**, **506**, **508**, **510**, **512**, and **514** in the flowchart of Figure 5.

[0069] Once the pose of the camera mounted on the vehicle has been accurately estimated with respect to the scene, the position and orientation of the remote vehicle relative to the scene in the three dimensional model may be determined, step **916**. Because the mounted camera may be adjusted to rotate, tilt or zoom, parameters controlling these functions may need to be examined to determine the orientation of the camera relative to the remote vehicle.

[0070] The pose of the camera may be used independently of the position and orientation of the vehicle to update the model. At step **918**, the three dimensional model is updated based on data from the image and its estimated pose, step **918**, similarly to step **516** in Figure 5. Finally, the camera orientation, and possibly its position, relative to the remote vehicle are determined, step **920** to fix the position of the vehicle. The process begins again at step **902** when another image is taken.

[0071] In addition to the large-scale model refinement of object placement previously discussed with regard to Figure 7, an exemplary embodiment of the present invention may be used for detailed refinement of a three dimensional model, including definition of local surface shape and texture. The true shape of the surfaces in the scene may differ from the planar surfaces given by the given polyhedral model, even after refinement of object placement. For example, between the time of model construction and acquisition of the current video, the existing objects may have changed, and objects may be added or deleted. Some scene objects, especially natural objects like trees, may be absent from the model, or unsatisfactorily represented, because they are hard to represent using simple polyhedra. This can be clearly seen for the polyhedral model of cylinder **106** in Figure 2.

[0072] In another exemplary embodiment of the present invention, an untextured model, such as the previous mentioned polyhedral model, may be populated with pixels from a series of images of the scene, such as video sequences, using the estimated camera poses and corresponding estimated object placements. The brightness of an object in the scene may be approximated as being constant, independent of the viewpoint, and each surface pixel may be assigned a color value that is most typical of all the given images.

[0073] As part of this embodiment polygonal surfaces of a polyhedral three-dimensional model may be separated into approximately equally sized portions. This may allow for better mapping of surface detail from a series of images onto the model, particularly for surfaces that are only partially visible in some of the images. Figure 10 shows a perspective drawing of surface **200**, from Figure 2, which has been separated into approximately equal sized portions **1000**. Surface detail **1002** for one portion, which may be added to the polyhedral model, is also shown. By adding surface detail to a polyhedral model of the scene in this manner, a hybrid three-dimensional model of the scene may be created.

[0074] Figure 11 is a flowchart illustrating an exemplary embodiment of the present invention to create such a hybrid three dimensional model of a scene using a series of images of the scene. The first step is to create a polyhedral model the scene, step **1100**. The polyhedral model desirably includes a plurality of polygonal surfaces, which are larger than a predetermined size for surface portions. Any standard technique for creating the model may be used. The rough shape and placement of objects in the polyhedral model may be refined according to the techniques of either of the flowcharts in Figures 5 and 7 using previous, possibly low resolution, images of the scene and/or the series of images to be employed for adding surface detail to the model. It is also important to determine the camera poses of the series of images. The poses may be known, or may be determined by one of the methods described above.

[0076] Next a polygonal face is selected from the polyhedral model for determination of surface details, step **1102**. The selection may be predetermined to sweep the analysis from one side of the model to its opposite side, or it may be based on a determination of scene areas in the images where the modeled shape appears to differ significantly from the existing model. The latter selection method is most useful when

refinement of surface details is desirably to be performed only in those areas of the model that deviate from the images by an amount greater than a certain threshold.

[0077] At this point, it may be desirable to estimate and represent a refined surface shape as a height map associated with the selected planar surface. Given the previously determined camera poses, these height maps may be estimated by dense 3D estimation techniques from two or more observed images. The outcome of this process is a hybrid shape representation that augments the polyhedral model with local shape variation.

[0078] Several relevant techniques are previously disclosed: U.S. Patent number 5,963,664, entitled "METHOD AND SYSTEM FOR IMAGE COMBINATION USING A PARALLAX BASED TECHNIQUE", U.S. Patent number 5,259,040, entitled "METHOD FOR DETERMINING SENSOR MOTION AND SCENE STRUCTURE AND IMAGE PROCESSING SYSTEM THEREFOR", and U.S. Patent Application number 09/384118, entitled "METHOD AND APPARATUS FOR PROCESSING IMAGES". First, a batch of images is co-registered using the previously determined poses and shape model. Next, using change detection, regions are segmented out where the image alignment is consistently incorrect. In the detected change regions, the residual misalignment may be estimated, i.e. flow constrained along the epipolar lines. By progressing from coarse to fine image scale, such an estimation algorithm can handle a large amount of parallax, which may occur in areas of significant discrepancy between the given shape model and the actual 3D structure of the scene. Finally, the last step is to convert the resulting parallax magnitude to metric height.

[0079] In the cited patents and applications, it is recommended to sum up the image intensity errors over all pixels, between each inspection frame and a single designated reference frame. However, if the batch contains frames taken from widely disparate viewpoints, the appearance change may be large even if well aligned. Therefore, it may be desirable to sum up intensity errors only between adjacent images, or consecutive frames, if the series of images are a video sequence. A larger subset of images, or frames, may also be used, but it is often desirable for this subset to be selected to have viewpoints within a predetermined range.

[0080] If the batch of images used in the foregoing computation covers a sufficiently large range of views, the estimated shape may be very accurate; however,

occlusion and deocclusion areas cannot be well represented using a depth map with respect to one reference view. In practice, a smaller batch of images may produce a shape estimate good enough to align and synthesize viewpoints in the vicinity of the source data. It is contemplated that an alternative may be to use the parallax estimation methods to independently estimate and represent shape within a series of overlapping batches of images, each with its own reference view. Each such estimate would be stored in a hybrid scene representation consisting of a polyhedral model plus view-dependent local shape variations.

[0081] Whether a height map of the local surface shape has been constructed or not, a separate texture map is next constructed for each polyhedral face in the model. The local height map may assist in this construction, but is not a necessary step. The first step of this process, step **1104** in Figure 11, is to separate the selected polygonal surface into portions of approximately the predetermined size for surface portions. This predetermined size may be as small as a single element within the model, or it may be as large as the entire polygonal surface. Next one of these portions is selected, step **1106**. Z-buffering may be used to detect and discard those images which are occluded by some other face, leaving a subset of images which contain the selected surface portion, step **1108**.

[0082] To determine the color value for a portion X on the surface, X is mapped to every image in the subset, using object placement parameters for the surface, camera pose parameters and, if available, the previously estimated height maps. One method, possibly the simplest, is to combine the color values from the pixels in the subset of images corresponding to X. This may be done by averaging the color values, blending the color values or performing another mathematical function on the color values of the various images in the subset.

[0083] These methods of combining the color values ignore the possibly unequal quality of the images. The highest resolution, and most frontal view, of the face gives the most information about the surface appearance. Image resolution (e.g. in pixels/meter) can be assessed by the smaller singular value, μ, of the Jacobian dU_i/dX_l, where X_l is measured in a 2D face-aligned coordinate system and U_i is the position in the ith image

corresponding to X. Thus, the image having the maximum value of μ may be selected at step **1110**, and its color value(s) projected from pixel(s) U_i to portion X, step **1112**.

[0084] The color and brightness at corresponding points in different images may not be identical, due to camera gain variations and non-Lambertian surface materials. Abruptly switching between different source images while computing the appearance of a single face may cause seams to appear in the texture map. Accordingly, it may be desirable to use pixel values from a single image to map texture onto a given surface of the model, if possible.

[0085] Alternatively, once it has been determined that all of the portions of a given surface have been mapped, step **1114**, any artifacts caused by using multiple images to generate the texture maps of the portions of a single surface may be mitigated through multi-resolution blending of the portions, step **1116**, as taught in U.S. Patent number 6,075,905, entitled "METHOD AND APPARATUS FOR MOSAIC IMAGE CONSTRUCTION". This step may also be employed when a single image is used to map texture onto all of the portions of a given surface of the model.

[0086] The foregoing method to create a surface texture map of a hybrid three dimensional model may be used whether the scene is initially modeled by planar faces alone or by a model of planar faces plus shape variations. In the generalized representation using view-dependent local shape, texture may be recovered for each local reference view. The result would be a 3D-scene model with view-dependent shape and texture.

[0087] One exemplary method to synthesize a new image from a novel viewpoint may be to interpolate the shape and texture of two or more nearby reference views closest to the desired viewpoint, according to the teachings of U.S. Patent Application number 08/917402, entitled "METHOD AND SYSTEM FOR RENDERING AND COMBINING IMAGES TO FORM A SYNTHESIZED VIEW OF A SCENE CONTAINING IMAGE INFORMATION FROM A SECOND IMAGE".

[0088] Figure 12 is a perspective drawing of a scene, **1200**, illustrating an exemplary video flashlights method of the present invention, which may be employed to synthesize an image from a novel viewpoint using a dynamic three dimensional model, such as those previously described with regard to the flowcharts of Figures 5, 7, and 11.

The exemplary scene, **1200**, is being filmed by video cameras **1202**, which may be in motion. At any given time, images from these cameras contain only a portion of the scene, **1204**.

[0089] It has been previously demonstrated that current video images of a semi-urban environment can be aligned in near real-time to site models. The textured models can then be rendered using graphics pipeline processors. A visual metaphor for this process of combining models with videos is that of video flashlights '*illuminating*' portions **1204** of the model. The multiple camera views at a given time instant may be considered as video flashlights capturing the appearance of the scene from their respective viewpoints. The multiple appearances are coherently combined with the model to provide multiple users the ability to navigate through the environment while viewing the current appearance as derived from the video flashlights.

[0090] Figure 13 is a flowchart illustrating an exemplary embodiment of the present invention to create virtual images of a scene and a dynamic three-dimensional model of the scene using this video flashlight method.

[0091] This exemplary method involves two concurrent processes. Both of these processes start from a preexisting three dimensional model of the scene, **1300**. The first of these processes, updating the model using the incoming video data, is exemplified in Figure 13 as steps **1302**, **1304**, **1306** and **1308**. Any of the methods previously described above for updating a three dimensional model may be used. This dynamic updating process is continuous, so that the model may contain the most currently available data.

[0092] The second process is the creation of output image sequence(s) based on the dynamic three-dimensional model. This process involves the selection of a virtual viewpoint, step **1310**, and projection of the current model onto the selected viewpoint, step **1312**. The viewpoint selection may be controlled manually, set to track a feature, or object, in the model, or may follow a predetermined pattern. Projection of a three dimensional model to form an image as seen from selected point may be performed by a number of well known methods, such as Z-buffering.

[0093] Surveillance provides one possible application of this embodiment of the present invention. In a surveillance application using simultaneously deployed moving cameras, it may be difficult for a human operator to fuse and interpret real-time video

streams displayed on separate viewing screens. The relationship of the streams to the larger environment is not evident from the images, which may be unstable and narrow in field of view. Ideally, a visualization should portray the world as if the user were actually looking at the live scene, decoupled from the paths of the cameras that are collecting the imagery.

[0094] An exemplary embodiment of the present invention registers all video frames to the model so that images from several cameras at the same time instant can be projected onto the model, like flashlights illuminating the scene, which may then be rendered for any user-selected viewpoint. In this context of the scene model, it may become easy to interpret the imagery and the dynamic events taking place in all streams at once.

[0095] It is contemplated that the three dimensional model may be constructed to be devoid of moving objects and/or objects that are difficult to model onto polyhedra. These objects may appear in the video flashlights. In a virtual imaging system of this design, it may be desirable to make control of the video flashlight(s) responsive to movement of the virtual viewpoint(s).

[0096] Additionally, it is contemplated that the methods previously described may be carried out within a general purpose computer system instructed to perform these functions by means of a computer-readable medium. Such computer-readable media include; integrated circuits, magnetic and optical storage media, as well as audio-frequency, radio frequency, and optical carrier waves.

[0097] The embodiments of the present invention have been described with regard to polyhedral and hybrid three-dimensional models since they are appropriate for urban scenes dominated by planar structures, a present domain of application. Also, this format is well supported by software tools and graphics hardware. It is understood that those skilled in the art may find it advantageous to use other three dimensional models with these methods. Such use does not depart from the scope of the present invention. In the same vein, it will be understood by those skilled in the art that many modifications and variations may be made to the foregoing preferred embodiment without substantially altering the invention.

What is Claimed:

1. A method for accurately estimating a pose of a camera within a scene using a three dimension model of the scene, comprising the steps of:

(a) generating an initial estimate of the pose;

(b) selecting a set of relevant features of the three dimensional model based on the initial estimate of the pose;

(c) creating a virtual projection of the set of relevant features responsive to the initial estimate of the pose;

(d) matching a plurality of features of an image received from the camera to the virtual projection of the set of relevant features and measuring a plurality of matching errors; and

(e) updating the estimate of the pose to reduce the plurality of matching errors.

2. A method for accurately estimating a pose of an image of a scene using a three dimension model of the scene, comprising the steps of:

(a) performing a pyramid decomposition of the image to generate a set of pyramid levels of the image;

(b) selecting one pyramid level from the set of pyramid levels;

(c) generating an estimate of the pose using the selected pyramid level;

(d) selecting a set of relevant features of the three dimensional model based on the estimate of the pose;

(e) creating a virtual projection of the set of relevant features responsive to the estimate of the pose;

(f) matching a plurality of features of the selected pyramid level to the virtual projection of the set of relevant features and measuring a plurality of matching errors;

(g) updating the estimate of the pose to reduce the plurality of matching errors; and

(h) repeating to steps (e), (f), and (g) using the updated estimate of the pose until the plurality of matching errors are less

than predetermined matching criteria which is responsive to the selected pyramid level.

3. A method for refining a three dimensional model of a scene using an image of the scene taken by a camera having an unknown pose, comprising the steps of:

(a) comparing the image to the three dimension model of the scene to generate an estimate of the pose; and

(b) updating the three dimensional model of the scene based on data from the image and the estimate of the pose.

4. A method for accurately estimating a position of remote vehicle using a three dimension model and an image from a camera having a known orientation relative to the remote vehicle, comprising the steps of:

(a) comparing the image to the three dimension model of the scene to generate an estimate of the pose;

(b) selecting a set of relevant features of the three dimensional model based on the estimate of the pose;

(c) matching a plurality of features of the image to the set of relevant features and measuring a plurality of matching errors;

(d) updating the estimate of the pose based on the plurality of matching errors; and

(e) determining the position of the remote vehicle based on the estimate of the pose and the orientation of the camera.

5. A method for refining a three dimension model of a scene containing an object using a plurality of images of the scene, each image including the object, comprising the steps of:

(a) comparing a first image of the plurality of images to the three dimension model of the scene to generate an estimate of a first viewpoint corresponding to the first image;

(b) comparing a second image of the plurality of images to the three dimension model of the scene to generate an estimate of a second viewpoint corresponding to the second image;

(c) selecting a first set of relevant features of the three dimensional model based on the first viewpoint;

(d) matching a plurality of first features of the first image to the first set of relevant features and measuring a plurality of first matching errors;

(e) selecting a second set of relevant features of the three dimensional model based on the second viewpoint;

(f) matching a plurality of second features of the second image to the second set of relevant features and measuring a plurality of second matching errors; and

(g) updating a position estimate of the object within the three dimensional model of the scene based on the plurality of first matching errors and the plurality of second matching errors.

6. A method for refining a three dimension model of a scene containing an object using a plurality of images of the scene, each image including the object, comprising the steps of:

(a) selecting a subset of images from the plurality of images of the scene, the subset of frames containing at least two of the images;

(b) determining a plurality of approximate relative viewpoints of the subset of images;

(c) comparing each image in the subset of images to the three dimensional model to generate a subset of estimated viewpoints corresponding to the subset of images, the subset of estimated viewpoints constrained by the plurality of approximate relative viewpoints;

(d) selecting a set of relevant features of the three dimensional model corresponding to each estimated viewpoint;

(e) matching a plurality of features of the each image in the subset of images to the corresponding set of relevant features and measuring a plurality of matching errors; and

(f) updating a position estimate of the object within the three dimensional model of the scene based on the plurality of matching errors.

7. A method for creating a hybrid three dimension model of a scene using a plurality of images of the scene, comprising the steps of:

(a) creating a polyhedral model the scene including at least one polygonal surface;

(b) determining a first set of images containing at least a section of a first polygonal surface; and

(c) comparing a plurality of images selected from the first set of images to generate a local surface shape map corresponding to the first polygonal surface.

8. A method for creating a textured three dimension model of a scene using a plurality of images of the scene, comprising the steps of:

(a) creating a polyhedral model the scene including at least one polygonal surface;

(b) identifying at least one portion of the one polygonal surface;

(c) determining a first subset of images containing the at least one portion of the one polygonal surface;

(d) selecting at least one selected image of the first subset of images;

(e) projecting a corresponding section of each of the at least one selected image onto the at least one portion of the one polygonal surface of the textured three dimension model as a local color map;

(f) repeating steps (c), (d), and (e) for each remaining portion of the one polygonal surface of the polyhedral model

9. A method for creating a dynamic sequence of virtual images of a scene using a dynamically updated three dimension model of the scene, comprising the steps of:

(a) updating the three dimension model using a video sequence of images of the scene including the steps of;

(a1) determining a present viewpoint of a present image of the video sequence of images;

(a2) determining a relevant portion of the three dimensional model corresponding to the present image of the video sequence of images;

(a3) updating the relevant portion of the three dimensional model by projecting the present image onto the relevant portion of the three dimension model;

(b) selecting a first virtual viewpoint of a first virtual image of the dynamic sequence of virtual images;

(c) creating the first virtual image by projecting the dynamic three dimensional model onto the first virtual viewpoint; and

(d) repeating steps (b) and (c) for each remaining virtual image of the dynamic sequence of virtual images.

10. A computer readable medium adapted to instruct a general purpose computer to update a three dimensional model of a scene using the three dimensional model of the scene, an image received from a camera having an unknown pose, the method comprising the steps of:

(a) generating an estimate of the pose;

(b) selecting a set of relevant features of the three dimensional model based on the estimate of the pose;

(c) creating a virtual projection of the set of relevant features responsive to the estimate of the pose;

(d) matching a plurality of features of an image received from the camera to the virtual projection of the set of relevant features and measuring a plurality of matching errors;

(e) updating the estimate of the pose to reduce the plurality of matching errors; and

(f) updating the three dimensional model of the scene based on data from the image and the estimate of the pose.

11. An automatic three-dimensional model updating apparatus for accurately estimating a point of view of an image of a scene, relative to a three-dimensional model of the scene, and updating the three-dimensional model comprising:

(a) estimating means for providing an estimate of the point of view of the image;

(b) relevant feature selecting means for selecting a set of relevant features of the three dimensional model based on the estimate of the point of view;

(c) virtual projection means for creating a virtual projection of the set of relevant features responsive to the estimate of the point of view;

(d) matching means for matching a plurality of features of the image to the virtual projection of the set of relevant features;

(e) measurement means for measuring a plurality of matching errors;

(f) point of view refinement means for updating the estimate of the point of view to reduce the plurality of matching errors; and

(g) model refinement means, responsive to the estimated point of view and to the image, for updating the three-dimensional model.

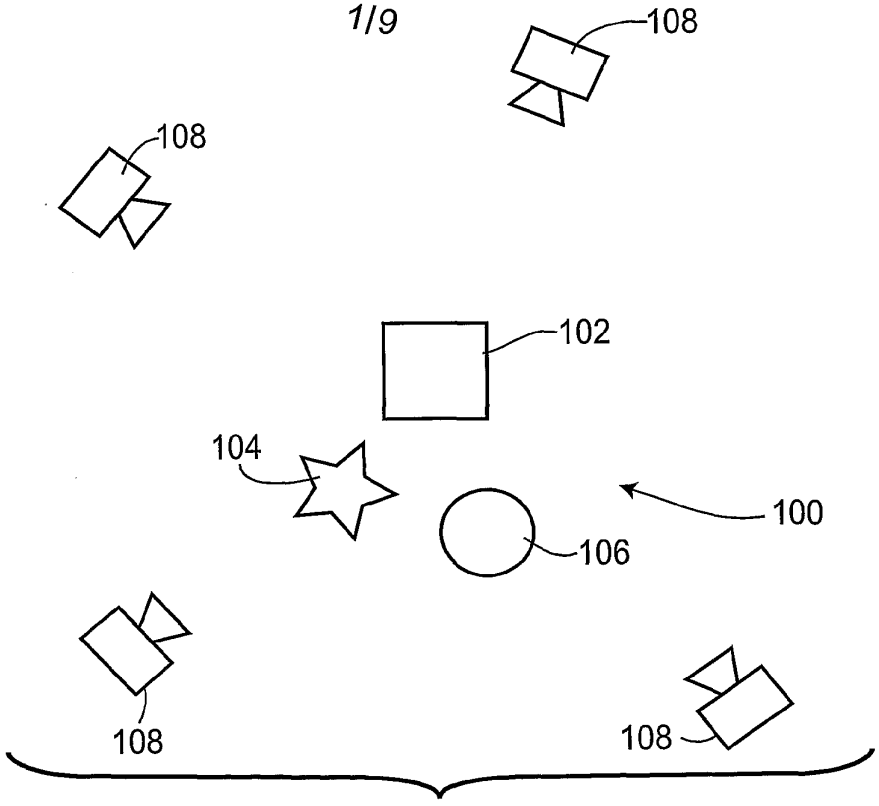


FIG. 1

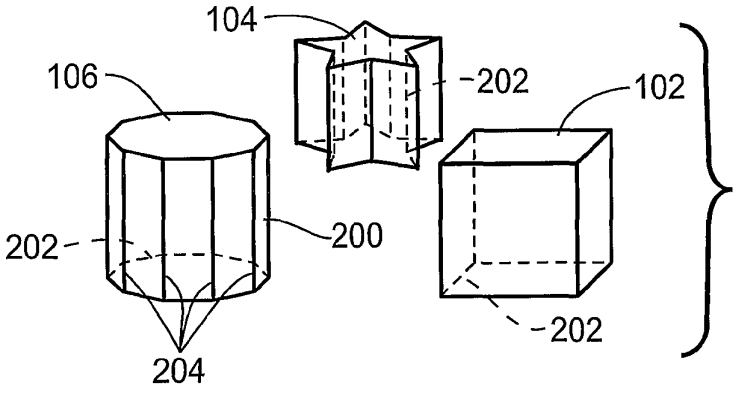


FIG. 2

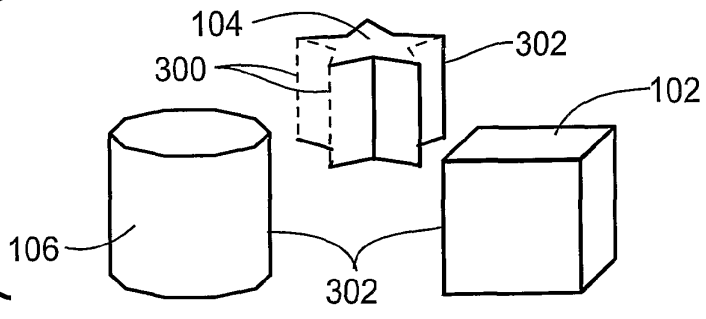


FIG. 3

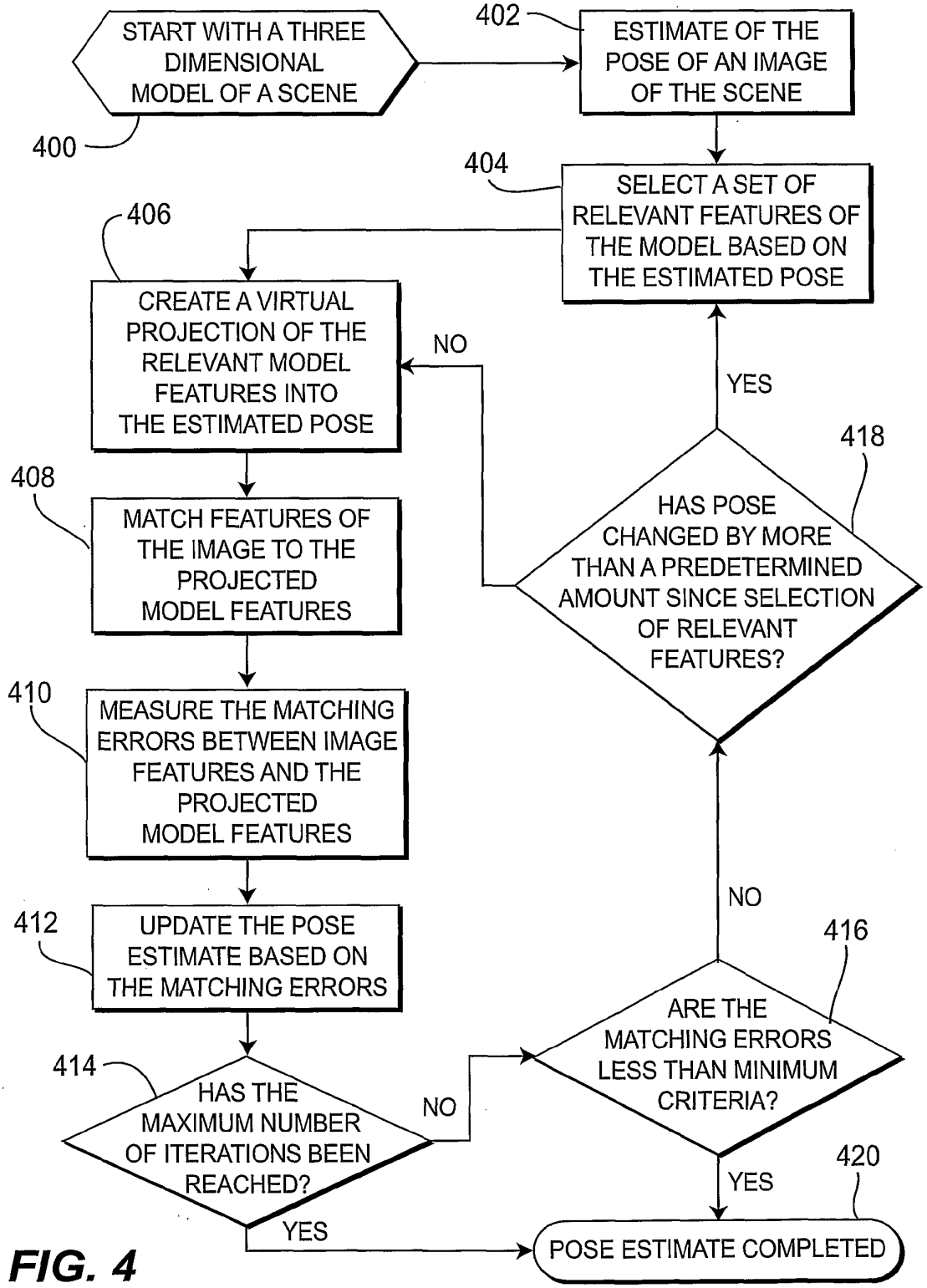


FIG. 4

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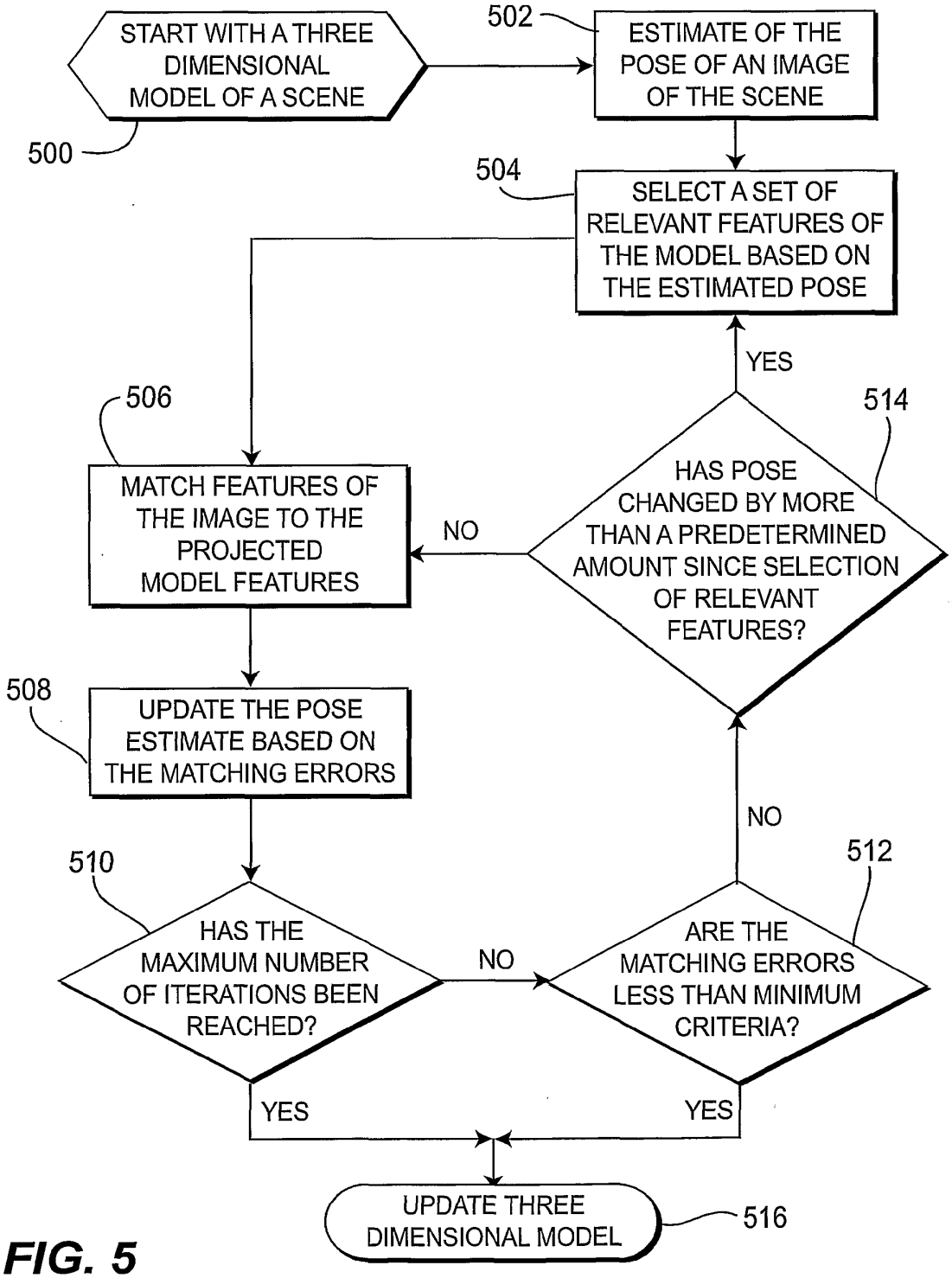


FIG. 5

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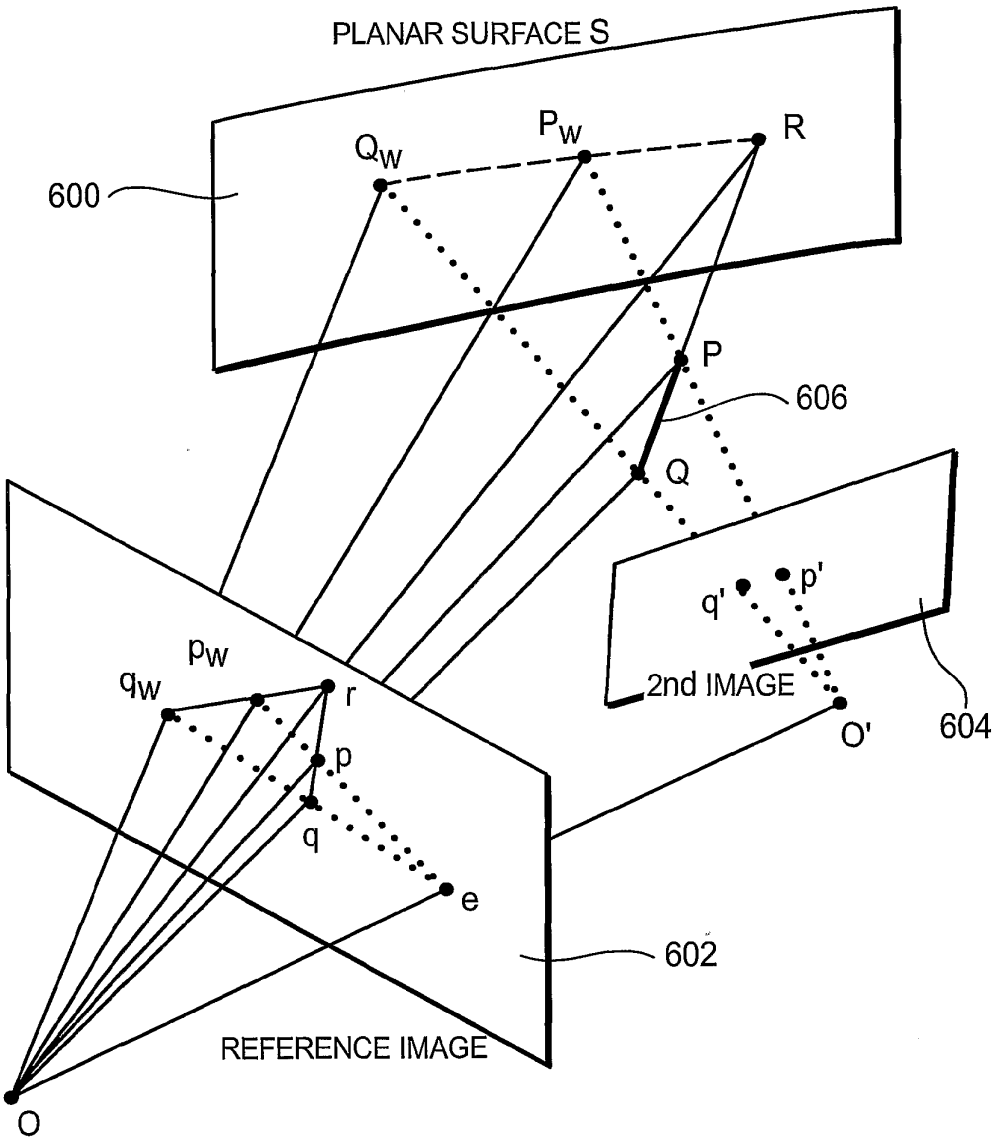

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FIG. 6

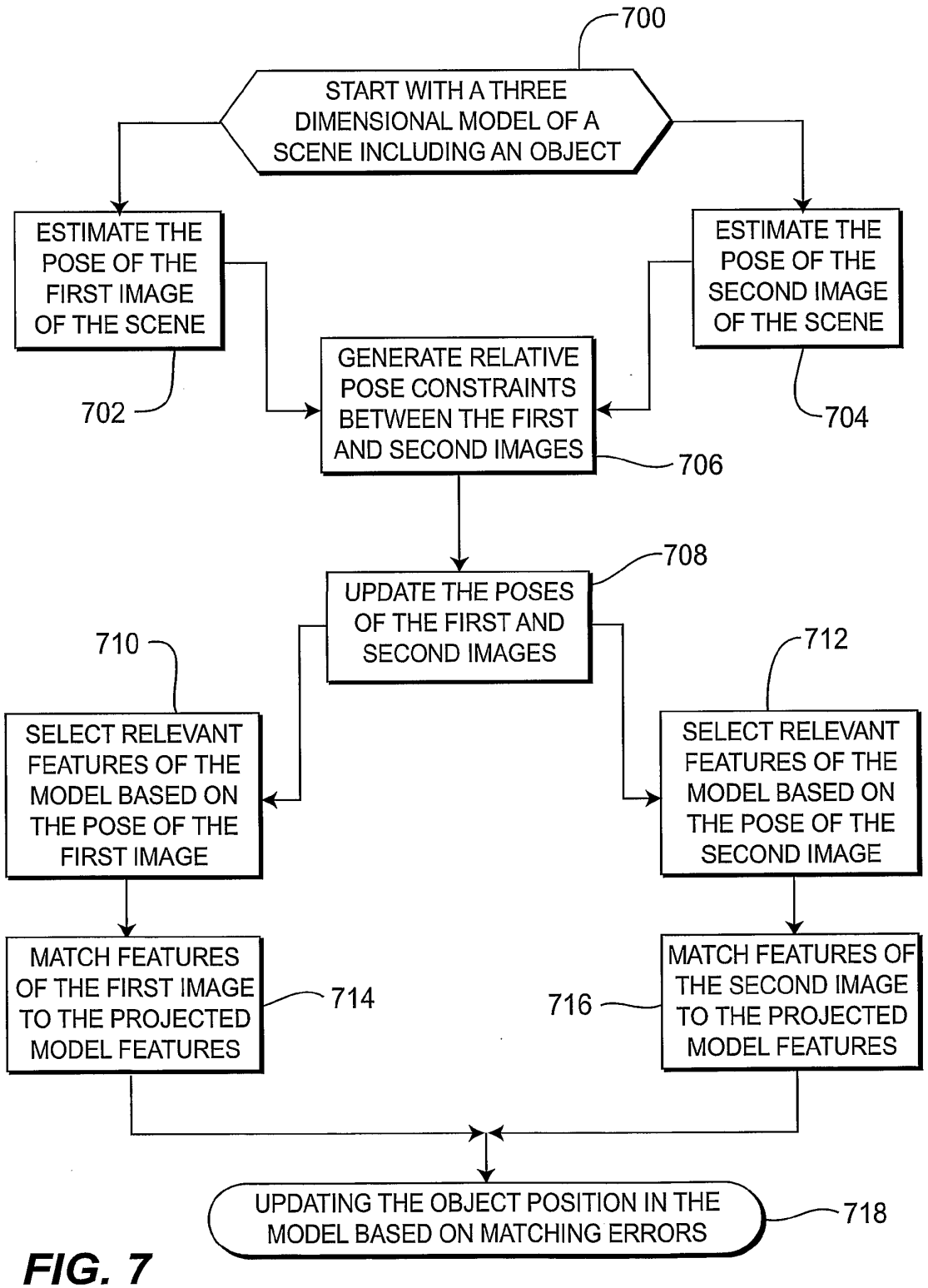


FIG. 7

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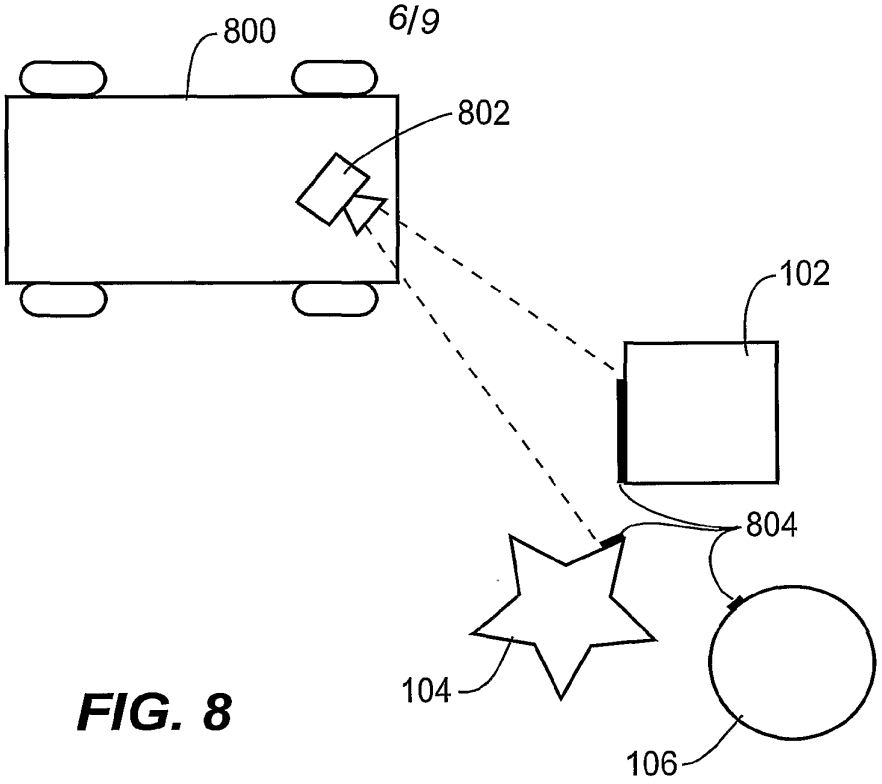


FIG. 8

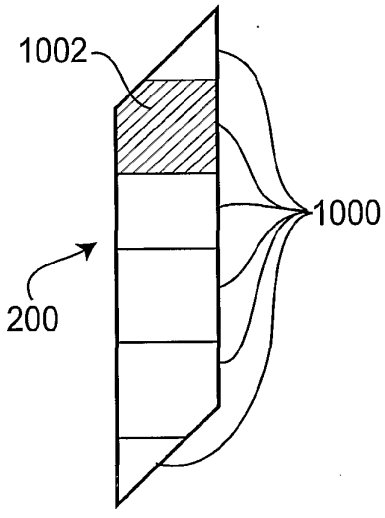


FIG. 10

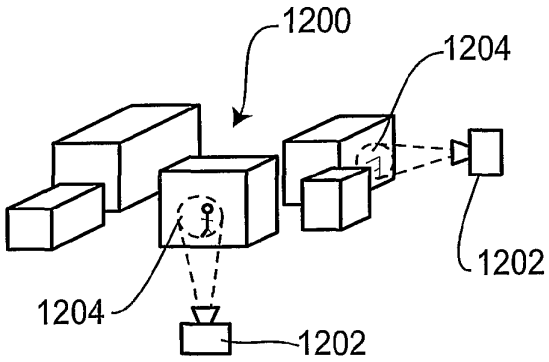


FIG. 12

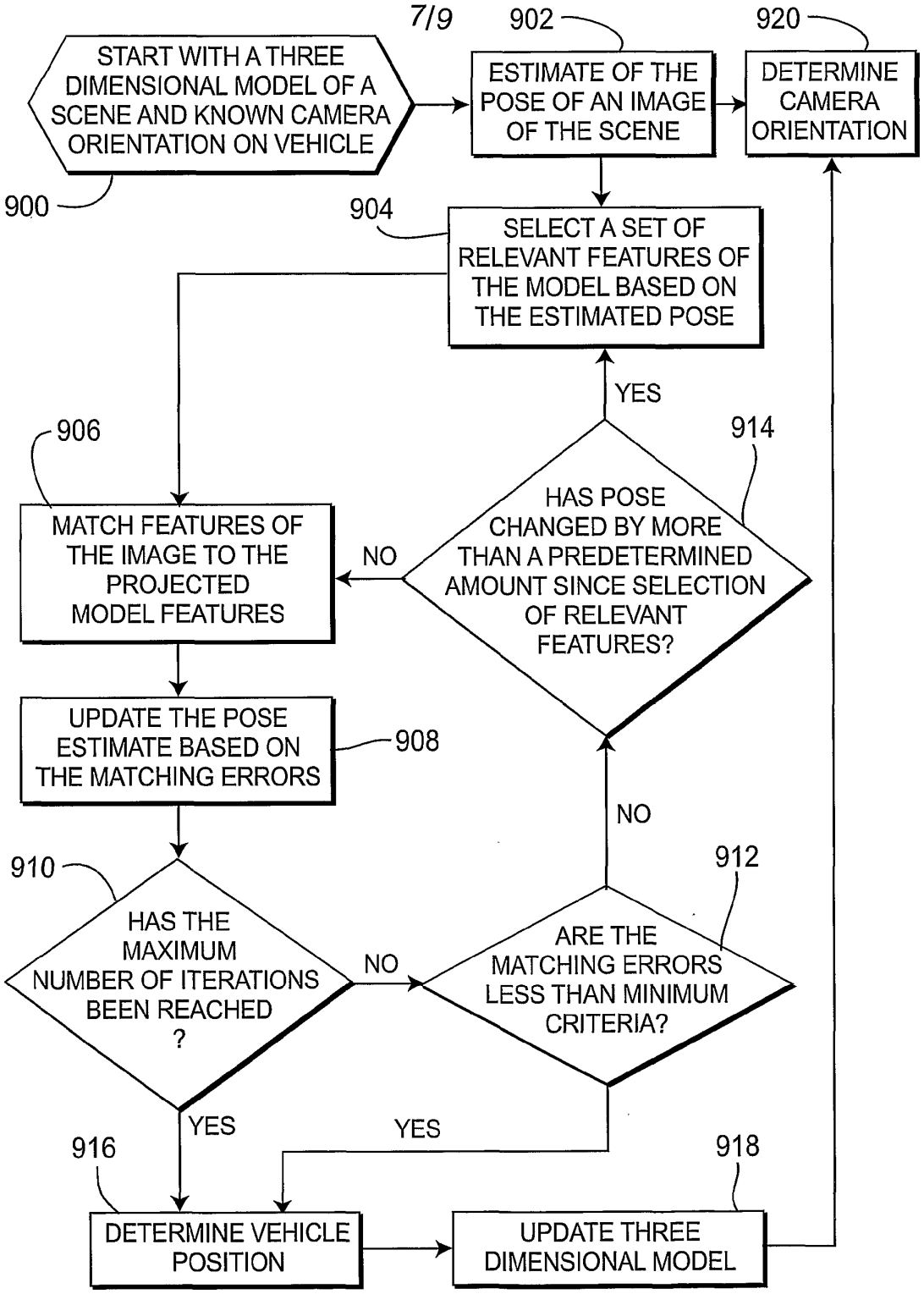


FIG. 9

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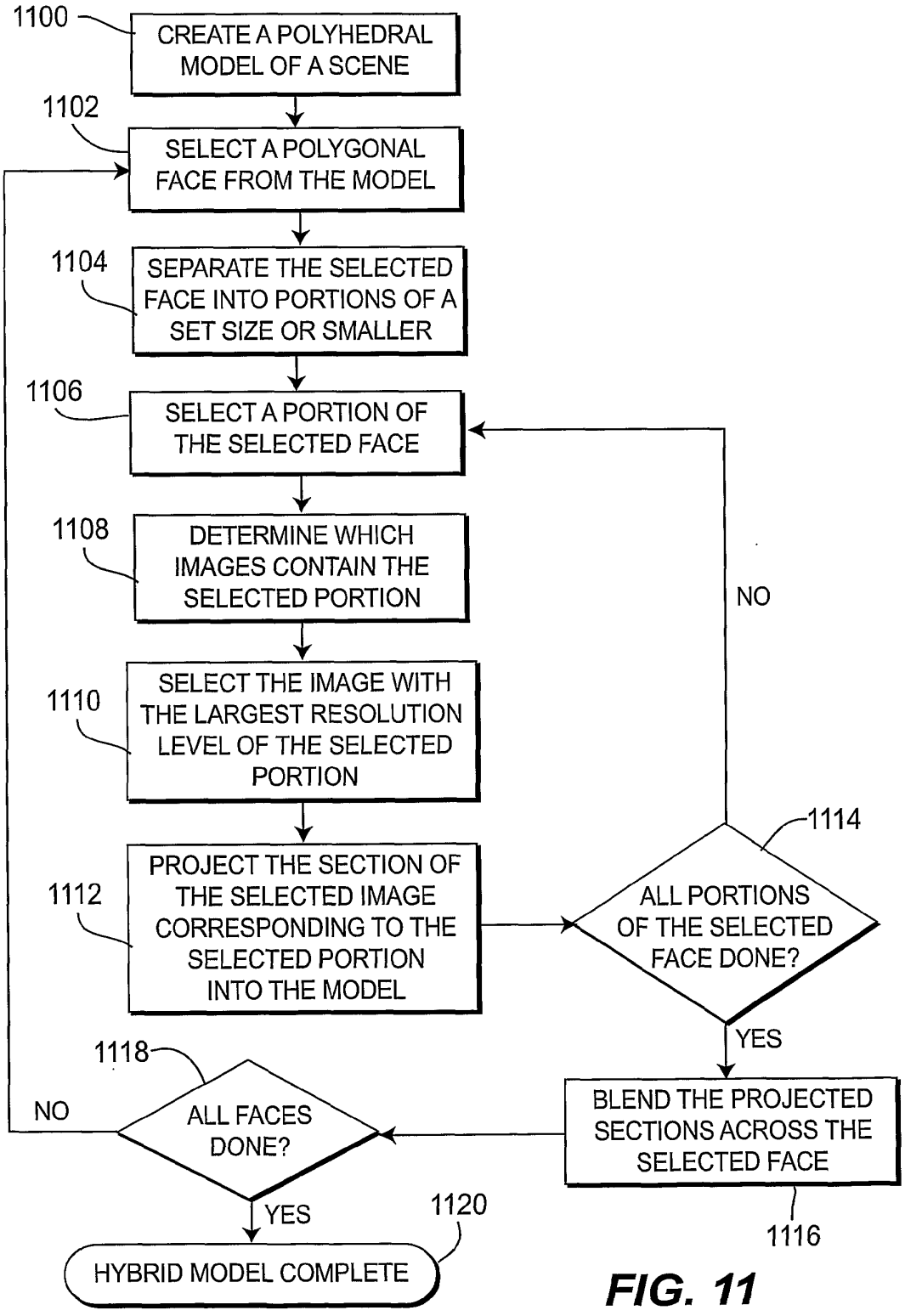


FIG. 11

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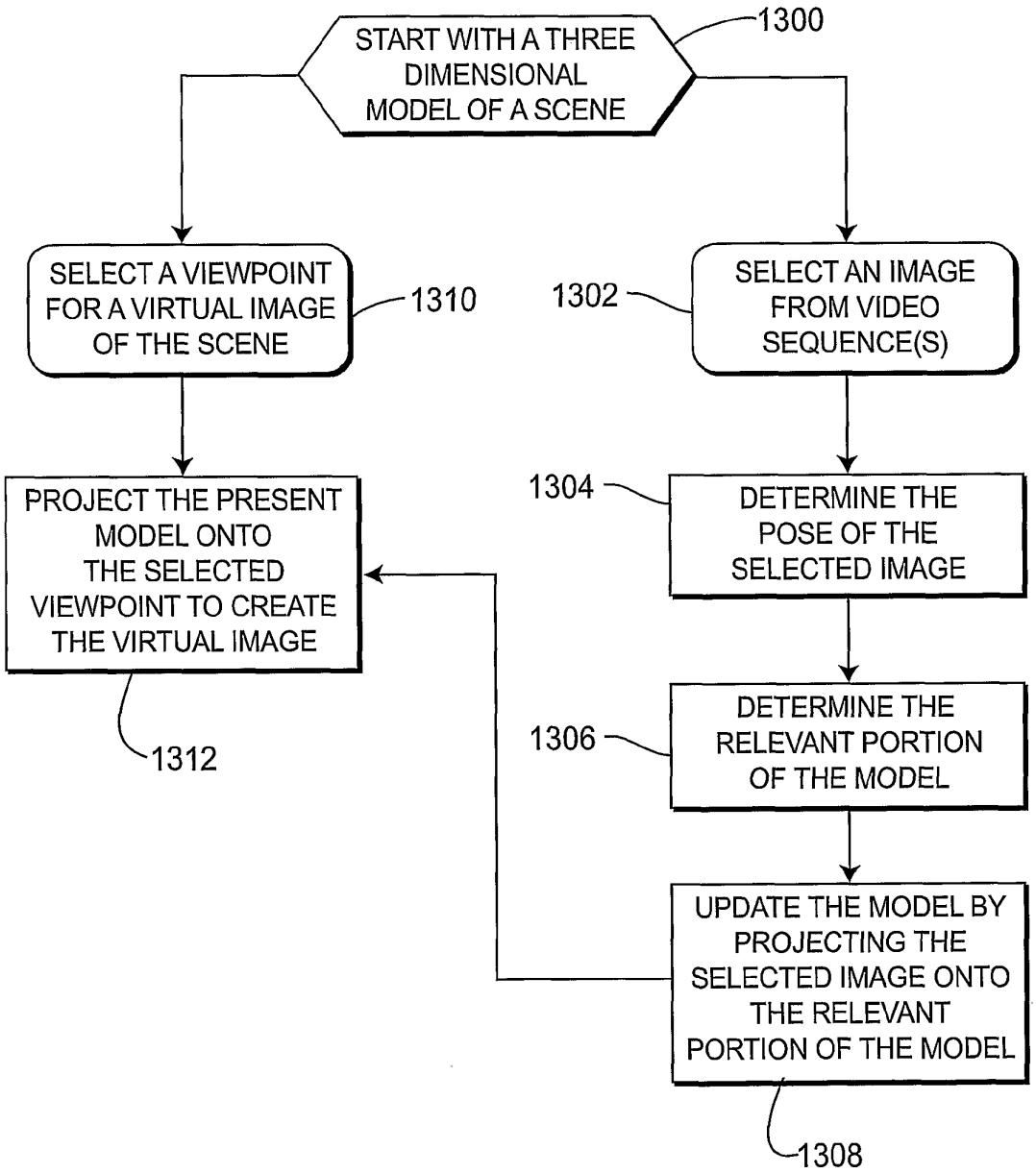


FIG. 13

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Declarations under Rule 4.17:

— *as to the identity of the inventor (Rule 4.17(i))*

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *of inventorship (Rule 4.17(iv))*

[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR OFFBOARD NAVIGATION OF A ROBOTIC DEVICE

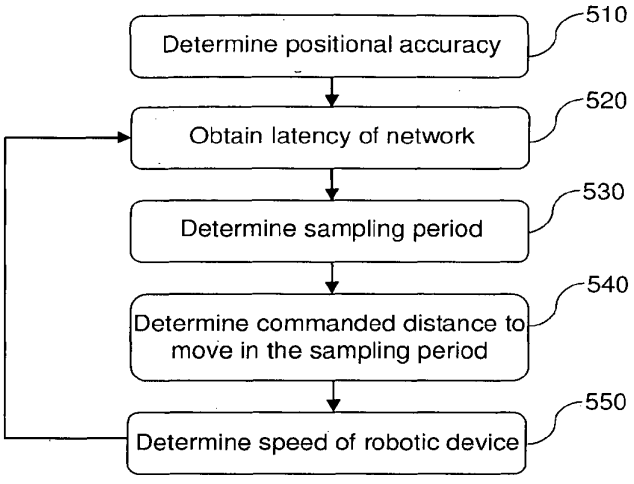


Fig. 5

(57) Abstract: There is provided a method and apparatus for offboard navigation of a 5 robotic device. The method comprising defining a threshold value of a positional accuracy of the robotic device, calculating latency of a network through which the robotic device and a server communicate, the latency of the network being a difference between sending sensor data from the robotic device to the server and receiving processed data corresponding to the 10 sent sensor data by the robotic device from the server, and determining speed of the robotic device based on the threshold value of the positional accuracy of the robotic device and the latency of the network.

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METHOD AND APPARATUS FOR OFFBOARD NAVIGATION OF A ROBOTIC DEVICE

Field of the Invention

The present invention relates to offboard navigation of a robotic device, and particularly, relates to adaptive offboard navigation that responds to changes in network conditions.

Background

Autonomous navigation is a key enabler for the widespread use of robotic devices in the consumer market and industry. These robotic devices move around a place to perform tasks relying on sensors and navigation systems without any human direction.

However, to achieve such navigation with a satisfactory level of accuracy is costly as it is computationally intensive and demanding in terms of processing load and power required to provide navigation commands in real time. Traditionally, navigation systems are provided on the robotic devices so that the robotics devices are capable of working independently by performing all navigation processing onboard. Thus, there is a trend to use more powerful computers and bigger batteries onboard. However, this approach results in higher costs. Besides the increase in cost, another disadvantage of this approach is the increase in the size of the robotic devices which may make these robotic devices unsuitable for applications where the size is one of the main concerns.

While existing Autonomous Guided Vehicles (AGVs) used in many industries are simpler, extensive, expensive and inflexible modifications to the building infrastructure are required for these vehicles to work. For example, one type of the AGVs has to follow markers or wires installed in the floor when navigating a place.

Another approach is to couple the robotic devices to a remote server via a communication link and harness the processing power of the server. The remote server may be, for example, a cloud-computing platform, and the communication link may be a wireless network. Thus, the navigation processing may be performed offboard entirely at the remote server, or be split into a mixture of onboard and offboard processing. As the majority of the computation can be allocated to the remote server or distributed among a group of remote servers equipped with powerful processors, minimum processing can be performed at the robotic devices adopting offboard navigation. Examples of the minimum processing at the robotic devices include transmitting sensor data obtained by the sensors

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of the robotic devices to the server and receiving navigation command and/or positional information from the remote sensor.

This approach addresses the cost and size issues, but it is subject to actual network conditions as there is always a delay in transmitting and receiving signals between the robotic devices and the remote server which affects the positional accuracy of the robotic devices.

Fig. 1 shows an ideal situation of the offboard navigation in which no latency of the network L exists (L=0). A robotic device 100 sends the sensor data obtained by its sensors to a server 110 via a wireless network at successive timings t_0, t_1, t_2... The sensor data is processed by the server 110 which calculates the actual position of the robotic device 100 and then sends this positional information or navigation command such as the distance and the direction to move, to the robotic device 100. Thus, the robotic device 100 is commanded to move based on its actual position and the destination or planned route. In the ideal situation where there is no latency of the network (similar to onboard navigation) the robotic device 100 receives the positional information or navigation command nearly at the same timings t_0, t_1, t_2..., assuming that the processing time of the server 110 is insignificant and negligible. Therefore, the navigation command is always given based on the actual current position of the robotic device 100 and thus the positional accuracy of the robotic device 100 is comparable to the onboard navigation. Fig. 3 illustrates the positional accuracy of the robotic device 100 as the maximum difference or error between the actual position 300 and an estimated position 300' of the robotic device 100. For example, if the robotic device 100 makes use of its odometry information to estimate its own position 300' (as shown in Fig. 3) while moving according to the navigation command, the positional accuracy of the robotic device 100 is the odometry error accumulated in a sampling period T, which is the period between two consecutive timings. The odometry error is defined as the difference between the commanded distance to be moved and the actual distance moved by the robotic device 100.

However, in reality, the positional accuracy of the robotic device is affected by the latency of the network (L>0). As shown in Fig. 2, there is always a difference between the time (for example, $t=t_0$) at which a packet of sensor data is sent from the robotic device 100 to the server 110 and the time (for example, $t=t_3$) at which a packet of the processed data corresponding to the sensor data sent at $t=t_0$ is received by the robotic device 100 from the server 100 and this difference t_3-t_0 is defined as the latency of the network.

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Therefore, during the period from t_3 to t_4, the robotic device 100 moves according to the navigation command received at t_3 which corresponds to the sensor data and the actual position of the robotic device 100 at $t=t_0$, but not the navigation command corresponding to its current position at t_3. Therefore, the positional accuracy of the robotic device 100 is affected due to the latency of the network.

The latency of the network between the robotic devices and the server is mainly influenced by the amount of sensor data and network bandwidth both of which are susceptible to environmental changes. While the positional error of the robotic devices due to the latency of the network may not be significant in good network conditions where L is low, the accumulation of this error may become intolerable in slow network conditions where L is high, especially if the robotic devices move at a high speed.

Therefore, there is a need to have an offboard navigation method and apparatus which give a certainty in the positional accuracy of the navigation by considering the delay caused by the communication network between the robotic devices and the remote sever.

Summary

In accordance with one aspect of the present invention, there is provided a method for offboard navigation of a robotic device, the method comprising: defining a threshold value of a positional accuracy of the robotic device, calculating latency of a network through which the robotic device and a server communicate, the latency of the network being a difference between sending sensor data from the robotic device to the server and receiving processed data corresponding to the sent sensor data by the robotic device from the server, and determining speed of the robotic device based on the threshold value of the positional accuracy of the robotic device and the latency of the network.

Determining the speed of the robotic device may comprise setting a sampling period in accordance to the latency of the network, the sampling period being a difference between two consecutive sendings of the sensor data from the robotic device to the server and determining a commanded displacement to be moved by the robotic device in the sampling period.

Determining the commanded displacement to be moved by the robotic device in the sampling period may comprise determining a desired displacement to be moved by the

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robotic device in the sampling period according to characteristics of odometry error of the robotic device and obtaining a positional error to be offset in the sampling period.

The characteristics of the odometry error of the robotic device may be represented by a profile curve of the odometry error of the robotic device calibrated in advance.

The threshold value of the positional accuracy of the robotic device may be determined based on the environment in which the robotic device operates.

The speed of the robotic device may be determined to be inversely proportional to the latency of the network.

The method may further comprise driving the robotic device to move at a speed equal to or less than the determined speed.

In accordance with another aspect of the present invention, there is provided an apparatus for offboard navigation, the apparatus comprising: a server, and a robotic device configured to move according to navigation command received from the server, the robotic device comprising sensors configured to obtain sensor data, an interface configured to receive a threshold value of a positional accuracy of the robotic device, and a processor configured to calculate latency of a network through which the robotic device and the server communicate, the latency of the network being a difference between sending sensor data from the robotic device to the server and receiving processed data corresponding to the sent sensor data by the robotic device from the server, and to determine speed of the robotic device based on the threshold value of the positional accuracy of the robotic device and the latency of the network.

The robotic device may further comprise an odometer configured to estimate the position of the robotic device.

The server may be configured to process the sensor data sent from the robotic device to obtain positional information of the robotic device corresponding to the sent senor data and send the positional information to the robotic device.

The processor may be further configured to set a sampling period in accordance to the latency of the network, the sampling period being a difference between two consecutive sendings of the sensor data from the robotic device to the server and to determine a commanded displacement to be moved by the robotic device in the set sampling period.

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The processor may be further configured to determine a desired displacement to be moved by the robotic device in the sampling period according to characteristics of odometry error of the robotic device and obtain a positional error to be offset in the sampling period to determine the commanded displacement to be moved as the desired displacement to be moved offset by the positional error.

The characteristics of the odometry error of the robotic device may be represented by a profile curve of the odometry error of the robotic device calibrated in advance.

The threshold value of the position accuracy of the robotic device may be determined based on the environment in which the robotic device operates.

The speed of the robotic device may be determined to be inversely proportional to the latency of the network.

The robotic device is driven to move at a speed equal to or less than the determined speed.

Brief Description of the Drawings

Embodiments of the method and the apparatus will now be described with reference to the accompanying figures in which:

Fig. 1 shows an ideal situation of offboard navigation where the latency of a network is zero.

Fig. 2 shows a real situation of offboard navigation where the latency of the network exists.

Fig. 3 illustrates a positional accuracy of a robotic device.

Fig. 4 is a schematic diagram of an example of an apparatus of offboard navigation.

Fig. 5 is a flowchart illustrating an example of a method of offboard navigation.

Fig. 6 shows an example of a profile curve of an odometry error of a robotic device used in the exemplary apparatus of offboard navigation.

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Fig. 7 shows a simple run-time example illustrating the method of offboard navigation.

Fig. 8 shows values of parameters at different timings according to the run-time example illustrated in Fig. 7.

Detailed Description

Fig. 4 illustrates an exemplary apparatus 400 of offboard navigation that responds to changes in network conditions. The apparatus 400 comprises a robotic device 410 coupled to a server 430 via a communication link such as a wireless network 440. The server 430 may be any type of device capable of receiving and sending data, and may comprise powerful processors suitable for navigation processing. The server 430 may be a cloud-computing platform so that the processing load is distributed among the cloud. Navigation applications having a user interface may also be installed at the server 430 so that a user is able to configure parameters related to offboard navigation at the server 430 and monitor the entire navigation process.

As illustrated, the robotic device 410 comprises a plurality of sensors 412, a processor 414, an interface 418 and an odometer 420.

The plurality of sensors 412 may be any type of sensor capable of obtaining data surrounding the robotic device 410 or data of the environment in which the robotic device 410 operates. The sensor data obtained are then transmitted to the server 430 for navigation processing in order to derive the actual position of the robotic device 410 and/or the navigation command to be sent to the robotic device 410.

The processor 414 is used to perform processing required at the robotic device 410 such as interacting with the other components of the robotic device 410 and performing routine functions. For example, it monitors the gathering of the sensor data obtained by the plurality of sensors 412, gives instruction to send sensor data to the server 430 at appropriate timings through the wireless network 440, monitors the positional information of the robotic device 410 and/or the navigation command received and instructs the motors (not shown) of the robotic device 410 to move according to the navigation command. If the server 430 is configured to send only the positional information of the robotic device 410 to the robotic device 410, the processor 414 also performs calculation to derive the navigation command, i.e. commanded distance to be moved. It is assumed

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that the server 430 only send the positional information of the robotic device 410 for simplicity in the description below.

Besides the above functions, the processor 414 also determines speed of the robotic device 410 with respect to latency of the wireless network 440 to achieve a satisfactory positional accuracy of the robotic device 410.

After the robotic device 410 starts to move according to the navigation command, the odometer 420 is used to measure the distance or displacement travelled by the robotic device 410. The navigation command is considered to be completed when the distance indicated in the odometer 420 corresponds to that of the navigation command. As discussed earlier, an odometry error occurs in the process and contributes to the positional error of the robotic device 410.

The interface 418 is configured to accept a user input, for example, accepting values of operating parameters used by the robotic device 410 in the navigation that are input by the user.

Fig. 5 shows the flowchart of the method of offboard navigation using the exemplary apparatus 400.

The positional accuracy or the maximum positional error A of the robotic device 410 is first defined based on the environment in which the robotic device 410 operates 510. For example, a maximum error of 50 cm may be allowed in an ordinary office corridor before the robotic device 410 crashes against the walls of the corridor, while a maximum error of 10 meters may be allowed in a large open plaza. When the maximum positional error allowed is defined, its value can be input into the robotic device 410 by the user as one of the operating parameters through the interface 418 of the robotic device 410 at the start of the navigation. Alternatively, its value can be loaded into the robotic device 410 through the server 430. The user may input the value at a user interface coupled to the server 430, for example, a user interface of a navigation application installed in the server or accessed by the server via wired communications. Such user interface may also be used for monitoring the performance of the offboard navigation and configuring operating parameters of the robotic device 410.

The latency of the wireless network 440 between the robotic device 410 and the server 430, L, is then obtained by the processor 414 of the robotic device 410, 520. The

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processor 414 obtains the time stamp at which a packet of the sensor data is sent from the robotic device 410 to the server 430 and the time stamp at which a packet of processed data corresponding to the former sensor data is received by the robotic device 410 from the server 430, and then calculates the difference between these two time stamps as the latency of the network. The latency of the network may be determined immediately before the start of the navigation by the processor 414 which causes test sensor data to be sent to the serve 430 and obtains the latency of the network when the robotic device 410 receives processed data of the test sensor data. During navigation, the latency of the network is determined dynamically. It may be defined as the period from sending the sensor data to receiving the positional information corresponding to the sensor data at the robotic device 410. Alternatively, during navigation, the robotic device 410 may be configured to send out a special packet of data independent from the sensor data, and obtain the latency of the network when receiving the response corresponding to this special packet of data from the server 430. To remove random short-term fluctuations in the network 440, a moving average of a number of successive values of the latency of the network can be used.

In accordance to the calculated value L of the latency of the network, a sampling period T is set by the processor 414, 530. The sampling period is defined as a period between two consecutive timings of sending the sensor data from the robotic device 410 and it may be set such that with the latest calculated value L of the latency of the network, the positional information corresponding to the movement of the robotic device 410 in the previous but one sampling period should be received by the robotic device 410 before or at the start of the movement in a particular sampling period. Fig. 7 is referred to for the illustration of the sampling period. As shown in Fig. 7, the exemplary robotic device 410 travels in a straight line. The sensor data from the robotic devices 410 are configured to be sent at successive timings t_0, t_1, t_2..., where T_n is the period between two consecutive timings t_{n-1} and t_n. With a known value L of the latency of the network, T_2 is set such that the positional information corresponding to the movement of the robotic device 410 in T_1 is received by the robotic device 410 before or at the start of T_3 (represented by a dotted line arrow 710 in Fig. 7). The positional information corresponding to the movement of the robotic device 410 in T_1 is derived based on the sensor data send from the robotic device 410 at $t=t_1$ by the server 430 (represented by a solid line arrow 720 in Fig. 7). Therefore, the value T of the sampling period has to be greater than or equal to the latest value L of the latency of the network ($T \geq L$). For example, the sampling period may be set to be the summation of the worst-case value of the latency of the network calculated so far and a pre-defined time buffer.

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When the sampling period is set in accordance to the calculated latency of the network, at the time instance $t=t_n$, the robotic device 410 receives the positional information representing its position at $t=t_{n-1}$ and sends the sensor data representing its current position at $t=t_n$.

As the latency of the network is constantly fluctuating during navigation due to the varying network conditions, the sampling period T may also fluctuate during navigation.

The navigation command or the commanded distance to be moved by the robotic device 410 in the set sampling period is then determined with reference to the odometry error of the robotic device 410, 540.

A profile curve of the odometry error of the robotic device 410 is used to determine the desired distance to be moved by the robotic device 410 in the sampling period. This profile curve is calibrated in advance by plotting the odometry error accumulated against the distance moved by the robotic device 410. An example of the profile curve 600 is shown in Fig. 6 where the relationship between the odometry error and the distance moved is non-linear and the odometry error is unbounded over the distance. As shown in the exemplary profile curve 600, a movement of 10 cm of the robotic device 410 causes an error of up to 1cm and a movement of 100 cm causes an error of up to 20cm.

For example, if it is decided that 20cm is the positional accuracy or maximum positional error with respect to a given environment, the positional error allowed in one sampling period T is determined to be 10 cm, which is 20 cm divided by 2 as the odometry error is propagated through two consecutive sampling periods. Based on the calibrated profile curve of the odometry error, the robotic device 410 can only move 50cm before the odometry error exceeds 10cm. Thus, the desired distance to be moved by the robotic device 410 during the sampling period T is determined as 50cm.

As discussed earlier, if the robotic device 410 makes use of its odometry information to estimate its own position while moving according to the navigation command, the odometry error which is the difference between the commanded distance to be moved and the actual distance moved by the robotic device 410 is accumulated in the sampling period. As the sampling period is set such that the sensor data corresponding to the actual position of the robotic device 410 at $t=t_n$ is sent to the server at $t=t_n$ and the actual position of the robotic device 410 at $t=t_n$ is sent back to the robotic device 410 before or at

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$t=t_{n+1}$, the odometry error E_{n-1} accumulated in the sampling period T_{n-1} is known by the robotic device 410 at $t=t_{n+1}$. To offset the odometry error E_{n-1}, the commanded distance to be moved determined at $t=t_{n+1}$ is determined to be the desired distance to be moved corrected by the odometry error E_{n-1}. Thus, the odometry error E_{n-1} accumulated in the sampling period T_{n-1} is reset in the sampling period T_{n+1}, i.e. the odometry error is propagated through two consecutive sampling periods.

The speed of the robotic device 410 in the sampling period is derived as the commanded distance divided by the sampling period 550. The process from obtaining the latency of the network 520 to determining the speed of the robotic device 410, 550, continues during navigation.

The profile curve of the odometry error of the robotic device 410 is stored in a memory device (not shown) of the robotic device 410 and is accessed by the processor 414 when determining the desired distance to be moved by the robotic device 410 in the sampling period. The processor 414 determines the commanded distance to be moved based on the desired distance taking into consideration of the odometry error accumulated in the previous but one sampling period, and then calculates the speed of the robotic device 410 at the start of the sampling period.

Therefore, the speed S of the robotic device 410 is derived by the processor 414 in accordance to the defined threshold value A (maximum allowable value) of the positional error of the robotic device 410 and the calculated value L of the latency of the network. In order for the robotic device 410 to have a positional accuracy equal to or less than the threshold value A, the robotic device 410 is driven to travel at a speed equal to or less than the derived speed S.

The speed of the robotic device 410 is determined dynamically during the navigation so that a change in network condition, i.e. a change in the latency of the network will result in an adjustment of the speed of the robotic device 410.

A simple run-time example showing a first few sampling periods of the navigation is described with reference to Fig. 7 and Fig. 8. The exemplary robotic device 410 in Fig. 7 travels in a straight line. The sensor data from the robotic devices 410 are configured to be sent at successive timings t_0, t_1, t_2..., where T_n is the period between two consecutive timings t_{n-1} and t_n. In the example, T is set to the latest calculated value of the latency of the network for simplicity in illustration.

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The desired distance to be moved by the robotic device 410 in the period T_n is denoted as D_n. The actual position at the time instant $t=t_n$ is denoted as $X(t_n)$ and the starting position at the starting time $t=t_0$ is $X(t_0)=0$.

Fig. 8 shows the desired distance and the commanded distance to be moved by the robotic device 410 in the sampling cycle T_n, the actual distance moved in the sampling cycle T_n, the desired position and the actual position of the robotic device 410, and the positional error of the robotic device 410 at different timings t_0, t_1, t_2...

At $t=t_0$, the robotic device 410 derives the desired distance D_1 to be moved based on the sampling period set according to the latency of the network and the positional accuracy input by a user according to its operating environment. The commanded distance to be moved is the same as the desired distance D_1 as there is no positional information received.

At $t=t_1$, the actual distance that has been moved by the robotic device 410 is D_1+E_1, where E_1 denotes the odometry error accumulated in the sampling period T_1, i.e. from t_0 to t_1. Therefore, the actual position of the robotic device 410 at $t=t_1$ is $X(t_1)=D_1+E_1$ and the corresponding positional error is $E(t_1)=E_1$. The robotic device 410 sends the sensor data representing its current position to the server 430 and derives the desired distance D_2 to be moved in the sampling period T_2, i.e. from t_1 to t_2. The commanded distance to be moved is D_2 as the robotic device 410 only receives the positional information, corresponding to the sensor data sent at $t=t_0$, at $t=t_1$.

The robotic device 410 is commanded to move a distance of D_2 in the sampling period T_2 at $t=t_1$, but the actual distance moved is D_2+E_2. Thus, at $t=t_2$, the actual position of the robotic device 410 is $X(t_2)=D_1+D_2+E_1+E_2$ and the corresponding positional error is $E(t_2)=E_1+E_2$.

At $t=t_2$, the robotic device 410 sends the sensor data representing its current position to the server 430 and receives the positional information corresponding to the sensor data sent at $t=t_1$ (represented by the dotted line arrow 710), which means that the actual position of the robotic device $X(t_1)$ at $t=t_1$ is considered in deriving the commanded distance to be moved from t_2 to t_3 (in the sampling period T_3). To compensate the odometry error E_1 accumulated during the sampling period T_1, the commanded distance is determined to be D_3-E_1 at $t=t_2$.

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From t_2 to t_3, the actual distance moved is D_3-E_1+E_3. Thus, the actual position of the robotic device 410 at $t=t_3$ is $X(t_3)= D_1+D_2+D_3+E_2+E_3$, and the corresponding positional accuracy is E_2+E_3.

Therefore, at any time t, the positional error of the robotic device 410 is the odometry error of the robotic device 410 accumulated over two consecutive sampling periods which are set in accordance to the calculated L of the latency of the network. If the threshold value A of positional accuracy is known, the value E of the odometry error allowed in one sampling period can be derived. For a known E, at the start of a particular sampling period, the desired distance and the commanded distance are determined with reference to the calibrated profile curve of the odometry error of the robotic device 410 and the odometry error accumulated in the previous but one sampling period. Therefore, the speed S can be derived based on a given A and calculated L.

In reality, the robotic device is able to move in any direction, and thus the positional accuracy and the speed of the robotic device may be two dimensional vectors.

The example above illustrates the relationship among the latency of the network L, the average positional accuracy A of the robotic device, and the average speed S of the robotic device. A trade-off exists between the speed of the robotic device and its localization accuracy when navigation processing is performed offboard due to the latency of the network. In addition, the odometry error accumulates with the distance travelled, but can be reset to keep it within a certain boundary.

In slow network conditions where the value of L is high, the speed of the robotic devices can be reduced so that the accumulated odometry error is reduced, and the robotic devices will still have an acceptable positional accuracy. Conversely, in good network conditions where the value of L is low, the speed of the robotic devices can be increased as the positional updates are so frequent that the accumulated odometry error can never become significant, and the robotic devices will still have an acceptable positional accuracy. Theoretically, the robotic devices need not ever come to a complete stop even if the network speed is very slow, and still have an acceptable positional accuracy.

Although the description above focuses on achieving an acceptable positional accuracy of the robotic device, these three variables, L, A and S, can be manipulated through the above-mentioned relationship to optimize at least one of these variables. For example,

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the speed of the robotic device can be adjusted dynamically based on the latency of the network, given that the positional accuracy of the robotic device is fixed. Alternatively, the latency of the network L may be reduced by sending less sensor data so that the speed of the robotic devices can be increased, if the positional accuracy could be relaxed.

Whilst there has been described in the foregoing description embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design or construction may be made without departing from the present invention.

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Claims

1. A method for offboard navigation of a robotic device, the method comprising:

defining a threshold value of a positional accuracy of the robotic device;

calculating latency of a network through which the robotic device and a server communicate, the latency of the network being a difference between sending sensor data from the robotic device to the server and receiving processed data corresponding to the sent sensor data by the robotic device from the server; and

determining speed of the robotic device based on the threshold value of the positional accuracy of the robotic device and the latency of the network.

2. The method according to claim 1, wherein determining the speed of the robotic device comprises setting a sampling period in accordance to the latency of the network, the sampling period being a difference between two consecutive sendings of the sensor data from the robotic device to the server.

3. The method according to claim 2, wherein determining the speed of the robotic device further comprises determining a commanded displacement to be moved by the robotic device in the sampling period.

4. The method according to claim 3, wherein determining the commanded displacement to be moved by the robotic device in the sampling period comprises determining a desired displacement to be moved by the robotic device in the sampling period according to characteristics of odometry error of the robotic device and obtaining a positional error to be offset in the sampling period.

5. The method according to claim 4, wherein the characteristics of the odometry error of the robotic device is represented by a profile curve of the odometry error of the robotic device calibrated in advance.

6. The method according to any one of the preceding claims, wherein the threshold value of the positional accuracy of the robotic device is determined based on the environment in which the robotic device operates.

7. The method according to any one of the preceding claims, wherein the speed of the robotic device is determined to be inversely proportional to the latency of the network.

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8. The method according to any one of the preceding claims, further comprising driving the robotic device to move at a speed equal to or less than the determined speed.

9. An apparatus for offboard navigation, the apparatus comprising:

a server; and

a robotic device configured to move according to navigation command received from the server,

the robotic device comprising

sensors configured to obtain sensor data;

an interface configured to receive a threshold value of a positional accuracy of the robotic device; and

a processor configured to

calculate latency of a network through which the robotic device and the server communicate, the latency of the network being a difference a difference between sending sensor data from the robotic device to the server and receiving processed data corresponding to the sent sensor data by the robotic device from the server, and

determine speed of the robotic device based on the threshold value of the positional accuracy of the robotic device and the latency of the network.

10. The apparatus according to claim 9, wherein the robotic device further comprises an odometer configured to estimate the position of the robotic device.

11. The apparatus according to claim 9 or 10, wherein the server is configured to process the sensor data sent from the robotic device to obtain positional information of the robotic device corresponding to the sent sensor data and send the positional information to the robotic device.

12. The apparatus according to any one of claims 9 to 11, wherein the processor is further configured to

set a sampling period in accordance to the latency of the network, the sampling period being a difference between two consecutive sendings of the sensor data from the robotic device to the server; and

determine a commanded displacement to be moved by the robotic device in the set sampling period.

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13. The apparatus according to claim 12, wherein the processor is further configured to determine a desired displacement to be moved by the robotic device in the sampling period according to characteristics of odometry error of the robotic device and obtain a positional error to be offset in the sampling period to determine the commanded displacement to be moved as the desired displacement to be moved offset by the positional error.

14. The apparatus according to claim 13, wherein the characteristics of the odometry error of the robotic device is represented by a profile curve of the odometry error of the robotic device calibrated in advance.

15. The apparatus according to any one of claims 9 to 14, wherein the threshold value of the position accuracy of the robotic device is determined based on the environment in which the robotic device operates.

16. The apparatus according to any one of claims 9 to 15, wherein the speed of the robotic device is determined to be inversely proportional to the latency of the network.

17. The apparatus according to any one of claims 9 to 15, wherein the robotic device is driven to move at a speed equal to or less than the determined speed.

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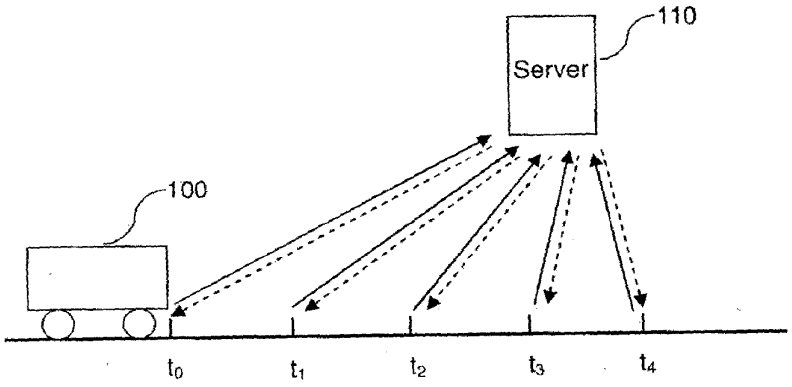


Fig. 1

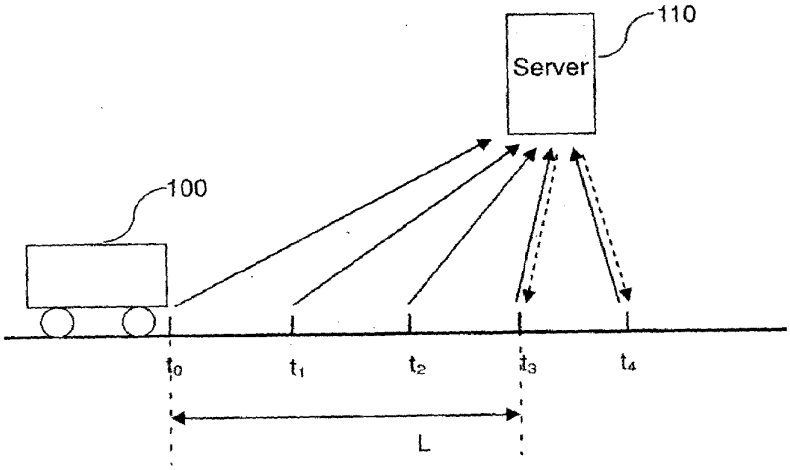


Fig 2

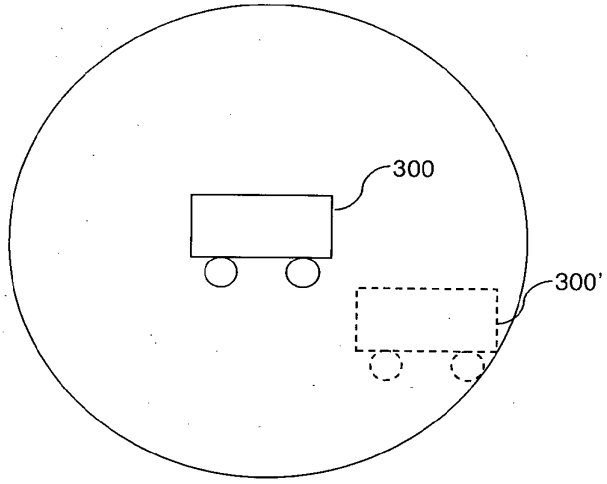

300
300'

Fig. 3

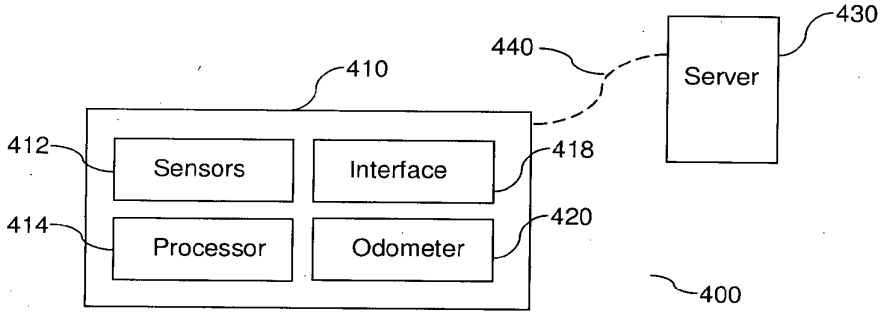

430
440
Server
410
412
Sensors
Interface
418
414
Processor
Odometer
420
400

Fig. 4

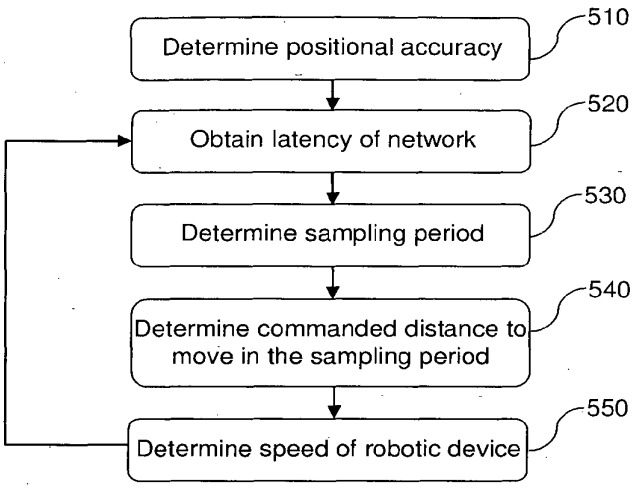

Determine positional accuracy
510
Obtain latency of network
520
Determine sampling period
530
Determine commanded distance to move in the sampling period
540
Determine speed of robotic device
550

Fig. 5

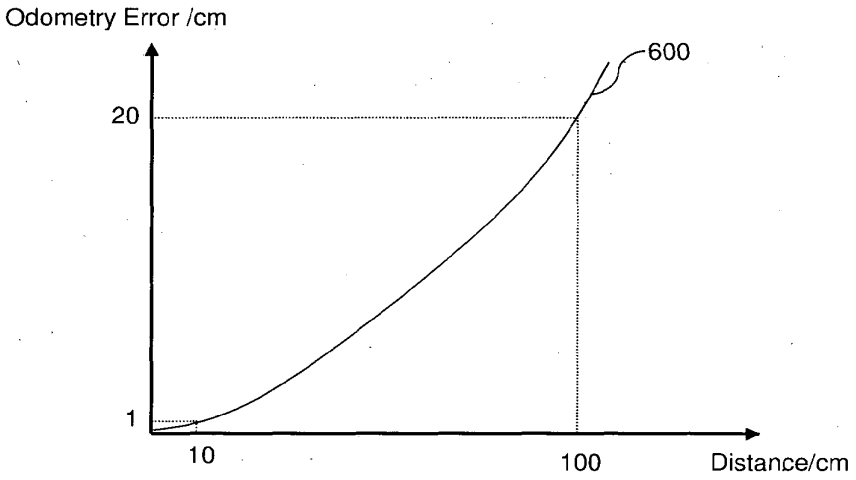

Odometry Error /cm
600
20
1
10
100
Distance/cm

Fig. 6

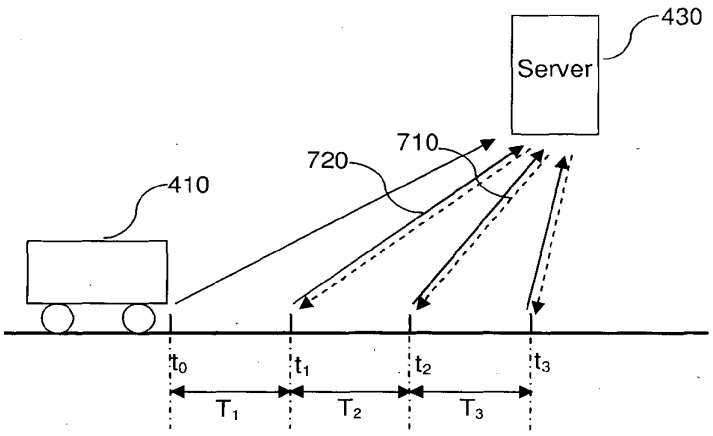


Fig. 7

t	Desired Distance	Commanded Distance to Move from t_n to t_{n+1}	Actual Distance Moved from t_{n-1} to t_n	Desired Position	Actual Position	Positional Error
t_0	D_1	D_1	-	0	0	0
t_1	D_2	D_2	D_1+E_1	D_1	D_1+E_1	E_1
t_2	D_3	D_3-E_1	D_2+E_2	D_1+D_2	$D_1+D_2+E_1+E_2$	E_1+E_2
t_3	D_4	D_4-E_2	$D_3-E_1+E_3$	$D_1+D_2+D_3$	$D_1+D_2+D_3+E_2+E_3$	E_2+E_3

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2013/000262

A. CLASSIFICATION OF SUBJECT MATTER

G01C 21/00 (2006.01) G01S 19/00 (2010.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

GOOGLE PATENTS: offboard navigation robot threshold latency speed
GOOGLE SCHOLAR : robotic device positional accuracy latency threshold delay
GOOGLE: robotic device positional accuracy latency threshold delay
EPOQUE:
TXTE: off-board, navigation, robot, threshold, position, accuracy, error, latency, delay, speed, network and similar terms.
INSPEC: off-board, navigation, robot, position, accuracy, threshold, network, latency, delay and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [ ] See patent family annex

* Special categories of cited documents:

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 October 2013	01 October 2013

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INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	**PCT/SG2013/000262**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GLOYE, A et al.: "Predicting away robot control latency", Technical Report B-08-03 [retrieved on 09 August 2013]. Retrieved from Internet <URL: http://web.archive.org/web/20070824191108/http://page.mi.fu-berlin.de/rojas/2003/B-08-03.pdf> published on 24 August 2007 as per Wayback Engine Whole document	1-17

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Declarations under Rule 4.17:

— *as to the identity of the inventor (Rule 4.17(i))*

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

[Continued on next page]

(54) **Title**: OFFBOARD NAVIGATION APPARATUS CAPABLE OF BEING COUPLED TO A MOVABLE PLATFORM

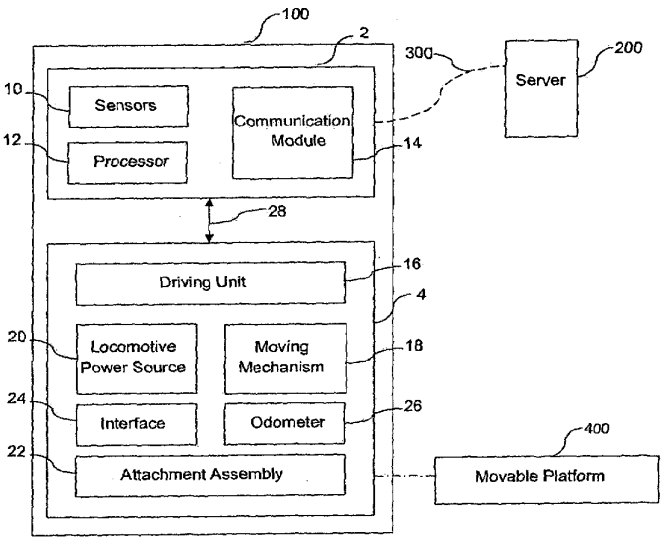


Fig. 1

(57) **Abstract**: An offboard navigation apparatus capable of being coupled to a movable platform used for the transportation and delivery of a load is provided, the offboard navigation apparatus comprising: a base unit configured to be capable of being attached to the movable platform and providing locomotive power to the movable platform; and a navigation unit configured to drive the base unit to navigate the movable platform, the navigation unit comprising: sensors configured to obtain sensor data; and a communication unit configured to transmit sensor data to a server and receive navigation information of the offboard navigation apparatus from the server.

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— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

Offboard Navigation Apparatus Capable of being Coupled to a Movable Platform

Field of the Invention

The present invention relates to an offboard navigation apparatus capable of being coupled to a movable platform used for the transportation and delivery of a load, and particularly, relates to an offboard navigation apparatus that provides locomotive power to the movable platform to make the movable platform capable of self-navigation when being attached to the offboard navigation apparatus.

Background

With the technology of autonomous navigation, robotic devices are widely used in the consumer market and industry. These robotic devices move around a place relying on sensors and navigation systems without any human intervention whilst it is on the move. One example of such robotic devices is the Autonomous Guided Vehicles (AGVs) used to transport articles or objects around in a premises. However, the AGVs are inflexible to re-planning as extensive, expensive and inflexible modifications to the infrastructure are required for these vehicles to work. For example, one type of the AGVs has to follow markers or wires installed in the floor when navigating a place. The AGVs are usually huge platforms built for designated purposes. Thus, their size and fixed footprint prevent them from providing services in smaller or confined areas.

As a result, manpower is still largely employed to transport objects from one place to another in a number of industries, such as logistics, material-handling, medical, and manufacturing industries, when it is impossible or uneconomical to use the AGVs and other existing robotic devices. For example, in the hospitals, nurses or orderlies have to use trolleys to transport medical instruments and medicines to and from the wards.

Smaller AGVs or mobile robotic devices are devised to reduce manpower needed in these circumstances. However, the size of these devices still remains quite

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significant as the navigation processing is performed onboard, i.e. on the moving devices themselves, and these devices must be equipped with powerful computing facilities to provide navigation commands in real time. In addition, these devices are mainly designed for carrying the load themselves, and they are not designed to work with existing general movable platforms used for transportation, such as push-carts, trolleys, wheelchairs and the like.

Therefore, it is desirable to have a navigation apparatus that is capable being attached to the existing general movable platforms used for transportation to provide locomotive power to make the movable platform capable of self-navigation.

Summary

In accordance with one aspect of the present invention, there is provided an offboard navigation apparatus capable of being coupled to a movable platform used for the transportation and delivery of a load, comprising: a base unit configured to be capable of being attached to the movable platform and providing locomotive power to the movable platform; and a navigation unit configured to drive the base unit to navigate the movable platform, the navigation unit comprising: sensors configured to obtain sensor data; and a communication unit configured to transmit sensor data to a server and receive navigation information of the offboard navigation apparatus from the server.

The base unit may comprise an attachment assembly configured to attach the offboard navigation apparatus to the moveable platform; the navigation unit may further comprise a processor to process the navigation information of the offboard navigation apparatus to provide a navigation instruction; the communication unit may be further configured to receive a navigation instruction from the server.

The navigation unit may be coupled directly to a driving system of the movable platform to navigate the movable platform when the movable platform itself is a self-powered platform.

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The base unit may further comprise a power source; a moving mechanism configured to make the offboard navigation apparatus movable; and a driving unit driven by power supplied from the power source and configured to drive the moving mechanism.

The driving unit may be configured to receive a navigation instruction from the navigation unit and drives the moving mechanism according to the navigation instruction.

The moving mechanism may be a number of wheels; the moving mechanism may be continuous tracks.

The power source may be a battery; the power source may be a combustion engine.

The navigation unit may further comprise a processor configured to calculate a latency of a network through which the offboard navigation apparatus and the server communicate, the latency of the network being a difference between sending sensor data from the offboard navigation apparatus to the server and receiving processed data corresponding to the sent sensor data by the offboard navigation apparatus from the server, and determine the speed of the offboard navigation apparatus based on a threshold value of a positional accuracy of the offboard navigation apparatus and the latency of the network.

The offboard navigation apparatus may further comprise an interface configured to receive the threshold value of the positional accuracy of the offboard navigation apparatus from a user.

The offboard navigation apparatus may further comprise an odometer configured to estimate the position of the offboard navigation apparatus.

The speed of the offboard navigation apparatus may be determined to be inversely proportional to the latency of the network.

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Brief Description of the Drawings

Embodiments of the offboard navigation apparatus will now be described with reference to the accompanying figures in which:

Fig. 1 shows a schematic diagram of an offboard navigation apparatus according to an embodiment of the present invention, a server with which the offboard navigation apparatus communicates, and a movable platform to which the offbard navigation apparatus is attached.

Fig. 2 is a perspective view of an example of the offboard navigation apparatus.

Fig. 3 is a perspective view of the offboard navigation apparatus of Fig. 2 and an example of the movable platform when the offboard navigation apparatus is not attached to the movable platform.

Fig. 4 is a perspective view of the offboard navigation apparatus and the movable platform of Fig. 3 when the offboard navigation apparatus is attached to the movable platform.

Fig. 5 illustrates how the offboard navigation apparatus of Fig. 3 is attached to the movable platform of Fig. 3.

Detailed Description

Fig. 1 illustrates a schematic diagram of an exemplary offboard navigation apparatus 100 working with a server 200 to navigate a movable platform 400 mainly used for the transportation and delivery of a load. The offboard navigation apparatus 100 is capable of being coupled to the movable platform 400 to drive the movable platform. The offboard navigation apparatus 100 also communicates with the remote server 200 via a communication link such as a wireless network 300 (for example, WiFi, 3G, 4G, etc.) to harness the processing power of the server 200 to perform navigation processing.

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The server 200 may be any type of device capable of receiving and sending data, and may comprise powerful processors suitable for navigation processing. The server 200 may be a cloud-computing platform so that the processing load is distributed among the cloud. Navigation applications having a user interface may also be installed at the server 200 so that a user is able to configure parameters related to offboard navigation at the server 200 and monitor the entire navigation process.

The movable platforms 400 may be push-carts, trolleys and wheelchairs which are being pushed or pulled by human. However, they are not limited to wheeled vehicles including vehicles on spherical wheels (i.e. ball-based vehicles), and they may be any platform that can be pushed or pulled from one place to another, such as platforms having sliders on the bottom surface. The movable platforms may be powered platforms, i.e. movable platforms equipped with a power source, such as electric wheelchairs.

A navigation unit 2 and a base unit 4 which are electrically connected with each other by wiring 28 are included in the offboard navigation apparatus 100.

The navigation unit 2 configured to drive the base unit 4 comprises a plurality of sensors 10, a processor 12 and a communication module 14.

The plurality of sensors 10 may be any type of sensor capable of obtaining data surrounding the offboard navigation apparatus 100 or data of the environment in which the offboard navigation apparatus 100 operates. Cameras, LIDARS or inertial measurement units or a combination of aforementioned devices may be used as the plurality of sensors 10. The sensor data obtained are then transmitted to the server 200 through the communication module 14 for navigation processing in order to derive the actual position of the offboard navigation apparatus 100.

The processor 12 is used to perform processing required at the navigation unit 2. As the majority of the navigation computation is allocated to the server 200 equipped with powerful processors, minimum processing, such as interacting with the other components of the navigation unit 2 and performing routine functions, is

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performed by the processor 12. For example, it monitors the gathering of the sensor data obtained by the plurality of sensors 10, pre-processes the sensor data before transmitting it to the server 200, gives instruction to send sensor data to the server 200 at appropriate timings through the wireless network 300, monitors the positional information or navigation information of the offboard navigation apparatus 100 received through the communication module 14 from the server 200 and provides a navigation instruction signal to the base unit 4 based on the positional information received. It may be possible for the server 200 to send the navigation instruction instead of the positional information of the offboard navigation apparatus 100 to the navigation unit 2. In such cases, the processing of the positional information to provide the navigation instruction is not performed by the processor 12.

Various existing offboard navigation methodologies can be used in the offboard navigation apparatus 100. The method described in the Singapore Patent Application No. 201304289-0 which provides adaptive offboard navigation that responds to changes in network conditions may be employed in the offboard navigation apparatus 100. In such cases, the processor 12 also determines the speed of the offboard navigation apparatus 100 with respect to a latency of the wireless network 300 to achieve a satisfactory positional accuracy of the offboard navigation apparatus 100. To maintain a specific level of positional accuracy, the speed of the offboard navigation apparatus 100 is determined to be inversely proportional to the latency of the network 300.

The communication module 14 transmits the sensor data from the navigation unit 2 to the server 200 and receives the processed data for navigation from the server 200.

The base unit 4 is capable of being attached to the movable platform 400 and provides locomotive power to the movable platform 400 by either pushing or pulling the movable platform 400. It comprises a driving unit 16, a moving mechanism 18, a locomotive power source 20 and an attachment assembly 22.

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The base unit 4 is removably mounted to the movable platform 400 via the attachment assembly 22. A variety of mechanical means such as clamps or inserts can be used as the attachment assembly 22. The offboard navigation apparatus 100 becomes a bolt-on component of the movable platform 400 when it is rigidly attached to the movable platform 400 via the attachment assembly 22, and thus makes the movable platform 400 capable of self-navigation.

The driving unit 16 of the base unit 4 receives the navigation instruction signal from the processor 12 of the navigation unit 2 through the wiring 28 and drives the moving mechanism 18 according to the navigation instruction signal to move the base unit 4 (i.e. the offboard navigation apparatus 100) in a specific direction with a specific speed. The driving unit 16 is powered by the locomotive power source 20.

Any kind of portable power source may be used as the locomotive power source 20 to supply driving forces to the driving unit 16. For example, a battery or a relatively small combustion engine may be used. If a battery is used as the locomotive power source 20, the battery also provides power to the various electrical and/or electronic components of the offboard navigation apparatus 100. If another kind of power source is used as the locomotive power source 20, a separate battery has to be provided to supply power to the various components of the offboard navigation apparatus 100.

The moving mechanism 18 may be a number of wheels. Continuous tracks, a belt capable of providing motive traction, may also be used to replace the wheels as the moving mechanism 18 so that the offboard navigation apparatus 100 is suitable to move on uneven surfaces. In such cases, if the movable platform 400 to which the offboard navigation apparatus 100 is attached is also equipped with continuous tracks, the movable platform 400 is able to navigate smoothly on the uneven surfaces as the tracks glide over bumps, small obstacles and trenches on the surfaces.

When the method of the Singapore Patent Application No. 201304289-0 is employed in the offboard navigation apparatus 100, an interface 24 configured to

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accept a positional accuracy of the offboard navigation apparatus 100 that is input by the user and an odometer 26 used to estimate the distance or displacement travelled the offboard navigation apparatus 100 are provided. As illustrated in Fig. 1, these two components are provided in the base unit 4. It is also possible to provide these two components in the navigation unit 2. Other than the conventional odometry methods for wheeled and tracked vehicles, the visual odometry method in which the distance travelled is estimated by using sequential camera images can also be used in the offboard navigation apparatus 100. At least one camera is provided in the offboard navigation apparatus 100 when visual odometry method is desired.

The base unit 4 may also be provided with additional sensors as anti-collision measures to enhance safety. When the offboard navigation apparatus 100 attached to the movable platform 400 is in operation, i.e. moving according to the navigation information, if an obstacle such as a person or a large object is detected by these sensors within a predefined safety distance from the base unit 4, the offboard navigation apparatus 100 may be brought to a stop for a certain period. The movement of the offboard navigation apparatus 100 is then resumed when the obstacle is no longer present within the safety distance.

The offboard navigation apparatus 100 as shown in Fig. 1 makes the movable platform 400 capable of self-navigation when it is attached to the movable platform 400 via the attachment assembly 22. During self-navigation of the movable platform 400 in which the offboard navigation apparatus 100 become the bolt-on component, the plurality of the sensors 10 of the navigation unit 2 obtains sensor data concerning the environs of the movable platform 400. The processor 12 then pre-processes the sensor data obtained and send it to the server 200 through the communication module 14. Based on the sensor data received, the server 200 performs navigation processing to calculate the positional information of the offboard navigation apparatus 100 (which would be the same as the positional information of the movable platform 400) and send it back to the navigation unit 2. After receiving the positional information of the movable platform 400, the processor 12 derives the navigation instruction based on the positional information and sends a signal to the driving unit 16 of the base unit 4. The driving unit 16

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powered by the locomotive power source 20 drives the moving mechanism 18 to move the offboard navigation apparatus 100 according to the navigation instruction so that the movable platform 400 is pushed or pulled to and from designated locations without any human direction and manpower.

If the offboard navigation apparatus 100 is powered by a battery, that is, the locomotive power source 20 is a battery, the offboard navigation apparatus 100 may be configured to work with a docking station. When the battery is running low, the offboard navigation apparatus 100 may be automatically navigated to the docking station by the navigation unit 2 to charge the battery. It may also be configured to leave the docking station when the battery is fully charged so that the docking station is available to other similar offboard navigation apparatuses in the premises.

When the movable platform 400 is a self-powered platform, the navigation unit 2 may be coupled directly to the drive system of the movable platform 400 by sending the navigation instruction to the drive system to navigate the movable platform 400.

An example of the offboard navigation apparatus 100 is shown in Fig. 2, and Fig. 3 and Fig. 4 illustrate the exemplary offboard navigation apparatus 100 before and after being attached to an example of the movable platform 400 respectively. For simplicity, a trolley is presented as the example of the movable platform 400.

The exemplary offboard navigation apparatus 100 comprises the navigation unit 2 (a mast unit) and the base unit 4 connected by a post 3 which covers the wiring 28 between the navigation unit 2 and the base unit 4. The base unit 4 is in contact with the ground and the navigation unit 2 is arranged on top of the post 3. In such arrangement, the plurality of sensors 10 of the navigation unit 2 is not blocked by the movable platform 400 when the offboard navigation apparatus 100 is attached to the movable platform 400. Thus, the sensor data obtained is not affected by the different movable platforms 400 used. The navigation unit 2 may be disposed at other positions so long as consistent sensor data can be obtained. The processor 12 is covered in the casing of the navigation unit 2.

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The driving unit 16 and the locomotive power source 20 are enclosed in the casing of the base unit 4. Two wheels are shown as the moving mechanism 18 driven by the driving unit 16.

The attachment assembly 22 is provided on the front surface of the base unit 4 facing the movable platform 400. It is attached to the movable platform 400 through an adapter 410. The adapter 410 may not be part of the offboard navigation apparatus 100. As illustrated in Fig. 5, the attachment assembly 22 has a plate-like structure to be fastened to a corresponding connecting part of the adapter 410 with bolts and nuts. The adapter 410 grips the metal columns of the trolley 400 with bolts and nuts as well. The adapter 410 may be designed with a different mechanism for attachment to another kind of movable platform 400, providing flexibility in mounting the offboard navigation apparatus 100 to various kinds of movable platform 400 without any modification of the attachment assembly 22.

The offboard navigation apparatus 100 shown in Figs. 2 to 5 and described above is only a workable example, and various modifications can be made. For example, the adapter 410 may not be necessary and the attachment assembly 22 is attached directly to the movable platform 400. Further, a variety of mechanical means such as clamps or inserts can be used as the attachment assembly 22.

As described above, offboard navigation is employed in the offboard navigation apparatus 100 such that the majority of the processing is performed by the server 200. Therefore, the navigation unit 2 and base unit 4 can be kept relatively small and inexpensive without the requirement of powerful computational facilities in the offboard navigation apparatus 100. Further, no infrastructure modifications are required as the navigation unit 2 uses the plurality of sensors 10 to locate the offboard navigation apparatus 100 using existing features of a place.

In addition, the offboard navigation apparatus 100 is capable of being attached to any movable platforms, even small ones like ordinary trolleys, and thus provides a degree of flexibility hardly achieved by the AGVs or other existing mobile robotic

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devices. It is a modular add-on autonomous kit that can be attached to any ordinary movable platform to transform it into an intelligent self-navigating platform, and the user is offered with the flexibility to decide which movable platform he or she would like to automate by simply attaching the offboard navigation apparatus 100 to the selected movable platform. The user is also offered with the flexibility to revert back to manual push/pull by simply removing the offboard navigation apparatus 100 from the selected movable platform.

Whilst there has been described in the foregoing description embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design or construction may be made without departing from the present invention.

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Claims

1. An offboard navigation apparatus capable of being coupled to a movable platform used for the transportation and delivery of a load, comprising:

a base unit configured to be capable of being attached to the movable platform and providing locomotive power to the movable platform; and

a navigation unit configured to drive the base unit to navigate the movable platform,

the navigation unit comprising:

sensors configured to obtain sensor data; and

a communication unit configured to transmit sensor data to a server and receive navigation information of the offboard navigation apparatus from the server.

2. The offboard navigation apparatus according to claim 1, wherein the base unit comprises an attachment assembly configured to attach the offboard navigation apparatus to the moveable platform.

3. The offboard navigation apparatus according to claim 1 or 2, wherein the navigation unit further comprises a processor to process the navigation information of the offboard navigation apparatus to provide a navigation instruction.

4. The offboard navigation apparatus according to claim 1 or 2, wherein the communication unit is further configured to receive a navigation instruction from the server.

5. The offboard navigation apparatus according to any one of claims 1 to 4, wherein the navigation unit is coupled directly to a drive system of the movable platform to navigate the movable platform when the movable platform is a self-powered platform.

6. The offboard navigation apparatus according to any one of claims 1 to 4, wherein the base unit further comprises

a power source;

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a moving mechanism configured to make the offboard navigation apparatus movable; and

a driving unit driven by power supplied from the power source and configured to drive the moving mechanism.

7. The offboard navigation apparatus according to claim 6, wherein the driving unit is configured to receive a navigation instruction from the navigation unit and drives the moving mechanism according to the navigation instruction.

8. The offboard navigation apparatus according to claim 6 or 7, wherein the moving mechanism is a number of wheels.

9. The offboard navigation apparatus according to claim 6 or 7, wherein the moving mechanism is continuous tracks.

10. The offboard navigation apparatus according to any one of claims 6 to 9, wherein the power source is a battery.

11. The offboard navigation apparatus according to any one of claims 6 to 9, wherein the power source is a combustion engine.

12. The offboard navigation apparatus according to any of claims 1 to 11, wherein the navigation unit further comprises a processor configured to

calculate a latency of a network through which the offboard navigation apparatus and the server communicate, the latency of the network being a difference between sending sensor data from the offboard navigation apparatus to the server and receiving processed data corresponding to the sent sensor data by the offboard navigation apparatus from the server, and

determine the speed of the offboard navigation apparatus based on a threshold value of a positional accuracy of the offboard navigation apparatus and the latency of the network.

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13. The offboard navigation apparatus according to claim 12, further comprises an interface configured to receive the threshold value of the positional accuracy of the offboard navigation apparatus from a user.

14. The offboard navigation apparatus according to claim 12 or 13, further comprises an odometer configured to estimate the position of the offboard navigation apparatus.

15. The offboard navigation apparatus according to any one of claims 12 to 14, wherein the speed of the offboard navigation apparatus is determined to be inversely proportional to the latency of the network.

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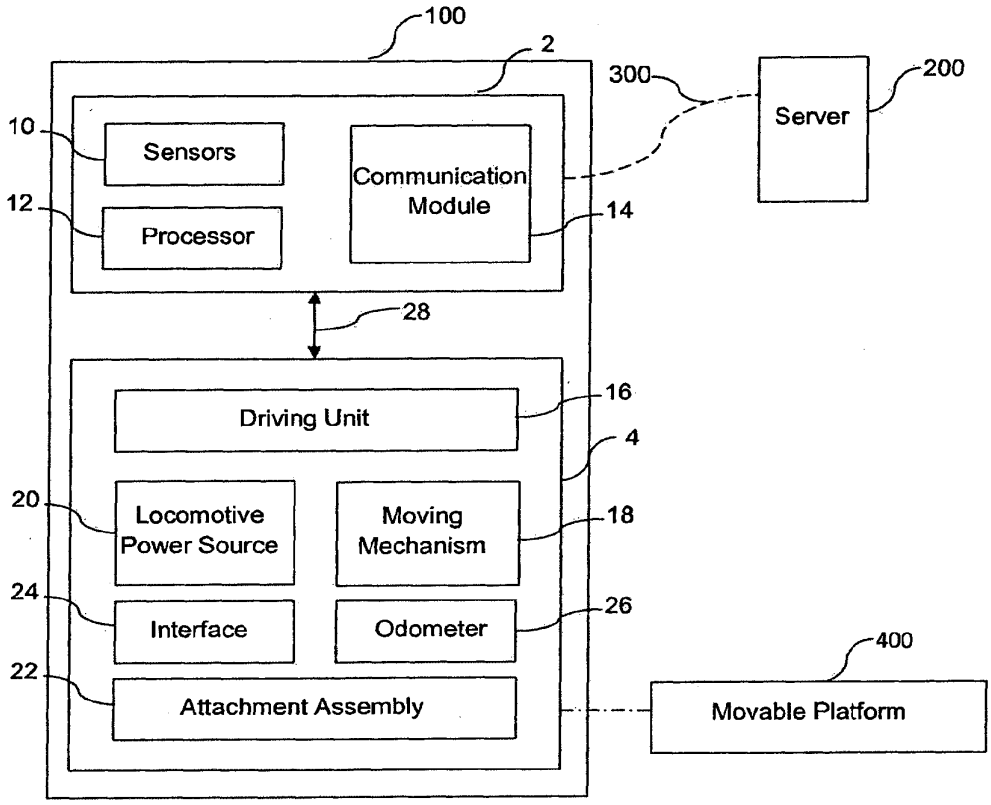

100
2
300
200
Server
10
Sensors
12
Processor
Communication Module
14
28
16
Driving Unit
4
20
Locomotive Power Source
Moving Mechanism
18
24
Interface
Odometer
26
22
Attachment Assembly
400
Movable Platform

Fig. 1

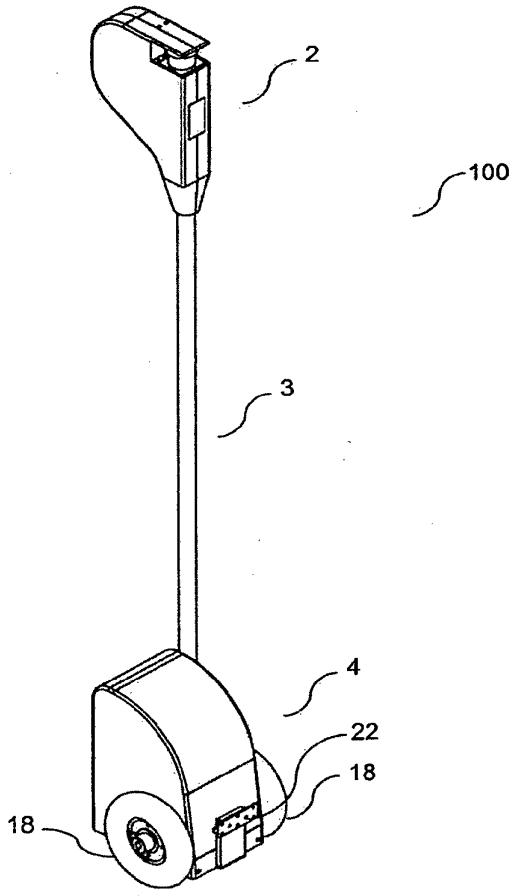


Fig. 2

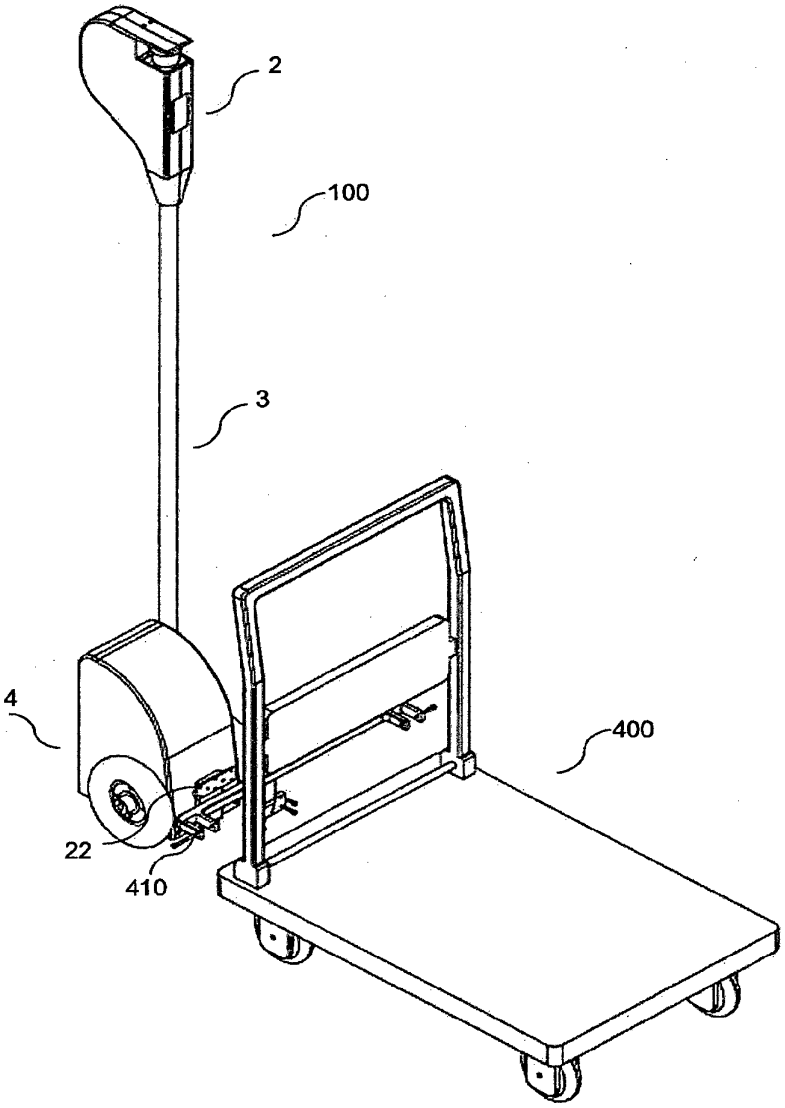


Fig. 3

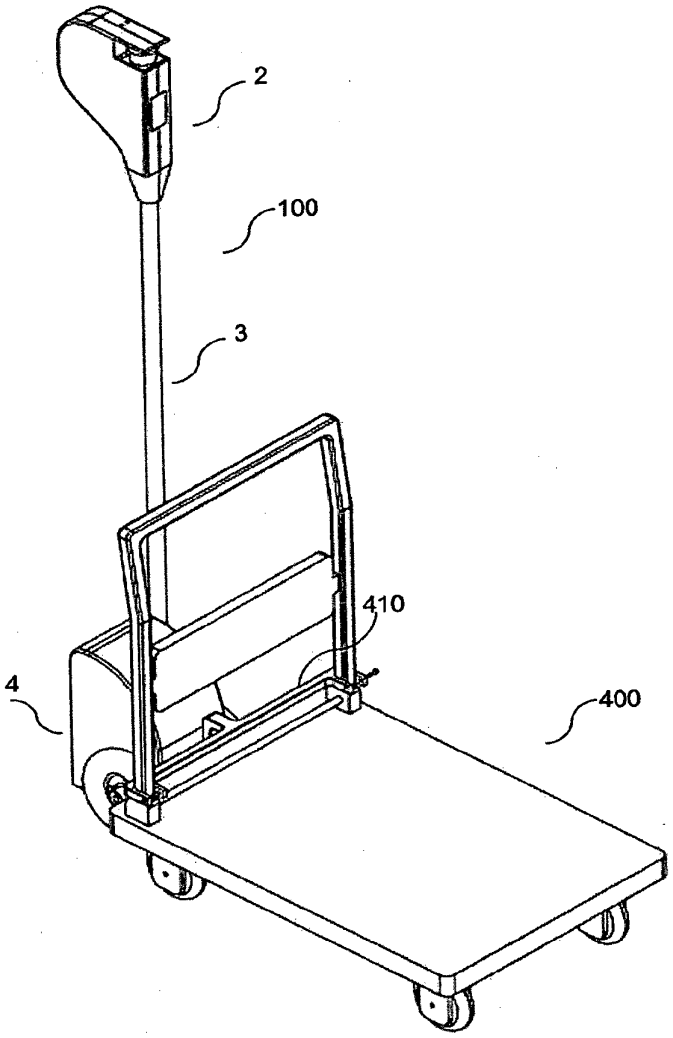


Fig. 4

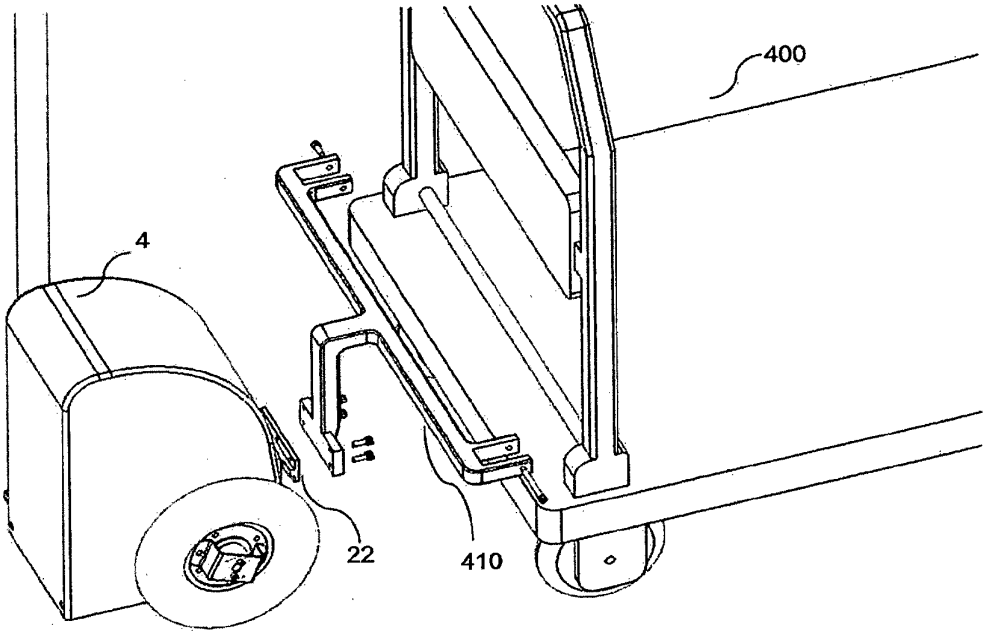


Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2014/000454

A. CLASSIFICATION OF SUBJECT MATTER

G05D 1/02 (2006.01) B62D 1/02 (2006.01) B62D 6/00 (2006.01) B62D 3/00 (2006.01) G05B 11/00 (2006.01) G05B 13/00 (2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

Databases: EPODOC, WPI. Searched with CPC marks G05D2201/0216, G05D2201/0206, G05D2201/0208, G05D2201/0211, B62B5/0069, G05D1/021, B66F9/063, B62B3/0612 and keywords such as autonomous guided vehicle, automatic, AGVs, trolley, cart, wheelchair, platform, tray, navigate, control, guide, detach, attach, offboard, external, sensor, detect, server, computer, position, speed, path, transport, lift, deliver, remote, antenna, radio, wifi, network and like terms. Broader IPC/CPC mark searches were also conducted by using G05D1/00, G05D3/00, G05D2201/02, G05B11/00, G05B13/00, B62D1/02, B62D3/00, A61G62/00, A01G5/04, B66F9/06, B62B3/00 (including the subclass/lower marks of each of the above IPC/CPC marks) with similar keywords as above. Search results were also crossed to English Full Text databases (TXTE) for further search with keywords as above.

Databases-Espacenet (Worldwide) and AusPat: Applicant/Inventor name search. Database-Google Patent: keywords: autonomous guided vehicle with detachable navigation unit, and like terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 November 2014	11 November 2014
Name and mailing address of the ISA/AU	**Authorised officer**
AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustralia.gov.au	Aisha Qi AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 0262832951

Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		International application No. **PCT/SG2014/000454**
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/0093900 A1 (REEVES et al.) 09 April 2009 Figs 1-3, page 1 para [0012] — page 3 para [0026]	1-15
X	EP 1752850 A2 (RICOH COMPANY, LTD, et al.) 14 February 2007 Figs 1-17, column 8 para [0038] — column 18 para [0084]	1-15
X	US 3738443 A (KUBO) 12 June 1973 Figs 1-7, column 2 line 9 — column 4 line 47	1-15
X	US 6049745 A (DOUGLAS et al.) 11 April 2000 abstract, Figs 1-5, column 4 line 29 — column 8 line 25	1-15
X	US 2013/0162396 A1 (YANG) 27 June 2013 Figs 1-9, page 2 para [0055] — page 3 para [0068]	1-15

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/SG2014/000454**

This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document/s Cited in Search Report		**Patent Family Member/s**	
Publication Number	**Publication Date**	**Publication Number**	**Publication Date**
US 2009/0093900 A1	09 April 2009	US 7599756 B2	06 Oct 2009
		EP 2198356 A2	23 Jun 2010
		EP 2198356 B1	08 Aug 2012
		JP 2010540344 A	24 Dec 2010
		WO 2009045854 A2	09 Apr 2009
EP 1752850 A2	14 February 2007	EP 1752850 B1	03 Sep 2014
		JP 2007038818 A	15 Feb 2007
		JP 4965094 B2	04 Jul 2012
US 3738443 A	12 June 1973	JP S4919756 B1	20 May 1974
US 6049745 A	11 April 2000	AU 6152198 A	26 Aug 1998
		EP 0956523 A1	17 Nov 1999
		EP 0956523 B1	19 Dec 2001
		WO 9835276 A1	13 Aug 1998
US 2013/0162396 A1	27 June 2013	TW 201331076 A	01 Aug 2013
		TW I419805 B	21 Dec 2013
		TW 201325964 A	01 Jul 2013
		TW I424932 B	01 Feb 2014

End of Annex

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

COMBINED DECLARATION AND ASSIGNMENT FOR PATENT APPLICATIONS

Title of Invention: **SYSTEMS AND METHODS FOR ROBOTIC MAPPING**

As a below named inventor (hereinafter designated as the undersigned), I hereby declare that:

This declaration is directed to the application attached hereto. If the application is not attached hereto, the application is as identified by the attorney docket number as set forth above and/or the following:

U.S. Application Serial No.: 15/340,807; or
PCT International Application No.:_____
Filed on: November 1, 2016

The above-identified application was made or authorized to be made by me. I believe that I am the original inventor or an original joint inventor of a claimed invention in the application. I have reviewed and understand the contents of the above-identified application, including the claims. I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations § 1.56.

WHEREAS, **BRAIN CORPORATION**, with its principal place of business at 9401 Waples Street, Suite 100, San Diego, CA 92121, its heirs, successors, legal representatives and assigns (hereinafter designated as the Assignee) is desirous of acquiring the entire right, title and interest in and to said invention and in and to any Letters Patent(s) that may be granted therefor in the United States of America and in any foreign countries.

NOW, THEREFORE, for good and valuable consideration, the receipt and sufficiency of which is hereby acknowledged, the undersigned has sold, assigned and transferred, and by these presents does (do) sell, assign and transfer unto said Assignee the full and exclusive right to the said invention in the United States of America, its territories, dependencies and possessions and the entire right, title and interest in and to any and all Letters Patent(s) which may be granted therefor in the United States of America, its territories, dependencies and possessions, and if the box above is designated, in any and all foreign countries; and to any and all divisions, reissues, re-examinations, continuations, conversions and extensions thereof, and provisional applications to which priority is claimed therefrom, for the full term or terms for which the same may be granted.

The undersigned agrees to execute all papers necessary in connection with this application and any continuing, divisional, conversion, re-exam, provisional, or reissue applications thereof and also to execute separate assignments in connection with such applications as the Assignee may deem necessary or expedient.

The undersigned agrees to execute all papers necessary in connection with any interference which may be declared concerning this application or continuation, division, conversion, re-exam, provisional, or reissue thereof or Letters Patent(s) or reissue patent issued thereon and to cooperate with the Assignee in every way possible in obtaining and producing evidence and proceeding with such interference.

The undersigned agrees to execute all papers and documents and to perform any act which may be necessary in connection with claims or provisions of the International Convention for the Protection of Industrial Property or similar agreements.

COMBINED DECLARATION AND ASSIGNMENT FOR PATENT APPLICATIONS

The undersigned agrees to perform all affirmative acts which may be necessary to obtain a grant of (a) valid United States of America patent(s) or a grant of (a) valid United States of America and any foreign patent(s) to the Assignee and to vest all rights therein hereby conveyed to said Assignee as fully and entirely as the same would have been held by the undersigned if this Assignment and sale had not been made.

The undersigned hereby authorizes and requests the Patent and Trademark Office Officials in the United States of America and in any foreign countries to issue any and all Letters Patent(s) resulting from said application or any continuing, divisional conversion or reissue applications thereof to the said Assignee, as Assignee of the entire interest, and hereby covenants that he has the full right to convey the entire interest herein assigned, and that he has not executed, and will not execute, any agreement in conflict herewith.

The undersigned hereby grants the law firm of GAZDZINSKI & ASSOCIATES, PC, Customer No. **132059**, the power to insert any further identification which may be necessary or desirable in order to comply with the rules of the U.S. Patent and Trademark Office.

The undersigned hereby covenants that no assignment, sale, agreement or encumbrance has been or will be made or entered into which would conflict with this assignment.

The undersigned hereby acknowledges that any willful false statement made in this declaration is punishable under 18 U.S.C. § 1001 by fine or imprisonment of not more than five (5) years, or both.

Executed by the undersigned on the date opposite the undersigned name.

LEGAL NAME OF INVENTOR

Inventor's Name: **JALDERT ROMBOUTS** Date: April 13th, 2017

Signature: _____

An application data sheet (PTO/AIA/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use a separate form for each inventor; or check the box below and complete the attached page(s) to list additional inventors.

☐ Additional inventors are being named on the 1 supplemental sheet(s) attached hereto.

SUPPLEMENTAL SHEET FOR COMBINED DECLARATION AND ASSIGNMENT

LEGAL NAME OF JOINT INVENTOR, IF ANY

Inventor's Name: **BORJA IBARZ GABARDOS** Date: _____

Signature: _____

LEGAL NAME OF JOINT INVENTOR, IF ANY

Inventor's Name: **JEAN-BAPTISTE PASSOT** Date: 4-10-2017

Signature: _____

LEGAL NAME OF JOINT INVENTOR, IF ANY

Inventor's Name: **ANDREW SMITH** Date: 4-10-2017

Signature: _____

GAZDZINSKI & ASSOCIATES, PC
16644 West Bernardo Drive, Suite 201, San Diego, CA 92127
Telephone: (858) 675-1670 - Facsimile: (858) 675-1674 - Email: docket@gazpat.com

SUPPLEMENTAL SHEET FOR COMBINED DECLARATION AND ASSIGNMENT

LEGAL NAME OF JOINT INVENTOR, IF ANY

Inventor's Name: **BORJA IBARZ GABARDOS** Date: 4/11/2017

Signature: _____

LEGAL NAME OF JOINT INVENTOR, IF ANY

Inventor's Name: **JEAN-BAPTISTE PASSOT** Date: _____

Signature: _____

LEGAL NAME OF JOINT INVENTOR, IF ANY

Inventor's Name: **ANDREW SMITH** Date: _____

Signature: _____

GAZDZINSKI & ASSOCIATES, PC
16644 West Bernardo Drive, Suite 201, San Diego, CA 92127
Telephone: (858) 675-1670 - Facsimile: (858) 675-1674 - Email: docket@gazpat.com

Electronic Acknowledgement Receipt	
EFS ID:	29092518
Application Number:	15340807
International Application Number:	
Confirmation Number:	3030
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Customer Number:	132059
Filer:	Peter John Gutierrez III/Catherine Miller
Filer Authorized By:	Peter John Gutierrez III
Attorney Docket Number:	BRAIN.133A/BC201608A
Receipt Date:	02-MAY-2017
Filing Date:	01-NOV-2016
Time Stamp:	14:55:43
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Oath or Declaration filed	Brain_133A_Exec_Dec.pdf	1068440 94145554c0a48f7e901ff5091205efea1d574d1d	no	4

Warnings:

Information:	
Total Files Size (in bytes):	1068440

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

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.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/AIA/80 (07-12)
Approved for use through 11/30/2014. OMB 0651-0035
U.S. Patent and Trademark Office: U.S DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE USPTO

I hereby revoke all previous powers of attorney given in the application identified in the attached statement under 37 CFR 3.73(c).

I hereby appoint:

☒ Practitioners associated with Customer Number: 132059

OR

☐ Practitioner(s) named below (if more than ten patent practitioners are to be named, then a customer number must be used):

Name	Registration Number	Name	Registration Number

As attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with any and all patent applications assigned only to the undersigned according to the USPTO assignment records or assignments documents attached to this form in accordance with 37 CFR 3.73(c).

Please change the correspondence address for the application identified in the attached statement under 37 CFR 3.73(c) to:

☑ The address associated with Customer Number: 132059

OR

☐	Firm or Individual Name		
	Address		
	City	State	Zip
	Country		
	Telephone	Email	

Assignee Name and Address: Brain Corporation
9401 Waples Street, Suite 100
San Diego, CA 92121

A copy of this form, together with a statement under 37 CFR 3.73(c) (Form PTO/AIA/96 or equivalent) is required to be Filed in each application in which this form is used. The statement under 37 CFR 3.73(c) may be completed by one of The practitioners appointed in this form, and must identify the application in which this Power of Attorney is to be filed.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee

Signature	Eugene Izhikevich	Date	9/2/2016
Name	Dr. Eugene M. Izhikevich	Telephone	
Title	Co-founder, Chairman, and CEO of Brain Corporation		

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. 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 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application 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.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: Jaldert Rombouts, et al.

Application No./Patent No.: 15/340,807 Filed/Issue Date: November 1, 2016

Titled: SYSTEMS AND METHODS FOR ROBOTIC MAPPING

Brain Corporation, a Corporation

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☑ The assignee of the entire right, title, and interest.

2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):

   ☐ The extent (by percentage) of its ownership interest is _____%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

   ☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. ☐ The recipient, via a court proceeding or the like (*e.g.*, bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

A. ☑ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel 042215, Frame 0172, or for which a copy thereof is attached.

B. ☐ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

   1. From: _____ To: _____

      The document was recorded in the United States Patent and Trademark Office at

      Reel _____, Frame _____, or for which a copy thereof is attached.

   2. From: _____ To: _____

      The document was recorded in the United States Patent and Trademark Office at

      Reel _____, Frame _____, or for which a copy thereof is attached.

This collection of information is required by 37 CFR 3.73(b). 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 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application 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**.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/AIA/96 (08-12)
Approved for use through 01/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

STATEMENT UNDER 37 CFR 3.73(c)

3. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

4. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

5. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

6. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☑ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Peter J. Gutierrez, III/	2017-05-15
Signature	Date
Peter J. Gutierrez, III	56,732
Printed or Typed Name	Title or Registration Number

Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
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.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Acknowledgement Receipt	
EFS ID:	29215712
Application Number:	15340807
International Application Number:	
Confirmation Number:	3030
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Customer Number:	132059
Filer:	Peter John Gutierrez III/Catherine Miller
Filer Authorized By:	Peter John Gutierrez III
Attorney Docket Number:	BRAIN.133A/BC201608A
Receipt Date:	15-MAY-2017
Filing Date:	01-NOV-2016
Time Stamp:	19:08:53
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	POA_Brain.pdf	483945 da07d920c96cba156b8359a4bc79e8e1438f0573	no	1

Warnings:

Information:					
2	Assignee showing of ownership per 37 CFR 3.73	AssignState_3_73c.pdf	134860 f71b64f85d3d5703018fd6ccfcb3e2775b6df8ae	no	3
Warnings:					
Information:					
			Total Files Size (in bytes):	618805	

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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.
New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

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United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/340,807	11/01/2016	Jaldert Rombouts	BRAIN.133A/BC201608A

CONFIRMATION NO. 3030

132059
Gazdzinski & Associates, PC
16644 West Bernardo Drive
Suite 201
San Diego, CA 92127

POA ACCEPTANCE LETTER

OC000000091444616

Date Mailed: 05/18/2017

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 05/15/2017.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/zretta/

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventors	:	Jaldert Rombouts, et al.
App. No.	:	15/340,807
Filed	:	November 1, 2016
For	:	**SYSTEMS AND METHODS FOR ROBOTIC MAPPING**
Examiner	:	Unknown
Group Art Unit:		Unknown

CUSTOMER NO. 132059

CERTIFICATE OF ELECTRONIC (EFS-WEB) TRANSMISSION

I hereby certify that this correspondence is being transmitted via the Office electronic filing system in accordance with 37 C.F.R. § 1.8(a)(1)(i)(C) from the Pacific Time Zone of the United States on the local date shown below.

Date: May 2, 2018

/Peter J. Gutierrez, III/
Peter J. Gutierrez, III, Reg. No. 56,732

INFORMATION DISCLOSURE STATEMENT

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Examiner:

Applicant submits herewith an IDS citing forty-three (43) references for consideration by the Office.

This Information Disclosure Statement is being filed before the mailing date of a first Office Action on the merits, and presumably no fee is required in accordance with 37 C.F.R. § 1.97(b)(3). If a first Office Action on the merits was mailed before the mailing date of this Statement, it is requested that the Commissioner charge any fees under 37 C.F.R. § 1.16 and § 1.17 to Deposit Account No. 501423.

Pursuant to 37 C.F.R. § 1.97(g) and (h), Applicant makes no representation that a search has been made or that the information cited is considered to be material to patentability.

Additionally, inclusion on this list is not an admission that any of the cited documents are prior art in this application. Further, Applicant makes no representation regarding the completeness of this list or that better art does not exist.

Respectfully submitted,

GAZDZINSKI & ASSOCIATES, PC

Dated: May 2, 2018

By: /Peter J. Gutierrez, III/
Peter J. Gutierrez, III
Registration No. 56,732
16644 West Bernardo Drive, Suite 201
San Diego, CA 92127
Telephone: (858) 675-1670
Facsimile: (858) 675-1674

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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 1 of 5

Complete if Known	
Application Number	15340807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	001	US-5155684	10-13-1992	BURKE; Steven A. et al.	
	002	US-5341540	08-30-1994	SOUPERT; Jean-Louis D. C. et al.	
	003	US-7212651	05-01-2007	VIOLA; Paul A. et al.	
	004	US-7576639	08-18-2009	BOYLES; Tonnie Michael et al.	
	005	US-8174568	05-08-2012	SAMARASEKERA; Supun et al.	
	006	US-8514236	08-20-2013	WANG; Feng-Feng et al.	
	007	US-8774970	07-08-2014	KNOPOW; Jeremy F. et al.	
	008	US-8843244	09-23-2014	PHILLIPS; Emilie et al.	
	009	US-9192869	11-24-2015	MORIYA; Toshio	
	010	US-9298183	03-29-2016	ARTÉS; Harold et al.	
	011	US-9315192	04-19-2016	ZHU; Jiajun et al.	
	012	US-9746339	08-29-2017	MATTILA; Ville-Veikko et al.	
	013	US-9775681	10-03-2017	QUAID; Arthur et al.	
	014	US-20020107649	08-08-2002	TAKIGUCHI; Kiyoaki et al.	
	015	US-20040258307	12-23-2004	VIOLA; Paul A. et al.	
	016	US-20060187017	08-24-2006	KULESZ; James J. et al.	
	017	US-20070229238	10-04-2007	BOYLES; Tonnie Michael et al.	
	018	US-20070229522	10-04-2007	WANG; Feng-Feng et al.	
	019	US-20080059015	03-06-2008	WHITTAKER; William L. et al.	
	020	US-20090228166	09-10-2009	DURKOS; Larry G. et al.	

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.97 and 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application 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, 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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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 2 of 5

Complete if Known	
Application Number	15340807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	021	US-20120001787	01-05-2012	VAN; Dorp Philip	
	022	US-20120072166	03-22-2012	KEAL; William Kerry et al.	
	023	US-20120109150	05-03-2012	QUAID; Arthur et al.	
	024	US-20130325325	12-05-2013	DJUGASH; Joseph Maria Angelo	
	025	US-20130332065	12-12-2013	HAKIM; Daniel et al.	
	026	US-20140002843	01-02-2014	MIYAMOTO; Naruyuki et al.	
	027	US-20150199458	07-16-2015	BACON; James A. et al.	
	028	US-20150205299	07-23-2015	SCHNITTMAN; Mark et al.	
	029	US-20150234387	08-20-2015	MULLAN; Pramila et al.	
	030	US-20150261223	09-17-2015	FONG; Philip et al.	
	031	US-20150283703	10-08-2015	IZHIKEVICH; Eugene M. et al.	
	032	US-20150323197	11-12-2015	BURDETT; Michael P. et al.	
	033	US-20150362921	12-17-2015	HANAOKA; Tohru et al.	
	034	US-20160065909	03-03-2016	DERENNE; Richard A. et al.	
	035	US-20160078303	03-17-2016	SAMARASEKERA; Supun et al.	
	036	US-20160121487	05-05-2016	MOHAN; Siddharth et al.	
	037	US-20160182502	06-23-2016	SMITH; Ned M. et al.	
	038	US-20160282862	09-29-2016	DUFFLEY; Samuel et al.	
	039	US-20160287044	10-06-2016	TANAKA; Shoji et al.	
	040	US-20160309973	10-27-2016	SHEIKH; Faizan et al.	

Examiner Signature		Date Considered	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 3 of 5

Complete if Known	
Application Number	15340807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	041	US-20170139551	05-18-2017	LUPCHO III; Albert R. et al.	
	042	US-20170329333	11-16-2017	PASSOT; Jean-Baptiste et al.	
	043	US-20170329347	11-16-2017	PASSOT; Jean-Baptiste et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]-Number[4]-Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures Appear	T[6]
		None				

Examiner Signature		Date Considered	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Sheet 4 of 5

Complete if Known	
Application Number	15340807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A

NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No.[1]	Include name of the author(in CAPITAL LETTERS),title of the article(when appropriate), title of the item (book,magazine,journal,serial,symposium,catalog,etc.),date,page(s),volume-issue number(s),publisher, city and/or country where published.	T[2]
		None	

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application 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, 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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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 5 of 5

Complete if Known	
Application Number	15340807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☒ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☐ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Peter J. Gutierrez, III/	Date (YYYY-MM-DD)	2018-05-02
Name/Print	Peter J. Gutierrez, III	Registration Number	56,732

This collection of information is required by 37 CFR 1.97 and 1.98. 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 CFR1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application 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.**

Electronic Acknowledgement Receipt	
EFS ID:	32517702
Application Number:	15340807
International Application Number:	
Confirmation Number:	3030
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Customer Number:	132059
Filer:	Peter John Gutierrez III/Catherine Miller
Filer Authorized By:	Peter John Gutierrez III
Attorney Docket Number:	BRAIN.133A/BC201608A
Receipt Date:	02-MAY-2018
Filing Date:	01-NOV-2016
Time Stamp:	19:55:26
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Information Disclosure Statement (IDS) Form (SB08)	BRAIN_133A_IDS.pdf	344795 df7a2c7459706d2bd4b227f991a1e9bad851ba30	no	7

Warnings:

Information:	
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Total Files Size (in bytes):	344795

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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.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/340,807	11/01/2016	Jaldert Rombouts	BRAIN.133A/BC201608A

CONFIRMATION NO. 3030

132059
Gazdzinski & Associates, PC
16644 West Bernardo Drive
Suite 201
San Diego, CA 92127

PUBLICATION NOTICE

OC000000099273966

Title:SYSTEMS AND METHODS FOR ROBOTIC MAPPING

Publication No.US-2018-0120116-A1
Publication Date:05/03/2018

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Public Records Division. The Public Records Division can be reached by telephone at (571) 272-3150 or (800) 972-6382, by facsimile at (571) 273-3250, by mail addressed to the United States Patent and Trademark Office, Public Records Division, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently https://portal.uspto.gov/pair/PublicPair. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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Alexandria, Virginia 22313-1450
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/340,807	11/01/2016	Jaldert Rombouts	BRAIN.133A/BC201608A	3030

132059 7590 05/31/2018

Gazdzinski & Associates, PC
16644 West Bernardo Drive
Suite 201
San Diego, CALIFORNIA 92127
UNITED STATES OF AMERICA

EXAMINER	
MOYER, DALE S	

ART UNIT	PAPER NUMBER
3664	

MAIL DATE	DELIVERY MODE
05/31/2018	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 15/340,807	Applicant(s) Rombouts et al.	
	Examiner DALE MOYER	Art Unit 3664	AIA Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☑ Responsive to communication(s) filed on 01 November 2016.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL.** 2b) ☑ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5) ☑ Claim(s) 1-20 is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6) ☑ Claim(s) 1-7 is/are allowed.

7) ☑ Claim(s) 8,10,13-16 and 18 is/are rejected.

8) ☑ Claim(s) 9,11,17 and 19-20 is/are objected to.

9) ☐ Claim(s) _____ are subject to restriction and/or election requirement

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to **PPHfeedback@uspto.gov.**

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☑ Notice of References Cited (PTO-892)

2) ☑ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date 03/02/2017 and 05/02/2018.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date _____.

4) ☐ Other: _____.

DETAILED ACTION

Notice of Pre-AIA or AIA Status

The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (a)(1) the claimed invention was patented, described in a printed publication, or in public use, on sale or otherwise available to the public before the effective filing date of the claimed invention.

Claim(s) 8, 10, 13-16 and 18 is/are rejected under 35 U.S.C. 102(a)(1) as being anticipated by Eade et al. (US 2012/0121161 A1).

Regarding claims 8, 16 and 18, Eade et al. disclose a robot comprising: a sensor (Fig. 1, element 104) configured to take scans of an environment at a plurality of nodes (Fig. 2; Fig. 4, element 1804, landmark nodes), wherein each node is associated with a location (paragraph 0099, 0144); and a mapping and localization unit (Fig. 3, element 604, paragraph 0113) configured to: create a graph of the nodes based at least in part on the taken scans (paragraph 0045); determine extended scan groups (Fig. 6, step 1010) based at least in part on groups of the plurality of nodes (paragraphs 0148-0153) and perform scan matching (Figs. 7-8, step 2702) on the extended scan groups (paragraphs 0164, 0166-0167).

Regarding claim 10, Eade et al. disclose the robot as applied to claim 8 above, wherein the mapping and localization unit is further configured to determine confidences associated with the location of each node (paragraph 0135).

Regarding claim 13, Eade et al. disclose the robot as applied to claim 8 above, further comprising an actuator (Fig. 1, element 110) configured to move the robot between locations (paragraph 0100).

Regarding claim 14, Eade et al. disclose the robot as applied to claim 8 above, further comprising a user interface configured for user control of the robot (paragraph 0232).

Regarding claim 15, Eade et al. disclose the robot as applied to claim 8 above, further comprising a navigation unit configured to navigate the robot autonomously (paragraph 0046, 0103).

Allowable Subject Matter

Claims 1-7 are allowed. Claims 9, 11-12, 17 and 19-20 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to DALE MOYER whose telephone number is (571)270-7821. The examiner can normally be reached on Monday-Friday 8am-5pm.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at http://www.uspto.gov/interviewpractice.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Khoi H Tran can be reached on 571-272-6919. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available

through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Dale Moyer/
Primary Examiner, Art Unit 3664

Notice of References Cited	Application/Control No. 15/340,807	Applicant(s)/Patent Under Reexamination Rombouts et al.	
	Examiner DALE MOYER	Art Unit 3664	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-20170105592-A1	04-2017	Fong; Philip	A47L9/2873	1/1
*	B	US-20120121161-A1	05-2012	Eade; Ethan	G09B29/007	382/153
*	C	US-20130138246-A1	05-2013	Gutmann; Jens-Steffen	G05D1/0231	700/253
*	D	US-20150304634-A1	10-2015	Karvounis; John George	H04N13/239	348/46
*	E	US-20160290805-A1	10-2016	Irish; Andrew T.	G01C21/005	1/1
	F					
	G					
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FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/340,807	Rombouts et al.
	Examiner	Art Unit
	DALE MOYER	3664

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

CLAIMS

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	05/29/2018								
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	16	✓								
	17	O								
	18	✓								
	19	O								
	20	O								

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/340,807	Rombouts et al.
	Examiner	Art Unit
	DALE MOYER	3664

CPC - Searched*		
Symbol	**Date**	**Examiner**
G05D1/0251	05/09/2018	DM
G05D1/0253	05/09/2018	DM
B25J9/1697	05/09/2018	DM
B25J15/0616	05/29/2018	DM
G05D2201/0207	05/29/2018	DM
G05D1/0225	05/29/2018	DM
G05D2201/0215	05/29/2018	DM

CPC Combination Sets - Searched*		
Symbol	**Date**	**Examiner**

US Classification - Searched*			
Class	**Subclass**	**Date**	**Examiner**

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	**Date**	**Examiner**
considered IDS received 03/02/2017	05/09/2018	DM
considered IDS received 05/02/2018	05/09/2018	DM
inventor name search	05/09/2018	DM
see attached EAST Search History Report	05/29/2018	DM

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/340,807	Rombouts et al.
	Examiner	Art Unit
	DALE MOYER	3664

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
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S2	156	("20020158599" | "20020175894" | "20020198854" | "20030023347" | "20030025082" | "20030108415" | "20030144764" | "20030220714" | "20040030449" | "20040036437" | "20040051493" | "20040167641" | "20040172166" | "20040172168" | "20040267404" | "20050008227" | "20050065651" | "20050069207" | "20050125099" | "20060207419" | "20060250101" | "20070074177" | "20070151389" | "20070200525" | "20070255454" | "20070260356" | "20080040040" | "20080097644" | "20080112596" | "20080140257" | "20080319929" | "20090037033" | "20090231359" | "20090234501" | "20090265036" | "20090272585" | "20100114372" | "20100152896" | "20100152899" | "20100228264" | "20100286824" | "20100305758" | "20100312730" | "20110026770" | "20110035188" | "20110060460" | "20110067479" | "20110144802" | "20110158476" | "20110160906" | "20110160907" | "20110196199" | "20110218676" | "20110244919" | "20110282169" | "20110296944" | "20120008838" | "20120017232" | "20120045068" | "20120079670" | "20120143495" | "20120144242" | "20120150777" | "20120209432" | "20120221147" | "20120303091" | "20120303160" | "20120308076" | "20120308136" | "20130000480" | "20130044139" | "20130066468" | "20130096719" | "20130116827" | "20130173060" | "20130206170" | "20130218339" | "20130245829" | "20130274924" | "20130310979" | "20130325775" | "20130346347" | "20140016858" | "20140081895" | "20140089232" | "20140114479" | "20140187519" | "20140190514" | "20140276951" | "20140277718" | "20140350723" | "20140358828" |	US-PGPUB; USPAT	OR	OFF	2018/05/09 12:45

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			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
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S11	2	WO-2015047195-$	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2018/05/09 12:53
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S14	17	S12 S13	US-PGPUB; USPAT	OR	OFF	2018/05/09 13:15
S15	5	S14 AND ray	US-PGPUB; USPAT	OR	OFF	2018/05/09 13:15
S16	123	SLAM WITH graph	US-PGPUB; USPAT	OR	OFF	2018/05/09 13:19
S17	3519	(localization ADJ2 mapping)	US-PGPUB; USPAT	OR	OFF	2018/05/09 13:29
S18	950	(localization ADJ2 mapping) AND robot.ti,ab,bsum.	US-PGPUB; USPAT	OR	OFF	2018/05/09 13:29
S19	1051	S16 S18	US-PGPUB; USPAT	OR	OFF	2018/05/09 13:29
S20	422	(localization ADJ2 mapping).ti,ab,bsum. AND robot.ti,ab,bsum.	US-PGPUB; USPAT	OR	OFF	2018/05/09 13:32
S21	380	(simultaneous ADJ localization ADJ2 mapping).ti,ab,bsum. AND robot.ti,ab,bsum.	US-PGPUB; USPAT	OR	OFF	2018/05/09 13:32
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S24	422	(simultaneous ADJ2 (localisation OR location OR localization) ADJ2 mapping).ti,ab,bsum. AND robot.ti,ab,bsum.	US-PGPUB; USPAT	OR	OFF	2018/05/09 13:34
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S26	1128	S19 S25	US-PGPUB; USPAT	OR	ON	2018/05/09 13:40
S27	2	S26 AND (map WITH graph WITH ray)	US-PGPUB; USPAT	OR	ON	2018/05/09 13:40
S28	1	("2016/0290805").URPN.	USPAT	OR	OFF	2018/05/09 13:59
S29	0	(15/038702).APP.	USPAT; USOCR	OR	OFF	2018/05/09 14:00
S30	7	("20050234679" | "20080033645" | "20110102545" | "20120159408" | "20120245844" | "20130080045" | "6900758").PN.	US-PGPUB; USPAT	OR	ON	2018/05/09 14:01
S31	226	(US-20020107649-$ or US-20040258307-$ or US-20060187017-$ or US-20070229238-$ or US-20070229522-$ or US-20080059015-$ or US-20090228166-$ or US-20120001787-$ or US-20120072166-$ or US-20120109150-$ or US-20130325325-$ or US-20130332065-$ or US-20140002843-$ or US-20150199458-$ or US-20150205299-$ or US-20150234387-$ or US-20150261223-$ or US-20150283703-$ or US-20150323197-$ or US-20150362921-$ or US-20160065909-$ or US-20160078303-$ or US-20160121487-$ or US-20160182502-$ or US-20160282862-$ or US-20160287044-$).did. or (US-20160309973-$ or US-20170139551-$ or US-20170329333-$ or US-20170329347-$ or US-20020158599-$ or US-20020175894-$ or US-20020198854-$ or US-20030023347-$ or US-20030025082-$ or US-20030108415-$ or US-20030144764-$ or US-20030220714-$ or US-20040030449-$ or US-20040036437-$ or US-20040051493-$ or US-20040167641-$ or US-20040172166-$ or US-20040172168-$ or US-20040267404-$ or US-20050008227-$ or US-20050065651-$ or US-20050069207-$ or US-20050125099-$ or US-20060207419-$ or US-20060250101-$ or US-20070074177-$ or US-20070151389-$).did. or (US-20070200525-$ or US-20070255454-$ or US-20070260356-$ or US-20080040040-$ or US-20080097644-$ or US-20080112596-$ or US-20080140257-$ or US-20080319929-$ or US-20090037033-$ or US-20090231359-$ or US-20090234501-$ or US-20090265036-$ or US-20090272585-$ or US-20100114372-$ or US-20100152896-$ or US-20100152899-$ or US-20100228264-$ or US-20100286824-$ or US-20100305758-$ or US-20100312730-$ or US-20110026770-$ or US-	US-PGPUB; USPAT	OR	OFF	2018/05/09 14:07

		20110035188-$ or US-20110060460-$ or US-20110067479-$ or US-20110144802-$ or US-20110158476-$ or US-20110160906-$).did. or (US-20110160907-$ or US-20110196199-$ or US-20110218676-$ or US-20110244919-$ or US-20110282169-$ or US-20110296944-$ or US-20120008838-$ or US-20120017232-$ or US-20120045068-$ or US-20120079670-$ or US-20120143495-$ or US-20120144242-$ or US-20120150777-$ or US-20120209432-$ or US-20120221147-$ or US-20120303091-$ or US-20120303160-$ or US-20120308076-$ or US-20120308136-$ or US-20130000480-$ or US-20130044139-$ or US-20130066468-$ or US-20130096719-$ or US-20130116827-$ or US-20130173060-$ or US-20130206170-$ or US-20130218339-$).did. or (US-20130245829-$ or US-20130274924-$ or US-20130310979-$ or US-20130325775-$ or US-20130346347-$ or US-20140016858-$ or US-20140081895-$ or US-20140089232-$ or US-20140114479-$ or US-20140187519-$ or US-20140190514-$ or US-20140276951-$ or US-20140277718-$ or US-20140350723-$ or US-20140358828-$ or US-20140371907-$ or US-20140371912-$ or US-20150032258-$ or US-20150094850-$ or US-20150094852-$ or US-20150120128-$ or US-20150127155-$ or US-20150185027-$ or US-20150204559-$ or US-20150213299-$ or US-20150306761-$ or US-20150317357-$).did. or (US-20150339589-$ or US-20160057925-$ or US-20160075026-$ or US-20180120116-$ or US-20170153646-$ or US-20140100768-$ or US-20170344013-$ or US-20160071278-$ or US-20080294338-$ or US-20180114293-$ or US-20180113469-$ or US-20180112985-$ or US-20180088597-$ or US-20180077534-$ or US-20170048816-$ or US-20160290805-$ or US-20110194755-$ or US-20130080045-$ or US-20120245844-$ or US-20120159408-$ or US-20110102545-$ or US-20080033645-$ or US-20050234679-$).did. or (US-5155684-$ or US-5341540-$ or US-7212651-$ or US-7576639-$ or US-8174568-$ or US-8514236-$ or US-8774970-$ or US-8843244-$ or US-9192869-$ or US-9298183-$ or US-9315192-$ or US-9746339-$ or US-9775681-$ or US-4638445-$ or US-4763276-$ or US-4852018-$ or US-5121497-$ or US-				

		5280179-$ or US-5446356-$ or US-5602761-$ or US-5612883-$ or US-5673367-$ or US-5719480-$ or US-5841959-$ or US-5994864-$ or US-6124694-$).did. or (US-6169981-$ or US-6243622-$ or US-6366293-$ or US-6442451-$ or US-6560511-$ or US-6584375-$ or US-6636781-$ or US-6697711-$ or US-6760645-$ or US-6812846-$ or US-6961060-$ or US-7002585-$ or US-7148644-$ or US-7243334-$ or US-7342589-$ or US-7668605-$ or US-8145492-$ or US-8364314-$ or US-8380348-$ or US-8380652-$ or US-8419804-$ or US-8423225-$ or US-8452448-$ or US-8515162-$ or US-8639035-$ or US-8639644-$ or US-8679260-$).did. or (US-8793205-$ or US-8924021-$ or US-8958911-$ or US-8958912-$ or US-8958937-$ or US-9008840-$ or US-9015093-$ or US-9144907-$ or US-9242372-$ or US-9939814-$ or US-9286810-$ or US-9844879-$ or US-8576235-$ or US-7634336-$ or US-9720071-$ or US-6900758-$).did.				
S32	1330	S19 S25 S31	US-PGPUB; USPAT	OR	ON	2018/05/09 14:08
S33	1193	S32 AND @ad<"20161101"	US-PGPUB; USPAT	OR	ON	2018/05/09 14:08
S34	946	S33 AND (slam! OR graph)	US-PGPUB; USPAT	OR	ON	2018/05/09 14:08
S35	282	S33 AND (slam! AND graph)	US-PGPUB; USPAT	OR	ON	2018/05/09 14:08
S36	120	S33 AND (slam! AND graph) AND node	US-PGPUB; USPAT	OR	ON	2018/05/09 14:09
S37	467	(simultaneous$4 ADJ2 (localisation OR location OR localization) ADJ2 mapping).ti,ab,bsum. AND robot.ti,ab,bsum.	US-PGPUB; USPAT	OR	ON	2018/05/09 14:42
S38	0	(match$4).bi. AND "454."	US-PGPUB; USPAT	OR	ON	2018/05/09 14:42
S39	326	(match$4).bi. AND S37	US-PGPUB; USPAT	OR	ON	2018/05/09 14:42
S40	149	(pose SAME match$4).bi. AND S37	US-PGPUB; USPAT	OR	ON	2018/05/09 14:43
S41	467	(simultaneous$4 ADJ2 (localisation OR location OR localization) ADJ2 mapping).ti,ab,bsum. AND robot.ti,ab,bsum.	US-PGPUB; USPAT	OR	ON	2018/05/09 16:51
S42	29	(scan NEAR3 match$4).bi. AND S41	US-PGPUB; USPAT	OR	ON	2018/05/09 16:51
S43	81	(RANSAC).bi. AND S41	US-PGPUB; USPAT	OR	ON	2018/05/09 16:55
S44	34	((ICP! AND (iterative NEAR2 closest NEAR2 point))).bi. AND S41	US-PGPUB; USPAT	OR	ON	2018/05/09 16:56
S45	101	S43 S44	US-PGPUB; USPAT	OR	ON	2018/05/09 16:56

S46	115	S43 S44 S42	US-PGPUB; USPAT	OR	ON	2018/05/09 16:56
S47	38	S46 AND ray	US-PGPUB; USPAT	OR	ON	2018/05/09 16:56
S48	87	S46 AND trac$4	US-PGPUB; USPAT	OR	ON	2018/05/09 16:56
S49	2	S46 AND (ray NEAR3 trac$4)	US-PGPUB; USPAT	OR	ON	2018/05/09 16:57
S50	87	S47 S48	US-PGPUB; USPAT	OR	ON	2018/05/09 16:57
S51	16	S46 AND (trace OR tracing)	US-PGPUB; USPAT	OR	ON	2018/05/09 17:00
S52	256	(US-20020107649-$ or US-20040258307-$ or US-20060187017-$ or US-20070229238-$ or US-20070229522-$ or US-20080059015-$ or US-20090228166-$ or US-20120001787-$ or US-20120072166-$ or US-20120109150-$ or US-20130325325-$ or US-20130332065-$ or US-20140002843-$ or US-20150199458-$ or US-20150205299-$ or US-20150234387-$ or US-20150261223-$ or US-20150283703-$ or US-20150323197-$ or US-20150362921-$ or US-20160065909-$ or US-20160078303-$ or US-20160121487-$ or US-20160182502-$ or US-20160282862-$ or US-20160287044-$).did. or (US-20160309973-$ or US-20170139551-$ or US-20170329333-$ or US-20170329347-$ or US-20020158599-$ or US-20020175894-$ or US-20020198854-$ or US-20030023347-$ or US-20030025082-$ or US-20030108415-$ or US-20030144764-$ or US-20030220714-$ or US-20040030449-$ or US-20040036437-$ or US-20040051493-$ or US-20040167641-$ or US-20040172166-$ or US-20040172168-$ or US-20040267404-$ or US-20050008227-$ or US-20050065651-$ or US-20050069207-$ or US-20050125099-$ or US-20060207419-$ or US-20060250101-$ or US-20070074177-$ or US-20070151389-$).did. or (US-20070200525-$ or US-20070255454-$ or US-20070260356-$ or US-20080040040-$ or US-20080097644-$ or US-20080112596-$ or US-20080140257-$ or US-20080319929-$ or US-20090037033-$ or US-20090231359-$ or US-20090234501-$ or US-20090265036-$ or US-20090272585-$ or US-20100114372-$ or US-20100152896-$ or US-20100152899-$ or US-20100228264-$ or US-20100286824-$ or US-20100305758-$ or US-20100312730-$ or US-20110026770-$ or US-	US-PGPUB; USPAT	OR	OFF	2018/05/09 17:03

		20110035188-$ or US-20110060460-$ or US-20110067479-$ or US-20110144802-$ or US-20110158476-$ or US-20110160906-$).did. or (US-20110160907-$ or US-20110196199-$ or US-20110218676-$ or US-20110244919-$ or US-20110282169-$ or US-20110296944-$ or US-20120008838-$ or US-20120017232-$ or US-20120045068-$ or US-20120079670-$ or US-20120143495-$ or US-20120144242-$ or US-20120150777-$ or US-20120209432-$ or US-20120221147-$ or US-20120303091-$ or US-20120303160-$ or US-20120308076-$ or US-20120308136-$ or US-20130000480-$ or US-20130044139-$ or US-20130066468-$ or US-20130096719-$ or US-20130116827-$ or US-20130173060-$ or US-20130206170-$ or US-20130218339-$).did. or (US-20130245829-$ or US-20130274924-$ or US-20130310979-$ or US-20130325775-$ or US-20130346347-$ or US-20140016858-$ or US-20140081895-$ or US-20140089232-$ or US-20140114479-$ or US-20140187519-$ or US-20140190514-$ or US-20140276951-$ or US-20140277718-$ or US-20140350723-$ or US-20140358828-$ or US-20140371907-$ or US-20140371912-$ or US-20150032258-$ or US-20150094850-$ or US-20150094852-$ or US-20150120128-$ or US-20150127155-$ or US-20150185027-$ or US-20150204559-$ or US-20150213299-$ or US-20150306761-$ or US-20150317357-$).did. or (US-20150339589-$ or US-20160057925-$ or US-20160075026-$ or US-20180120116-$ or US-20170153646-$ or US-20140100768-$ or US-20170344013-$ or US-20160071278-$ or US-20080294338-$ or US-20180114293-$ or US-20180113469-$ or US-20180112985-$ or US-20180088597-$ or US-20180077534-$ or US-20170048816-$ or US-20160290805-$ or US-20110194755-$ or US-20130080045-$ or US-20120245844-$ or US-20120159408-$ or US-20110102545-$ or US-20080033645-$ or US-20050234679-$ or US-20130216098-$ or US-20130184865-$ or US-20120316784-$ or US-20110166737-$).did. or (US-20160271795-$ or US-20170123066-$ or US-20160259993-$ or US-20130138246-$ or US-20040073360-$ or US-20110123135-$ or US-20110010033-$ or US-20100049391-$ or US-20150161818-$ or US-					

		20180075643-$ or US-20150172626-$ or US-20120121161-$ or US-20150304634-$ or US-20140037136-$ or US-20150213617-$).did. or (US-5155684-$ or US-5341540-$ or US-7212651-$ or US-7576639-$ or US-8174568-$ or US-8514236-$ or US-8774970-$ or US-8843244-$ or US-9192869-$ or US-9298183-$ or US-9315192-$ or US-9746339-$ or US-9775681-$ or US-4638445-$ or US-4763276-$ or US-4852018-$ or US-5121497-$ or US-5280179-$ or US-5446356-$ or US-5602761-$ or US-5612883-$ or US-5673367-$ or US-5719480-$ or US-5841959-$ or US-5994864-$ or US-6124694-$).did. or (US-6169981-$ or US-6243622-$ or US-6366293-$ or US-6442451-$ or US-6560511-$ or US-6584375-$ or US-6636781-$ or US-6697711-$ or US-6760645-$ or US-6812846-$ or US-6961060-$ or US-7002585-$ or US-7148644-$ or US-7243334-$ or US-7342589-$ or US-7668605-$ or US-8145492-$ or US-8364314-$ or US-8380348-$ or US-8380652-$ or US-8419804-$ or US-8423225-$ or US-8452448-$ or US-8515162-$ or US-8639035-$ or US-8639644-$ or US-8679260-$).did. or (US-8793205-$ or US-8924021-$ or US-8958911-$ or US-8958912-$ or US-8958937-$ or US-9008840-$ or US-9015093-$ or US-9144907-$ or US-9242372-$ or US-9939814-$ or US-9286810-$ or US-9844879-$ or US-8576235-$ or US-7634336-$ or US-9720071-$ or US-6900758-$ or US-9952053-$ or US-9741140-$ or US-9606542-$ or US-9558424-$ or US-9483879-$ or US-9910444-$ or US-9870624-$ or US-9807365-$ or US-8209144-$ or US-9802322-$ or US-9947134-$).did.				
S53	72	(simultaneous$4 ADJ2 (localisation OR location OR localization) ADJ2 mapping).ti,ab. AND robot.ti,ab.	US-PGPUB; USPAT	OR	ON	2018/05/09 17:04
S54	8	S53 AND ((G05D1/0251 OR G05D1/0253).CPC.)	US-PGPUB; USPAT	OR	ON	2018/05/09 17:07
S55	8	S54 AND (cost OR kalman)	US-PGPUB; USPAT	OR	ON	2018/05/09 17:14
S56	4	S54 AND (manual$4)	US-PGPUB; USPAT	OR	ON	2018/05/09 17:16
S57	0	S54 AND (overlap$4)	US-PGPUB; USPAT	OR	ON	2018/05/09 17:17
S58	132	S41 AND (overlap$4)	US-PGPUB; USPAT	OR	ON	2018/05/09 17:17
S59	8	S54 AND (confidence)	US-PGPUB; USPAT	OR	ON	2018/05/09 17:24
S60	5	(US-20180120116-$ or US-20160290805-$ or US-20130138246-$	US-PGPUB	OR	OFF	2018/05/29 10:15

		or US-20120121161-$ or US-20150304634-$).did.				
S61	4	S60 AND graph	US-PGPUB	OR	OFF	2018/05/29 10:15
S62	0	S61 AND (base OR station OR dock$4)	US-PGPUB	OR	OFF	2018/05/29 10:16
S63	256	(US-20020107649-$ or US-20040258307-$ or US-20060187017-$ or US-20070229238-$ or US-20070229522-$ or US-20080059015-$ or US-20090228166-$ or US-20120001787-$ or US-20120072166-$ or US-20120109150-$ or US-20130325325-$ or US-20130332065-$ or US-20140002843-$ or US-20150199458-$ or US-20150205299-$ or US-20150234387-$ or US-20150261223-$ or US-20150283703-$ or US-20150323197-$ or US-20150362921-$ or US-20160065909-$ or US-20160078303-$ or US-20160121487-$ or US-20160182502-$ or US-20160282862-$ or US-20160287044-$).did. or (US-20160309973-$ or US-20170139551-$ or US-20170329333-$ or US-20170329347-$ or US-20020158599-$ or US-20020175894-$ or US-20020198854-$ or US-20030023347-$ or US-20030025082-$ or US-20030108415-$ or US-20030144764-$ or US-20030220714-$ or US-20040030449-$ or US-20040036437-$ or US-20040051493-$ or US-20040167641-$ or US-20040172166-$ or US-20040172168-$ or US-20040267404-$ or US-20050008227-$ or US-20050065651-$ or US-20050069207-$ or US-20050125099-$ or US-20060207419-$ or US-20060250101-$ or US-20070074177-$ or US-20070151389-$).did. or (US-20070200525-$ or US-20070255454-$ or US-20070260356-$ or US-20080040040-$ or US-20080097644-$ or US-20080112596-$ or US-20080140257-$ or US-20080319929-$ or US-20090037033-$ or US-20090231359-$ or US-20090234501-$ or US-20090265036-$ or US-20090272585-$ or US-20100114372-$ or US-20100152896-$ or US-20100152899-$ or US-20100228264-$ or US-20100286824-$ or US-20100305758-$ or US-20100312730-$ or US-20110026770-$ or US-20110035188-$ or US-20110060460-$ or US-20110067479-$ or US-20110144802-$ or US-20110158476-$ or US-20110160906-$).did. or (US-20110160907-$ or US-20110196199-$ or US-20110218676-$ or US-20110244919-$ or US-20110282169-$	US-PGPUB; USPAT	OR	OFF	2018/05/29 10:17

		or US-20110296944-$ or US-20120008838-$ or US-20120017232-$ or US-20120045068-$ or US-20120079670-$ or US-20120143495-$ or US-20120144242-$ or US-20120150777-$ or US-20120209432-$ or US-20120221147-$ or US-20120303091-$ or US-20120303160-$ or US-20120308076-$ or US-20120308136-$ or US-20130000480-$ or US-20130044139-$ or US-20130066468-$ or US-20130096719-$ or US-20130116827-$ or US-20130173060-$ or US-20130206170-$ or US-20130218339-$).did. or (US-20130245829-$ or US-20130274924-$ or US-20130310979-$ or US-20130325775-$ or US-20130346347-$ or US-20140016858-$ or US-20140081895-$ or US-20140089232-$ or US-20140114479-$ or US-20140187519-$ or US-20140190514-$ or US-20140276951-$ or US-20140277718-$ or US-20140350723-$ or US-20140358828-$ or US-20140371907-$ or US-20140371912-$ or US-20150032258-$ or US-20150094850-$ or US-20150094852-$ or US-20150120128-$ or US-20150127155-$ or US-20150185027-$ or US-20150204559-$ or US-20150213299-$ or US-20150306761-$ or US-20150317357-$).did. or (US-20150339589-$ or US-20160057925-$ or US-20160075026-$ or US-20180120116-$ or US-20170153646-$ or US-20140100768-$ or US-20170344013-$ or US-20160071278-$ or US-20080294338-$ or US-20180114293-$ or US-20180113469-$ or US-20180112985-$ or US-20180088597-$ or US-20180077534-$ or US-20170048816-$ or US-20160290805-$ or US-20110194755-$ or US-20130080045-$ or US-20120245844-$ or US-20120159408-$ or US-20110102545-$ or US-20080033645-$ or US-20050234679-$ or US-20130216098-$ or US-20130184865-$ or US-20120316784-$ or US-20110166737-$).did. or (US-20160271795-$ or US-20170123066-$ or US-20160259993-$ or US-20130138246-$ or US-20040073360-$ or US-20110123135-$ or US-20110010033-$ or US-20100049391-$ or US-20150161818-$ or US-20180075643-$ or US-20150172626-$ or US-20120121161-$ or US-20150304634-$ or US-20140037136-$ or US-20150213617-$ or US-20140350839-$).did. or (US-5155684-$ or US-5341540-$ or US-7212651-$ or US-7576639-$ or US-8174568-$ or US-					

		8514236-$ or US-8774970-$ or US-8843244-$ or US-9192869-$ or US-9298183-$ or US-9315192-$ or US-9746339-$ or US-9775681-$ or US-4638445-$ or US-4763276-$ or US-4852018-$ or US-5121497-$ or US-5280179-$ or US-5446356-$ or US-5602761-$ or US-5612883-$ or US-5673367-$ or US-5719480-$ or US-5841959-$ or US-5994864-$ or US-6124694-$).did. or (US-6169981-$ or US-6243622-$ or US-6366293-$ or US-6442451-$ or US-6560511-$ or US-6584375-$ or US-6636781-$ or US-6697711-$ or US-6760645-$ or US-6812846-$ or US-6961060-$ or US-7002585-$ or US-7148644-$ or US-7243334-$ or US-7342589-$ or US-7668605-$ or US-8145492-$ or US-8364314-$ or US-8380348-$ or US-8380652-$ or US-8419804-$ or US-8423225-$ or US-8452448-$ or US-8515162-$ or US-8639035-$ or US-8639644-$ or US-8679260-$).did. or (US-8793205-$ or US-8924021-$ or US-8958911-$ or US-8958912-$ or US-8958937-$ or US-9008840-$ or US-9015093-$ or US-9144907-$ or US-9242372-$ or US-9939814-$ or US-9844879-$ or US-8576235-$ or US-7634336-$ or US-9720071-$ or US-6900758-$ or US-9952053-$ or US-9741140-$ or US-9606542-$ or US-9558424-$ or US-9483879-$ or US-9910444-$ or US-9870624-$ or US-9807365-$ or US-8209144-$ or US-9802322-$ or US-9947134-$).did.				
S64	3	S63 AND (base OR station OR dock$4).ti,ab.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2018/05/29 10:17
S65	13605	b25j.cpcl. AND (base OR station OR dock$4).ti,ab.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2018/05/29 10:17
S66	3158	b25j.cpcl. AND (base OR station OR dock$4).ti,ab.	US-PGPUB; USPAT	OR	OFF	2018/05/29 10:18
S67	1487152	b25j.cpcl. AND (base OR station OR dock$4).ti,ab. ANG graph	US-PGPUB; USPAT	OR	OFF	2018/05/29 10:18
S68	136	b25j.cpcl. AND (base OR station OR dock$4).ti,ab. AND graph	US-PGPUB; USPAT	OR	OFF	2018/05/29 10:18
S69	262	b25j.cpcl. AND (base OR station OR dock$4).ti,ab. AND graph	US-PGPUB; USPAT	OR	ON	2018/05/29 10:18
S70	33	S69 AND ((B25J9/1697 OR B25J15/0616 OR G05D2201/0207).CPC.)	US-PGPUB; USPAT	OR	ON	2018/05/29 10:19

S71	144	(recharg$4 OR charg$4 OR dock$4 OR station).ti,ab. AND ((B25J9/1697 OR B25J15/0616 OR G05D2201/0207).CPC.)	US-PGPUB; USPAT	OR	ON	2018/05/29 10:20
S72	29	(recharg$4 OR charg$4 OR dock$4 OR station).ti,ab. AND ((G05D2201/0207).CPC.)	US-PGPUB; USPAT	OR	ON	2018/05/29 10:21
S73	6	S71 AND (route OR search).ti.ab.	US-PGPUB; USPAT	OR	ON	2018/05/29 10:21
S74	0	S71 AND (route OR search).ti,ab.	US-PGPUB; USPAT	OR	ON	2018/05/29 10:22
S75	11	S71 AND (route OR search).bsum.	US-PGPUB; USPAT	OR	ON	2018/05/29 10:22
S76	0	("2018/0004219").URPN.	USPAT	OR	OFF	2018/05/29 10:23
S77	0	(14/890414 | 15/685825).APP.	USPAT; USOCR	OR	OFF	2018/05/29 10:23
S78	2	(14/890414 | 15/685825).APP.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/05/29 10:23
S79	7	((B25J9/1697 AND G05D1/0225 AND G05D2201/0215).CPC.)	US-PGPUB; USPAT; USOCR	OR	OFF	2018/05/29 10:25
S80	1	S60 AND (scan ADJ match$4)	US-PGPUB	OR	OFF	2018/05/29 10:30
S81	5	S60 AND (match$4)	US-PGPUB	OR	OFF	2018/05/29 10:30
S82	1	(US-20120121161-$).did.	US-PGPUB	OR	OFF	2018/05/29 10:37
S83	1	S82 AND (graph WITH node)	US-PGPUB	OR	OFF	2018/05/29 10:37
S84	258	(US-20020107649-$ or US-20040258307-$ or US-20060187017-$ or US-20070229238-$ or US-20070229522-$ or US-20080059015-$ or US-20090228166-$ or US-20120001787-$ or US-20120072166-$ or US-20120109150-$ or US-20130325325-$ or US-20130332065-$ or US-20140002843-$ or US-20150199458-$ or US-20150205299-$ or US-20150234387-$ or US-20150261223-$ or US-20150283703-$ or US-20150323197-$ or US-20150362921-$ or US-20160065909-$ or US-20160078303-$ or US-20160121487-$ or US-20160182502-$ or US-20160282862-$ or US-20160287044-$).did. or (US-20160309973-$ or US-20170139551-$ or US-20170329333-$ or US-20170329347-$ or US-20020158599-$ or US-20020175894-$ or US-20020198854-$ or US-20030023347-$ or US-20030025082-$ or US-20030108415-$ or US-20030144764-$ or US-20030220714-$ or US-20040030449-$ or US-20040036437-$ or US-20040051493-$ or US-	US-PGPUB; USPAT	OR	OFF	2018/05/29 12:17

		20040167641-$ or US-20040172166-$ or US-20040172168-$ or US-20040267404-$ or US-20050008227-$ or US-20050065651-$ or US-20050069207-$ or US-20050125099-$ or US-20060207419-$ or US-20060250101-$ or US-20070074177-$ or US-20070151389-$).did. or (US-20070200525-$ or US-20070255454-$ or US-20070260356-$ or US-20080040040-$ or US-20080097644-$ or US-20080112596-$ or US-20080140257-$ or US-20080319929-$ or US-20090037033-$ or US-20090231359-$ or US-20090234501-$ or US-20090265036-$ or US-20090272585-$ or US-20100114372-$ or US-20100152896-$ or US-20100152899-$ or US-20100228264-$ or US-20100286824-$ or US-20100305758-$ or US-20100312730-$ or US-20110026770-$ or US-20110035188-$ or US-20110060460-$ or US-20110067479-$ or US-20110144802-$ or US-20110158476-$ or US-20110160906-$).did. or (US-20110160907-$ or US-20110196199-$ or US-20110218676-$ or US-20110244919-$ or US-20110282169-$ or US-20110296944-$ or US-20120008838-$ or US-20120017232-$ or US-20120045068-$ or US-20120079670-$ or US-20120143495-$ or US-20120144242-$ or US-20120150777-$ or US-20120209432-$ or US-20120221147-$ or US-20120303091-$ or US-20120303160-$ or US-20120308076-$ or US-20120308136-$ or US-20130000480-$ or US-20130044139-$ or US-20130066468-$ or US-20130096719-$ or US-20130116827-$ or US-20130173060-$ or US-20130206170-$ or US-20130218339-$).did. or (US-20130245829-$ or US-20130274924-$ or US-20130310979-$ or US-20130325775-$ or US-20130346347-$ or US-20140016858-$ or US-20140081895-$ or US-20140089232-$ or US-20140114479-$ or US-20140187519-$ or US-20140190514-$ or US-20140276951-$ or US-20140277718-$ or US-20140350723-$ or US-20140358828-$ or US-20140371907-$ or US-20140371912-$ or US-20150032258-$ or US-20150094850-$ or US-20150094852-$ or US-20150120128-$ or US-20150127155-$ or US-20150185027-$ or US-20150204559-$ or US-20150213299-$ or US-20150306761-$ or US-20150317357-$).did. or (US-20150339589-$ or US-20160057925-$ or US-20160075026-$ or US-						

		20180120116-$ or US-20170153646-$ or US-20140100768-$ or US-20170344013-$ or US-20160071278-$ or US-20080294338-$ or US-20180114293-$ or US-20180113469-$ or US-20180112985-$ or US-20180088597-$ or US-20180077534-$ or US-20170048816-$ or US-20160290805-$ or US-20110194755-$ or US-20130080045-$ or US-20120245844-$ or US-20120159408-$ or US-20110102545-$ or US-20080033645-$ or US-20050234679-$ or US-20130216098-$ or US-20130184865-$ or US-20120316784-$ or US-20110166737-$).did. or (US-20160271795-$ or US-20170123066-$ or US-20160259993-$ or US-20130138246-$ or US-20040073360-$ or US-20110123135-$ or US-20110010033-$ or US-20100049391-$ or US-20150161818-$ or US-20180075643-$ or US-20150172626-$ or US-20120121161-$ or US-20150304634-$ or US-20140037136-$ or US-20150213617-$ or US-20140350839-$ or US-20160091899-$ or US-20170105592-$).did. or (US-5155684-$ or US-5341540-$ or US-7212651-$ or US-7576639-$ or US-8174568-$ or US-8514236-$ or US-8774970-$ or US-8843244-$ or US-9192869-$ or US-9298183-$ or US-9315192-$ or US-9746339-$ or US-9775681-$ or US-4638445-$ or US-4763276-$ or US-4852018-$ or US-5121497-$ or US-5280179-$ or US-5446356-$ or US-5602761-$ or US-5612883-$ or US-5673367-$ or US-5719480-$ or US-5841959-$ or US-5994864-$ or US-6124694-$).did. or (US-6169981-$ or US-6243622-$ or US-6366293-$ or US-6442451-$ or US-6560511-$ or US-6584375-$ or US-6636781-$ or US-6697711-$ or US-6760645-$ or US-6812846-$ or US-6961060-$ or US-7002585-$ or US-7148644-$ or US-7243334-$ or US-7342589-$ or US-7668605-$ or US-8145492-$ or US-8364314-$ or US-8380348-$ or US-8380652-$ or US-8419804-$ or US-8423225-$ or US-8452448-$ or US-8515162-$ or US-8639035-$ or US-8639644-$ or US-8679260-$).did. or (US-8793205-$ or US-8924021-$ or US-8958911-$ or US-8958912-$ or US-8958937-$ or US-9008840-$ or US-9015093-$ or US-9144907-$ or US-9242372-$ or US-9939814-$ or US-9844879-$ or US-8576235-$ or US-7634336-$ or US-9720071-$ or US-6900758-$ or US-9952053-$ or US-9741140-$ or US-9606542-$ or US-9558424-$ or US-					

		9483879-$ or US-9910444-$ or US-9870624-$ or US-9807365-$ or US-8209144-$ or US-9802322-$ or US-9947134-$).did.				
S85	2	S84 NOT S63	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2018/05/29 12:18
S86	258	(US-20020107649-$ or US-20040258307-$ or US-20060187017-$ or US-20070229238-$ or US-20070229522-$ or US-20080059015-$ or US-20090228166-$ or US-20120001787-$ or US-20120072166-$ or US-20120109150-$ or US-20130325325-$ or US-20130332065-$ or US-20140002843-$ or US-20150199458-$ or US-20150205299-$ or US-20150234387-$ or US-20150261223-$ or US-20150283703-$ or US-20150323197-$ or US-20150362921-$ or US-20160065909-$ or US-20160078303-$ or US-20160121487-$ or US-20160182502-$ or US-20160282862-$ or US-20160287044-$).did. or (US-20160309973-$ or US-20170139551-$ or US-20170329333-$ or US-20170329347-$ or US-20020158599-$ or US-20020175894-$ or US-20020198854-$ or US-20030023347-$ or US-20030025082-$ or US-20030108415-$ or US-20030144764-$ or US-20030220714-$ or US-20040030449-$ or US-20040036437-$ or US-20040051493-$ or US-20040167641-$ or US-20040172166-$ or US-20040172168-$ or US-20040267404-$ or US-20050008227-$ or US-20050065651-$ or US-20050069207-$ or US-20050125099-$ or US-20060207419-$ or US-20060250101-$ or US-20070074177-$ or US-20070151389-$).did. or (US-20070200525-$ or US-20070255454-$ or US-20070260356-$ or US-20080040040-$ or US-20080097644-$ or US-20080112596-$ or US-20080140257-$ or US-20080319929-$ or US-20090037033-$ or US-20090231359-$ or US-20090234501-$ or US-20090265036-$ or US-20090272585-$ or US-20100114372-$ or US-20100152896-$ or US-20100152899-$ or US-20100228264-$ or US-20100286824-$ or US-20100305758-$ or US-20100312730-$ or US-20110026770-$ or US-20110035188-$ or US-20110060460-$ or US-20110067479-$ or US-20110144802-$ or US-20110158476-$	US-PGPUB; USPAT	OR	OFF	2018/05/29 13:33

		or US-20110160906-$).did. or (US-20110160907-$ or US-20110196199-$ or US-20110218676-$ or US-20110244919-$ or US-20110282169-$ or US-20110296944-$ or US-20120008838-$ or US-20120017232-$ or US-20120045068-$ or US-20120079670-$ or US-20120143495-$ or US-20120144242-$ or US-20120150777-$ or US-20120209432-$ or US-20120221147-$ or US-20120303091-$ or US-20120303160-$ or US-20120308076-$ or US-20120308136-$ or US-20130000480-$ or US-20130044139-$ or US-20130066468-$ or US-20130096719-$ or US-20130116827-$ or US-20130173060-$ or US-20130206170-$ or US-20130218339-$).did. or (US-20130245829-$ or US-20130274924-$ or US-20130310979-$ or US-20130325775-$ or US-20130346347-$ or US-20140016858-$ or US-20140081895-$ or US-20140089232-$ or US-20140114479-$ or US-20140187519-$ or US-20140190514-$ or US-20140276951-$ or US-20140277718-$ or US-20140350723-$ or US-20140358828-$ or US-20140371907-$ or US-20140371912-$ or US-20150032258-$ or US-20150094850-$ or US-20150094852-$ or US-20150120128-$ or US-20150127155-$ or US-20150185027-$ or US-20150204559-$ or US-20150213299-$ or US-20150306761-$ or US-20150317357-$).did. or (US-20150339589-$ or US-20160057925-$ or US-20160075026-$ or US-20180120116-$ or US-20170153646-$ or US-20140100768-$ or US-20170344013-$ or US-20160071278-$ or US-20080294338-$ or US-20180114293-$ or US-20180113469-$ or US-20180112985-$ or US-20180088597-$ or US-20180077534-$ or US-20170048816-$ or US-20160290805-$ or US-20110194755-$ or US-20130080045-$ or US-20120245844-$ or US-20120159408-$ or US-20110102545-$ or US-20080033645-$ or US-20050234679-$ or US-20130216098-$ or US-20130184865-$ or US-20120316784-$ or US-20110166737-$).did. or (US-20160271795-$ or US-20170123066-$ or US-20160259993-$ or US-20130138246-$ or US-20040073360-$ or US-20110123135-$ or US-20110010033-$ or US-20100049391-$ or US-20150161818-$ or US-20180075643-$ or US-20150172626-$ or US-20120121161-$ or US-20150304634-$ or US-20140037136-$						

		or US-20150213617-$ or US-20140350839-$ or US-20160091899-$ or US-20170105592-$).did. or (US-5155684-$ or US-5341540-$ or US-7212651-$ or US-7576639-$ or US-8174568-$ or US-8514236-$ or US-8774970-$ or US-8843244-$ or US-9192869-$ or US-9298183-$ or US-9315192-$ or US-9746339-$ or US-9775681-$ or US-4638445-$ or US-4763276-$ or US-4852018-$ or US-5121497-$ or US-5280179-$ or US-5446356-$ or US-5602761-$ or US-5612883-$ or US-5673367-$ or US-5719480-$ or US-5841959-$ or US-5994864-$ or US-6124694-$).did. or (US-6169981-$ or US-6243622-$ or US-6366293-$ or US-6442451-$ or US-6560511-$ or US-6584375-$ or US-6636781-$ or US-6697711-$ or US-6760645-$ or US-6812846-$ or US-6961060-$ or US-7002585-$ or US-7148644-$ or US-7243334-$ or US-7342589-$ or US-7668605-$ or US-8145492-$ or US-8364314-$ or US-8380348-$ or US-8380652-$ or US-8419804-$ or US-8423225-$ or US-8452448-$ or US-8515162-$ or US-8639035-$ or US-8639644-$ or US-8679260-$).did. or (US-8793205-$ or US-8924021-$ or US-8958911-$ or US-8958912-$ or US-8958937-$ or US-9008840-$ or US-9015093-$ or US-9144907-$ or US-9242372-$ or US-9939814-$ or US-9844879-$ or US-8576235-$ or US-7634336-$ or US-9720071-$ or US-6900758-$ or US-9952053-$ or US-9741140-$ or US-9606542-$ or US-9558424-$ or US-9483879-$ or US-9910444-$ or US-9870624-$ or US-9807365-$ or US-8209144-$ or US-9802322-$ or US-9947134-$).did.				
S87	109	S86 and cost	US-PGPUB; USPAT	OR	OFF	2018/05/29 13:34
S88	119	S86 and cost	US-PGPUB; USPAT	OR	ON	2018/05/29 13:34

EAST Search History (Interference)

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5/ 29/ 2018 2:10:16 PM
C:\ Users\ dmoyer\ Documents\ My Docket\ 15340807\ EAST Search.wsp

BRAIN.133A PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventors	:	Jaldert Rombouts, et al.
App. No.	:	15/340,807
Filed	:	November 1, 2016
For	:	**SYSTEMS AND METHODS FOR ROBOTIC MAPPING**
Examiner	:	Unknown
Group Art Unit:		Unknown

CUSTOMER NO. 132059

CERTIFICATE OF ELECTRONIC (EFS-WEB) TRANSMISSION

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Date: May 2, 2018

/Peter J. Gutierrez, III/
Peter J. Gutierrez, III, Reg. No. 56,732

INFORMATION DISCLOSURE STATEMENT

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Examiner:

Applicant submits herewith an IDS citing forty-three (43) references for consideration by the Office.

This Information Disclosure Statement is being filed before the mailing date of a first Office Action on the merits, and presumably no fee is required in accordance with 37 C.F.R. § 1.97(b)(3). If a first Office Action on the merits was mailed before the mailing date of this Statement, it is requested that the Commissioner charge any fees under 37 C.F.R. § 1.16 and § 1.17 to Deposit Account No. 501423.

Pursuant to 37 C.F.R. § 1.97(g) and (h), Applicant makes no representation that a search has been made or that the information cited is considered to be material to patentability.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /DM/

App. No. : 15/340,807
Filed : November 1, 2016

Additionally, inclusion on this list is not an admission that any of the cited documents are prior art in this application. Further, Applicant makes no representation regarding the completeness of this list or that better art does not exist.

Respectfully submitted,

GAZDZINSKI & ASSOCIATES, PC

Dated: May 2, 2018

By: /Peter J. Gutierrez, III/
Peter J. Gutierrez, III
Registration No. 56,732
16644 West Bernardo Drive, Suite 201
San Diego, CA 92127
Telephone: (858) 675-1670
Facsimile: (858) 675-1674

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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 1 of 5

Complete if Known	
Application Number	15340807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	001	US-5155684	10-13-1992	BURKE; Steven A. et al.	
	002	US-5341540	08-30-1994	SOUPERT; Jean-Louis D. C. et al.	
	003	US-7212651	05-01-2007	VIOLA; Paul A. et al.	
	004	US-7576639	08-18-2009	BOYLES; Tonnie Michael et al.	
	005	US-8174568	05-08-2012	SAMARASEKERA; Supun et al.	
	006	US-8514236	08-20-2013	WANG; Feng-Feng et al.	
	007	US-8774970	07-08-2014	KNOPOW; Jeremy F. et al.	
	008	US-8843244	09-23-2014	PHILLIPS; Emilie et al.	
	009	US-9192869	11-24-2015	MORIYA; Toshio	
	010	US-9298183	03-29-2016	ARTÉS; Harold et al.	
	011	US-9315192	04-19-2016	ZHU; Jiajun et al.	
	012	US-9746339	08-29-2017	MATTILA; Ville-Veikko et al.	
	013	US-9775681	10-03-2017	QUAID; Arthur et al.	
	014	US-20020107649	08-08-2002	TAKIGUCHI; Kiyoaki et al.	
	015	US-20040258307	12-23-2004	VIOLA; Paul A. et al.	
	016	US-20060187017	08-24-2006	KULESZ; James J. et al.	
	017	US-20070229238	10-04-2007	BOYLES; Tonnie Michael et al.	
	018	US-20070229522	10-04-2007	WANG; Feng-Feng et al.	
	019	US-20080059015	03-06-2008	WHITTAKER; William L. et al.	
	020	US-20090228166	09-10-2009	DURKOS; Larry G. et al.	

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.97 and 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application 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, 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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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Sheet 2 of 5

Complete if Known	
Application Number	15340807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	021	US-20120001787	01-05-2012	VAN; Dorp Philip	
	022	US-20120072166	03-22-2012	KEAL; William Kerry et al.	
	023	US-20120109150	05-03-2012	QUAID; Arthur et al.	
	024	US-20130325325	12-05-2013	DJUGASH; Joseph Maria Angelo	
	025	US-20130332065	12-12-2013	HAKIM; Daniel et al.	
	026	US-20140002843	01-02-2014	MIYAMOTO; Naruyuki et al.	
	027	US-20150199458	07-16-2015	BACON; James A. et al.	
	028	US-20150205299	07-23-2015	SCHNITTMAN; Mark et al.	
	029	US-20150234387	08-20-2015	MULLAN; Pramila et al.	
	030	US-20150261223	09-17-2015	FONG; Philip et al.	
	031	US-20150283703	10-08-2015	IZHIKEVICH; Eugene M. et al.	
	032	US-20150323197	11-12-2015	BURDETT; Michael P. et al.	
	033	US-20150362921	12-17-2015	HANAOKA; Tohru et al.	
	034	US-20160065909	03-03-2016	DERENNE; Richard A. et al.	
	035	US-20160078303	03-17-2016	SAMARASEKERA; Supun et al.	
	036	US-20160121487	05-05-2016	MOHAN; Siddharth et al.	
	037	US-20160182502	06-23-2016	SMITH; Ned M. et al.	
	038	US-20160282862	09-29-2016	DUFFLEY; Samuel et al.	
	039	US-20160287044	10-06-2016	TANAKA; Shoji et al.	
	040	US-20160309973	10-27-2016	SHEIKH; Faizan et al.	

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.97 and 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application 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, 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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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 3 of 5

Complete if Known	
Application Number	15340807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	041	US-20170139551	05-18-2017	LUPCHO III; Albert R. et al.	
	042	US-20170329333	11-16-2017	PASSOT; Jean-Baptiste et al.	
	043	US-20170329347	11-16-2017	PASSOT; Jean-Baptiste et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]-Number[4]-Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages Or Relevant Figures Appear	T[6]
		None				

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 4 of 5

Complete if Known	
Application Number	15340807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A

NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No.[1]	Include name of the author(in CAPITAL LETTERS),title of the article(when appropriate), title of the item (book,magazine,journal,serial,symposium,catalog,etc.),date,page(s),volume-issue number(s),publisher, city and/or country where published.	T[2]
		None	

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

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Application Number	15340807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☒ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☐ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Peter J. Gutierrez, III/	Date (YYYY-MM-DD)	2018-05-02
Name/Print	Peter J. Gutierrez, III	Registration Number	56,732

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Sheet 1 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	001	US-4638445	01-20-1987	MATTABONI; Paul J.	
	002	US-4763276	08-09-1988	PERREIRRA; Noel D. et al.	
	003	US-4852018	07-25-1989	GROSSBERG; Stephen et al.	
	004	US-5121497	06-09-1992	KERR; Randal H. et al.	
	005	US-5280179	01-18-1994	PRYOR; Timothy R. et al.	
	006	US-5446356	08-29-1995	KIM; Sang-Gwon	
	007	US-5602761	02-11-1997	SPOERRE; Julie K. et al.	
	008	US-5612883	03-18-1997	SHAFFER; Gary K. et al.	
	009	US-5673367	09-30-1997	BUCKLEY; Theresa M.	
	010	US-5719480	02-17-1998	BOCK; Otmar et al.	
	011	US-5841959	11-24-1998	GUIREMAND; Harry A.	
	012	US-5994864	11-30-1999	INOUE; Yasuyuki et al.	
	013	US-6124694	09-26-2000	BANCROFT; Allen J. et al.	
	014	US-6169981	01-02-2001	WERBOS; Paul J.	
	015	US-6243622	06-05-2001	YIM; Mark H. et al.	
	016	US-6366293	04-02-2002	HAMILTON; Jeffrey L. et al.	
	017	US-6442451	08-27-2002	LAPHAM; John R.	
	018	US-6560511	05-06-2003	YOKOO; Naohiro et al.	
	019	US-6584375	06-24-2003	BANCROFT; Allen et al.	
	020	US-6636781	10-21-2003	SHEN; Wei-Min et al.	
	021	US-6697711	02-24-2004	YOKONO; Jun et al.	

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

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Sheet 2 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

U. S. PATENT DOCUMENTS

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	022	US-6760645	07-06-2004	KAPLAN; Frederic et al.	
	023	US-6812846	11-02-2004	GUTTA; Srinivas et al.	
	024	US-6961060	11-01-2005	MOCHIZUKI; Yoshiyuki et al.	
	025	US-7002585	02-21-2006	WATANABE; Atsushi et al.	
	026	US-7148644	12-12-2006	YOURLO; Zhenya Alexander et al.	
	027	US-7243334	07-10-2007	BERGER; Kenneth A. et al.	
	028	US-7342589	03-11-2008	MISEROCCHI; Nathan P.	
	029	US-7668605	02-23-2010	BRAUN; Scott D. et al.	
	030	US-8145492	03-27-2012	FUJITA; Masahiro	
	031	US-8364314	01-29-2013	ABDALLAH; Muhammad E. et al.	
	032	US-8380348	02-19-2013	NEKI; Norio et al.	
	033	US-8380652	02-19-2013	FRANCIS Jr.; Anthony G.	
	034	US-8419804	04-16-2013	HERR; Hugh M. et al.	
	035	US-8423225	04-16-2013	HILLMAN Jr.; Henry L. et al.	
	036	US-8452448	05-28-2013	PACK; Robert T. et al.	
	037	US-8515162	08-20-2013	CHENG; Ting-Yuan	
	038	US-8639035	01-28-2014	SHIBA; Hisashi	
	039	US-8639644	01-28-2014	HICKMAN; Ryan et al.	
	040	US-8679260	03-25-2014	HILLMAN Jr.; Henry L. et al.	
	041	US-8793205	07-29-2014	FISHER; Dimitry et al.	

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

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Sheet 3 of 14

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Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

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	042	US-8924021	12-30-2014	DARIUSH; Behzad et al.	
	043	US-8958911	02-17-2015	WONG; Cheuk Wah et al.	
	044	US-8958912	02-17-2015	BLUMBERG; Bruce et al.	
	045	US-8958937	02-17-2015	HILLMAN Jr.; Henry L. et al.	
	046	US-9008840	04-14-2015	PONULAK; Filip et al.	
	047	US-9015093	04-21-2015	COMMONS; Michael Lamport	
	048	US-9144907	09-29-2015	SUMMER; Matthew D. et al.	
	049	US-9242372	01-26-2016	LAURENT; Patryk et al.	
	050	US-20020158599	10-31-2002	FUJITA; Masahiro et al.	
	051	US-20020175894	11-28-2002	GRILLO; Vince	
	052	US-20020198854	12-26-2002	BERENJI; Hamid R. et al.	
	053	US-20030023347	01-30-2003	KONNO; Reizo et al.	
	054	US-20030025082	02-06-2003	BREWINGTON; James Gabriel et al.	
	055	US-20030108415	06-12-2003	HOSEK; Martin et al.	
	056	US-20030144764	07-31-2003	YOKONO; Jun et al.	
	057	US-20030220714	11-27-2003	NAKAMURA; Yoshihiko et al.	
	058	US-20040030449	02-12-2004	SOLOMON; Neal	
	059	US-20040036437	02-26-2004	ITO; Masato	
	060	US-20040051493	03-18-2004	FURUTA; Takayuki et al.	
	061	US-20040167641	08-26-2004	KAWAI; Masakazu et al.	

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

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	062	US-20040172166	09-02-2004	LAPSTUN; Paul et al.	
	063	US-20040172168	09-02-2004	WATANABE; Atsushi et al.	
	064	US-20040267404	12-30-2004	DANKO; George	
	065	US-20050008227	01-13-2005	DUAN; Baofu et al.	
	066	US-20050065651	03-24-2005	AYERS; Joseph et al.	
	067	US-20050069207	03-31-2005	ZAKRZEWSKI; Radoslaw Romuald et al.	
	068	US-20050125099	06-09-2005	MIKAMI; Tatsuo et al.	
	069	US-20060207419	09-21-2006	OKAZAKI; Yasunao et al.	
	070	US-20060250101	11-09-2006	KHATIB; Oussama et al.	
	071	US-20070074177	03-29-2007	KURITA; Shigeru et al.	
	072	US-20070151389	07-05-2007	PRISCO; Giuseppe et al.	
	073	US-20070200525	08-30-2007	KANAOKA; Katsuya	
	074	US-20070255454	11-01-2007	DARIUSH; Behzad et al.	
	075	US-20070260356	11-08-2007	KOCK; Sonke et al.	
	076	US-20080040040	02-14-2008	GOTO; Takanori et al.	
	077	US-20080097644	04-24-2008	KAZNOV; Viktor et al.	
	078	US-20080112596	05-15-2008	RHOADS; Geoffrey B. et al.	
	079	US-20080140257	06-12-2008	SATO; Takashi et al.	
	080	US-20080319929	12-25-2008	KAPLAN; Frederic et al.	
	081	US-20090037033	02-05-2009	PHILLIPS; Emilie et al.	
	082	US-20090231359	09-17-2009	BASS II; Robert Leon et al.	

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

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	083	US-20090234501	09-17-2009	ISHIZAKI; Takehiro	
	084	US-20090265036	10-22-2009	JAMIESON; Josef et al.	
	085	US-20090272585	11-05-2009	NAGASAKA; Kenichiro	
	086	US-20100114372	05-06-2010	KNUTH Jr.; David M. et al.	
	087	US-20100152896	06-17-2010	KOMATSU; Mayumi et al.	
	088	US-20100152899	06-17-2010	CHANG; Chu-Yin et al.	
	089	US-20100228264	09-09-2010	ROBINSON; David et al.	
	090	US-20100286824	11-11-2010	SOLOMON; Neal	
	091	US-20100305758	12-02-2010	NISHI; Hiroji et al.	
	092	US-20100312730	12-09-2010	WENG; Juvang et al.	
	093	US-20110026770	02-03-2011	BROOKSHIRE; Jonathan David	
	094	US-20110035188	02-10-2011	MARTINEZ-HERAS; Jose Antonio et al.	
	095	US-20110060460	03-10-2011	OGA; Junichiro et al.	
	096	US-20110067479	03-24-2011	DAVIS; Donald R. et al.	
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	098	US-20110158476	06-30-2011	FAHN; Chin-Shyurng et al.	
	099	US-20110160906	06-30-2011	ORITA; Atsuo et al.	
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	101	US-20110196199	08-11-2011	DONHOWE; Caitlin Q. et al.	
	102	US-20110218676	09-08-2011	OKAZAKI; Yasunao	
	103	US-20110244919	10-06-2011	ALLER; Joshua V. et al.	

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

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Sheet 6 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

U. S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	104	US-20110282169	11-17-2011	GRUDIC; Gregory Zlatko et al.	
	105	US-20110296944	12-08-2011	CARTER; Troy Alexander et al.	
	106	US-20120008838	01-12-2012	GUYON; Isabelle et al.	
	107	US-20120017232	01-19-2012	HOFFBERG; Linda Irene et al.	
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	114	US-20120221147	08-30-2012	GOLDBERG; Randal P. et al.	
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	120	US-20130044139	02-21-2013	HERNANDEZ; Esteban Carlos	
	121	US-20130066468	03-14-2013	CHOI; Mun-Taek et al.	
	122	US-20130096719	04-18-2013	SANDERS; Adam M. et al.	

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Sheet 7 of 14

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Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
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	124	US-20130173060	07-04-2013	YOO; Su Jung et al.	
	125	US-20130206170	08-15-2013	SVENDSEN; Selma et al.	
	126	US-20130218339	08-22-2013	MAISONNIER; Bruno et al.	
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	132	US-20140016858	01-16-2014	RICHERT; Micah	
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	134	US-20140089232	03-27-2014	BUIBAS; Marius et al.	
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	141	US-20140358828	12-04-2014	PHILLIPPS; Kelly D. et al.	
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Sheet 8 of 14

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Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

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	144	US-20150032258	01-29-2015	PASSOT; Jean-Baptiste et al.	
	145	US-20150094850	04-02-2015	PASSOT; Jean-Baptiste et al.	
	146	US-20150094852	04-02-2015	LAURENT; Patryk et al.	
	147	US-20150120128	04-30-2015	ROSENSTEIN; Michael T. et al.	
	148	US-20150127155	05-07-2015	PASSOT; Jean-Baptiste et al.	
	149	US-20150185027	07-02-2015	KIKKERI; Harshavardhana et al.	
	150	US-20150204559	07-23-2015	HOFFBERG; Steven M. et al.	
	151	US-20150213299	07-30-2015	SOLANO; Ferrández José Vicente et al.	
	152	US-20150306761	10-29-2015	O'CONNOR; Peter et al.	
	153	US-20150317357	11-05-2015	HARMSEN; Jeremiah et al.	
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Sheet 9 of 14

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First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

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	001	WO-0167749-A2	09-13-2001	SARNOFF CORP [US]		☐
	002	WO-2014196925-A1	12-11-2014	CTRLWORKS PTE LTD [SG]		☐
	003	WO-2015047195-A1	04-02-2015	CTRLWORKS PTE LTD [SG]		☐

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Sheet 10 of 14

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First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

NON-PATENT LITERATURE DOCUMENTS			
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	001	ASENSIO et al., "Robot Learning Control Based on Neural Network Prediction" ASME 8th Annual Dynamic Systems and Control Conference joint with the JSME 11th Motion and Vibration Conference 2012 [Retrieved on: Jun. 24, 2014]. Retrieved fro internet:http://msc.berkeley.edu/wjchen/publications/DSC12.sub.--8726.sub.--FI-.pdf<http: />.	☐
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Sheet 11 of 14

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Application Number	15/340,807
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First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

NON-PATENT LITERATURE DOCUMENTS			
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	009	Hopkins, Chasing Water with Thermal Imaging, Infrared Training Center, 2011.	☐
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	013	Kalman Filter; wikipedia.	☐
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Attorney Docket Number	BRAIN.133A/BC201608A

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of the author(in CAPITAL LETTERS),title of the article(when appropriate), title of the item (book,magazine,journal,serial,symposium,catalog,etc.),date,page(s),volume-issue number(s),publisher, city and/or country where published.	T[2]
	018	ROSEBROCK,Tutorial "Find Distance from Camera to Object/marker using Python and OpenCV" 1-19-15, accessed 6-20-16 at the following Web address:http://www.pyimagesearch.com/2015/01/19/find-distance-camera-objectmarker-using-python-opencv/.	☐
	019	Rosenhahn, et al., Pose Estimation in Conformal Geometric Algebra Part I: The Stratification of Mathematical Spaces, Journal of Mathematical Imagine and Vision 22:27-48, 2005.	☐
	020	Steele, The Human Touch Makes Robots Defter, November 6, 2013, Cornell Chronicle. http://www.news.cornell.edu/stories/2013/11/human-touch-makes-robots-defter.	☐
	021	Thermal Imaging for Moisture and Restoration, retrieved on 2016-04-05 from the following Web address: www.flir.com/home.	☐
	022	TORRALBA, et al., "Depth Estimation from Image Structure, " Journal of IEEE Transactions on Pattern Analysis and Machine Intelligence, 2002, Vol. 24 (9), pp. 1226-1238.	☐
	023	TRIGGS, "Camera Pose and Calibration from 4 or 5 known 3D Points," 7th International Conference on Computer Vision (ICCV '99), IEEE Computer Society, 1999, Vol. 1, pp.278–284.	☐
	024	UNCC Machine Lab Wiki Documentation "ROS and Camera Calibration" accessed 6-20-16 at the following Web address: http://visionlab.uncc.edu/dokuwiki/ros_and_camera_calibration#aruco_-_augmented_reality_library_from_the_university_of_cordoba.	☐
	025	Video "TECNALIA-Limaccio Autonomous Cleaning Robot", published 2-22-13, available at the following Web address: http://www.youtube.com/watch?v=4GJ00EBbBfQ&sns=em.	☐
	026	WAN, et al., "Automatic Navigation System with Multiple Sensors," IFIP International Federation for Information Processing, Volume 259, Computer and Computing Technologies in Agriculture, 2008, Vol. 2, pp. 769-776.	☐

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application 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, 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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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 13 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

NON-PATENT LITERATURE DOCUMENTS			
Examiner Initials*	Cite No.[1]	Include name of the author(in CAPITAL LETTERS),title of the article(when appropriate), title of the item (book,magazine,journal,serial,symposium,catalog,etc.),date,page(s),volume-issue number(s),publisher, city and/or country where published.	T[2]
	027	Wikipedia Page "Pose (Computer Vision)" accessed 6-20-16, available at the following Web address: https://en.wikipedia.org/wiki/Pose_(computer_vision).	☐
	028	ZHANG, A Flexible New Technique for Camera Calibration, last updated 12-5-9, Technical Report MSR-TR-98-71, December 2, 1998.	☐

Examiner Signature	/Dale Moyer/	Date Considered	05/09/2018

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. 1 Applicant's unique citation designation number (optional). 2 Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. 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 2 hours to complete, including gathering, preparing, and submitting the completed application 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, 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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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet 14 of 14

Complete if Known	
Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Art Unit	Unknown
Examiner Name	Unknown
Attorney Docket Number	BRAIN.133A/BC201608A

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☒ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☐ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Mark I. Wang/	Date (YYYY-MM-DD)	2017-03-02
Name/Print	Mark I. Wang	Registration Number	65,282

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Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82A (07-13)
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NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	15/340,807
Filing Date	11-01-2016
First Named Inventor	Jaldert Rombouts
Title	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
Art Unit	3664
Examiner Name	MOYER, DALE S
Attorney Docket Number	

SIGNATURE of Applicant or Patent Practitioner

Signature	/Sidarth Kapoor/	Date (Optional)	08-21-2018
Name	Sidarth Kapoor	Registration Number	68159
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)			

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ *Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. 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 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application 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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Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82B (07-13)
Approved for use through 01/31/2018. OMB 0651-0035
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POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 26418

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☑ The address associated with the above-mentioned Customer Number

OR

☐ The address associated with Customer Number:

OR

☐ Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

Brain Corp

☐ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☑ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	Andy Ng	Date (Optional)	
Name	Andy Ng		
Title	General Counsel		

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ Total of 1 forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. 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 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application 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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Electronic Acknowledgement Receipt

EFS ID:	33476768
Application Number:	15340807
International Application Number:	
Confirmation Number:	3030
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Customer Number:	132059
Filer:	Sidharth Kapoor/Cody Nye
Filer Authorized By:	Sidharth Kapoor
Attorney Docket Number:	BRAIN.133A/BC201608A
Receipt Date:	21-AUG-2018
Filing Date:	01-NOV-2016
Time Stamp:	09:42:41
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	15340807_-_POA.pdf	1272608 9a5f4c0131235c23e6335cf7b7832fe9eacc4b64	no	2

Warnings:

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Total Files Size (in bytes):	1272608

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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.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Electronic Acknowledgement Receipt	
EFS ID:	33483165
Application Number:	15340807
International Application Number:	
Confirmation Number:	3030
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Customer Number:	132059
Filer:	Sidharth Kapoor/Cody Nye
Filer Authorized By:	Sidharth Kapoor
Attorney Docket Number:	BRAIN.133A/BC201608A
Receipt Date:	21-AUG-2018
Filing Date:	01-NOV-2016
Time Stamp:	12:38:00
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Amendment/Req. Reconsideration-After Non-Final Reject	2018-08-21_-_15340807_-_Response.pdf	518129 df0ae6b9cbaff3af0319b5fc517c633d5704decc	no	9

Warnings:

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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.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Jaldert ROMBOUTS	Examiner: MOYER, DALE
Serial No.: 15/340,807	Art Unit: 3664
Attorney Docket No.:	For: SYSTEMS AND METHODS FOR ROBOTIC MAPPING
	Date: **August 21, 2018**

AMENDMENT AND RESPONSE

In response to the non-final Office Action dated May 31, 2018, Applicant respectfully requests entry of this Amendment and Response. This Response is being timely filed on or before the three-month statutory time period of August 31, 2018. The Commissioner is hereby authorized to charge any additional fees, which may be required by this paper, to Deposit Account No. 18-0582.

Amendments to the Claims begin on page 2; and
Remarks begin on page 8.

AMENDMENTS TO THE CLAIMS

1. (Currently Amended) A method of generating a map by a robot, comprising:

traveling, by the robot, in an environment;

~~creating~~ generating a graph comprising a plurality of nodes, ~~wherein each~~ a respective node of the plurality of nodes corresponds to a scan ~~taken~~ generated by a sensor of the robot at a location in the environment;

~~constraining the graph to start and end at a substantially similar location~~;

performing scan matching on extended scan groups, the extended scan groups being determined ~~at least in part from groups~~ in-part on at least two or more nodes of the plurality of nodes; and

constraining the graph between a start location and an end location, the start location and the end location being at a substantially similar location in the environment

~~associating a range of possible locations with each of the plurality of nodes based at least in part on the scan matching;~~

~~determining confidences associated with each range of possible locations;~~

~~optimizing the graph to find a likely location of the plurality of nodes based at least in part on the associated confidences; and~~

~~generating the map from the optimized graph~~.

2. (Currently Amended) The method of Claim 1, further comprising:

associating a range of possible locations in the environment with the respective one of the plurality of nodes based at least in-part on the scan matching;

determining confidences associated with a respective one of the range of possible locations;

optimizing the graph to find a location of the plurality of nodes based at least in-part on the confidences; and

generating the map from the optimized graph, ~~wherein~~ the generation of the map comprises ray tracing with the scans ~~taken~~ generated by the sensor, the scans being associated with the plurality of nodes.

3. (Currently Amended) The method of Claim [[1]] 2, wherein the optimizing of the graph, comprises:

generating a cost function based at least in-part on: (1) relative locations of each of the plurality of nodes, and (2) the confidences associated with each of the plurality of nodes; and

solving the cost function for a minimum value.

4. (Currently Amended) The method of Claim 1, wherein the constraining of the graph to the start and end locations ~~at the substantially similar location further comprises~~ includes constraining the graph to the start and end locations in view of a home locator.

5. (Currently Amended) The method of Claim 1, wherein the traveling, by the robot, in the environment further ~~comprises~~ includes,

navigating the robot under user control.

6. (Currently Amended) The method of Claim [[1]] 2, wherein the associated confidences further ~~comprise~~ includes,

using a probability distribution indicative at least in-part of a probability that ~~a given~~ the respective node is in a ~~given~~ respective location.

7. The method of Claim 1, wherein the extended scan groups determined at least in part from groups of the plurality of nodes, further ~~comprises:~~ includes,

selecting a root node as a reference location;

finding ~~possible~~ overlap[[s]] in measurements of distinct features in scans taken at ~~other~~ least two of the respective nodes of the plurality of nodes, the root note is different from the respective node; and

grouping the ~~other~~ the at least two of the respective nodes into extended scan groups based at least in-part on overlapping distinct features of the scans at ~~those respective other~~ the at least two of the respective nodes.

8. (Currently Amended) A robot, comprising:

a sensor configured to ~~take~~ generate scans of an environment at a plurality of nodes, ~~wherein~~ a respective ~~each~~ node of the plurality of nodes is associated with a location in the environment; and

a mapping and localization unit configured to execute computer readable instructions to:

~~create~~ generate a graph of the plurality of nodes based at least in part on the ~~taken~~ generated scans;

determine extended scan groups ~~based at least in part on groups~~ in-part on at least two or more nodes of the plurality of nodes; [[and]]

perform scan matching on the extended scan groups; and

constrain the graph between a start location and an end location, the start location and the end location being at a substantially similar location in the environment.

9. (Cancelled).

10. (Currently Amended) The robot of Claim 8, wherein the mapping and localization unit is further configured to execute computer readable instructions to,

determine confidences associated with the location in the environment of each node of the plurality of nodes.

11. (Currently Amended) The robot of Claim 10, wherein the mapping and localization unit is further configured to execute computer readable instructions to,

generate a cost function based at least in-part on the confidences and the location[[s]] of each node of the plurality of nodes, ~~wherein the mapping and localization unit determines~~ the location of each node in the graph being determined based on solving the cost function for a minimum value.

12. (Currently Amended) The robot of Claim 8, ~~further comprising a processor that is further configured to~~ wherein the mapping and localization unit is further configured to execute computer readable instructions to,

render a map from the graph, the map ~~rendered~~ based at least in-part on ray tracings of the scans.

13. (Currently Amended) The robot of Claim 8, further comprising:

an actuator configured to move the robot between locations in the environment.

14. (Currently Amended) The robot of Claim 8, further comprising:

a user interface ~~configured for user control of~~ for controlling the robot by at least one user.

15. (Currently Amended) The robot of Claim 8, further comprising:

a navigation unit configured to navigate the robot autonomously without the user.

16. (Currently Amended) A non-transitory computer-readable ~~storage apparatus having a plurality of~~ medium having computer readable instructions stored thereon, ~~the instructions being executable by a processing apparatus to operate a robot, the instructions configured to, when executed by the processing apparatus, cause the processing apparatus~~ that when executed by at least one processor, configure the at least one processor to:

~~cause a~~ transmit a signal to at least one sensor to generate scans of an environment at a plurality of nodes, ~~wherein each~~ a respective node of the plurality of nodes being [[is]] associated with a location in the environment;

~~create~~ generate a graph of the plurality of nodes based in-part on the generated scans;

determine extended scan groups based at least in part ~~from scans associated with groups of the~~ on two or more nodes of the plurality of nodes; [[and]]

perform scan matching on the extended scan groups; and

constrain the graph between a start location and an end location, the start location and the end location being at a substantially similar location.

17. (Cancelled).

18. (Currently Amended) The non-transitory computer-readable ~~storage apparatus of~~ medium of Claim 16, wherein each extended scan group ~~comprises~~ includes at least three or more scans.

19. (Currently Amended) The non-transitory computer-readable ~~storage apparatus of~~ medium of Claim 16, ~~further comprising one or more instructions, when executed by the processing apparatus, that further cause the processing apparatus to~~ wherein the at least one processor is further configured to execute the computer readable instructions to,

determine a cost function based at least in-part on confidences associated with the location of each node of the plurality of nodes.

20. The non-transitory computer-readable ~~storage apparatus of~~ medium of Claim 19, ~~further comprising one or more instructions, when executed by the processing apparatus, that further cause the processing apparatus to~~ wherein the at least one processor is further configured to execute the computer readable instructions to,

generate a map based at least in-part on minimizing the cost function.

*****END OF CLAIM LISTING*****

REMARKS

Claims 1-8, 10-16, and 18-20 are pending in the present application. Claims 9 and 17 are cancelled via present amendment without prejudice. Accordingly, currently amended claims are presented for examination herein. No new matter has been introduced via present amendment.

Interview Summary

A telephonic interview was conducted with Examiner Moyer on August 21, 2018 to discuss the outstanding non-final Office action issued in the present application on May 31, 2018. Claim amendments with respect to independent claims 1, 8 and 16 were discussed in light of the Allowable Subject Matter indicated on page 3 of the Office action.

Examiner Moyer indicated that claim amendments presented in-light of the Allowable Subject Matter indicated in the Office action furthered prosecution, and further search and examination would need to be conducted to determine patent eligibility of the pending claims.

Applicants' thank Examiner Moyer for his time and effort to further prosecution of the present application.

Claim Rejections Under 35 U.S.C. § 102

On pages 2-3 of the outstanding Office action, the Examiner has rejected claims 8, 10, 13-16 and 18 under 35 USC § 102(a)(1) as allegedly being anticipated by U. Pat. Pub. 2012/0121161 ("Eade").

Without conceding to the Examiner's assertions set forth in the outstanding non-final Office Action, Applicants' assert that Eade does not disclose or fairly suggest, the amended features recited in amended claim 1. Accordingly, Applicants' respectfully request the Examiner

to reconsider and withdraw the aforementioned rejection under 35 USC § 102.

Similar arguments apply to amended independent claims 8 and 16.

In view of the foregoing amendments and remarks, Applicants respectfully submit that the application is in condition for allowance, and such action is respectfully requested at the Examiner's earliest convenience. Please apply any necessary charges or credits to Deposit Account 18-0582, referencing the above application number.

CONCLUSION

Based upon the foregoing remarks, Applicants submit that the application is condition for examination. Should the Examiner feel that a telephone conference with Applicant's attorney would expedite prosecution of the application, the Examiner is urged to contact the undersigned attorney.

Date: August 21, 2018

Respectfully submitted,
REED SMITH LLP
/Sidharth Kapoor/
Sidharth Kapoor
Reg. No. 68,159
skapoor@reedsmith.com
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Customer Number 26418
Reed Smith LLP
136 Main Street, #250
Princeton, NJ 08540

Attorney for Applicant

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 15/340,807	Filing Date 11/01/2016	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	08/21/2018	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 18	Minus	** 20	= 0	X $50 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X $230 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

SLIE
ERIC DANTZLER

This collection of information is required by 37 CFR 1.16. 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 12 minutes to complete, including gathering, preparing, and submitting the completed application 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.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/340,807	11/01/2016	Jaldert Rombouts	BRAIN.133A/BC201608A

CONFIRMATION NO. 3030

132059
Gazdzinski & Associates, PC
16644 West Bernardo Drive
Suite 201
San Diego, CA 92127

POWER OF ATTORNEY NOTICE

OC000000101760974

Date Mailed: 08/23/2018

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 08/21/2018.

- The Power of Attorney to you in this application has been revoked by the applicant. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/snguyen/

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/340,807	11/01/2016	Jaldert Rombouts	BRAIN.133A/BC201608A

CONFIRMATION NO. 3030

26418
REED SMITH LLP
P.O. BOX 488 (NYC)
PITTSBURGH, PA 15230-0488

POA ACCEPTANCE LETTER

OC000000101761010

Date Mailed: 08/23/2018

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 08/21/2018.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/snguyen/

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

26418 7590 12/18/2018

REED SMITH LLP
P.O. BOX 488 (NYC)
PITTSBURGH, PA 15230-0488

EXAMINER	
MOYER, DALE S	
ART UNIT	PAPER NUMBER
3664	

DATE MAILED: 12/18/2018

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/340,807	11/01/2016	Jaldert Rombouts	P23291US00	3030

TITLE OF INVENTION: SYSTEMS AND METHODS FOR ROBOTIC MAPPING

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	03/18/2019

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

26418 7590 12/18/2018
REED SMITH LLP
P.O. BOX 488 (NYC)
PITTSBURGH, PA 15230-0488

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/340,807	11/01/2016	Jaldert Rombouts	P23291US00	3030

TITLE OF INVENTION: SYSTEMS AND METHODS FOR ROBOTIC MAPPING

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	03/18/2019

EXAMINER	ART UNIT	CLASS-SUBCLASS
MOYER, DALE S	3664	700-258000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. Fees submitted: ❑Issue Fee ❑Publication Fee (if required) ❑Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

❑ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. _____

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

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Page 281 of 331

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/340,807	11/01/2016	Jaldert Rombouts	P23291US00	3030

26418 7590 12/18/2018

REED SMITH LLP
P.O. BOX 488 (NYC)
PITTSBURGH, PA 15230-0488

EXAMINER	
MOYER, DALE S	
ART UNIT	PAPER NUMBER
3664	

DATE MAILED: 12/18/2018

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. 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 30 minutes to complete, including gathering, preparing, and submitting the completed application 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, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
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.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 15/340,807	Applicant(s) Rombouts et al.	
	Examiner DALE MOYER	Art Unit 3664	AIA Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☑ This communication is responsive to the amendment received 21 August 2018.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☑ The allowed claim(s) is/are 1-8,10-16 and 18-20 . As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information , please see **http://www.uspto.gov/patents/init_events/pph/index.jsp** or send an inquiry to **PPHfeedback@uspto.gov.**

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:

   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____ .

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file areply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____ .

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____.
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material _____.
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date. _____.
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/Dale Moyer/
Primary Examiner, Art Unit 3664

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/340,807	Rombouts et al.
	Examiner	Art Unit
	DALE MOYER	3664

CPC							
Symbol						Type	Version
G01C	/	21	/	32		F	2013-01-01
G01S	/	17	/	89		I	2013-01-01
G01S	/	15	/	89		A	2013-01-01

CPC Combination Sets								
Symbol					Type	Set	Ranking	Version
	/		/					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	18	
/Dale Moyer/ Primary Examiner, Art Unit 3664	08 December 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No.: 20181206

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Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/340,807	Rombouts et al.
	Examiner	Art Unit
	DALE MOYER	3664

INTERNATIONAL CLASSIFICATION				
CLAIMED				
G01C	/	21	/	32
G01S	/	17	/	89
G01S	/	15	/	89

NON-CLAIMED				
	/		/	

US ORIGINAL CLASSIFICATION	
CLASS	SUBCLASS

CROSS REFERENCES(S)						
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)					

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	18	
/Dale Moyer/ Primary Examiner, Art Unit 3664	08 December 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No.: 20181206

Avidbots Ex1002
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Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/340,807	Rombouts et al.
	Examiner	Art Unit
	DALE MOYER	3664

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIMS

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	9	10	17	19										
2	2	10	11	18	20										
3	3	11	12												
5	4	12	13												
6	5	13	14												
4	6	14	15												
7	7	15	16												
8	8		17												
	9	16	18												

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	18	
/Dale Moyer/ Primary Examiner, Art Unit 3664	08 December 2018	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office Part of Paper No.: 20181206

Avidbots Ex1002
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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/340,807	Rombouts et al.
	Examiner	Art Unit
	DALE MOYER	3664

CPC - Searched*		
Symbol	**Date**	**Examiner**
G05D1/0251	05/09/2018	DM
G05D1/0253	05/09/2018	DM
B25J9/1697	05/09/2018	DM
B25J15/0616	05/29/2018	DM
G05D2201/0207	05/29/2018	DM
G05D1/0225	05/29/2018	DM
G05D2201/0215	05/29/2018	DM

CPC Combination Sets - Searched*		
Symbol	**Date**	**Examiner**

US Classification - Searched*			
Class	**Subclass**	**Date**	**Examiner**

* See search history printout included with this form or the SEARCH NOTES box below to determine the scope of the search.

Search Notes		
Search Notes	**Date**	**Examiner**
considered IDS received 03/02/2017	05/09/2018	DM
considered IDS received 05/02/2018	05/09/2018	DM
inventor name search	05/09/2018	DM
see attached EAST Search History Report	05/29/2018	DM

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	15/340,807	Rombouts et al.
	Examiner	Art Unit
	DALE MOYER	3664

Interference Search			
US Class/CPC Symbol	US Subclass/CPC Group	Date	Examiner
G01C	21/32	12/08/2018	DM
G01S	15/89, 17/89	12/08/2018	DM

Bibliographic Data

Application No: 15/340,807

Foreign Priority claimed: ○ Yes ◉ No

35 USC 119 (a-d) conditions met: ☐ Yes ☑ No ☐ Met After Allowance

Verified and Acknowledged: /Dale Moyer/ (Examiner's Signature) | (Initials)

Title: SYSTEMS AND METHODS FOR ROBOTIC MAPPING

FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
11/01/2016	700	3664	P23291US00
RULE			

APPLICANTS

BRAIN CORPORATION, San Diego, CA,

INVENTORS

Jaldert Rombouts San Diego, CA, UNITED STATES

Borja Ibarz Gabardos La Jolla, CA, UNITED STATES

Jean-Baptiste Passot Solana Beach, CA, UNITED STATES

Andrew Smith San Diego, CA, UNITED STATES

CONTINUING DATA

FOREIGN APPLICATIONS

IF REQUIRED, FOREIGN LICENSE GRANTED**

11/10/2016

** SMALL ENTITY **

STATE OR COUNTRY

UNITED STATES

ADDRESS

REED SMITH LLP
P.O. BOX 488 (NYC)
PITTSBURGH, PA 15230-0488
UNITED STATES

FILING FEE RECEIVED

$730

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S90	260	robot.ti,ab,bsum. AND (graph).ti,ab. AND map$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:21
S91	258	(US-20020107649-$ or US-20040258307-$ or US-20060187017-$ or US-20070229238-$ or US-20070229522-$ or US-20080059015-$ or US-20090228166-$ or US-20120001787-$ or US-20120072166-$ or US-20120109150-$ or US-20130325325-$ or US-20130332065-$ or US-20140002843-$ or US-20150199458-$ or US-20150205299-$ or US-20150234387-$ or US-20150261223-$ or US-20150283703-$ or US-20150323197-$ or US-20150362921-$ or US-20160065909-$ or US-20160078303-$ or US-20160121487-$ or US-20160182502-$ or US-20160282862-$ or US-20160287044-$).did. or (US-20160309973-$ or US-20170139551-$ or US-20170329333-$ or US-20170329347-$ or US-20020158599-$ or US-20020175894-$ or US-20020198854-$ or US-20030023347-$ or US-20030025082-$ or US-20030108415-$ or US-20030144764-$ or US-20030220714-$ or US-20040030449-$ or US-20040036437-$ or US-20040051493-$ or US-20040167641-$ or US-20040172166-$ or US-20040172168-$ or US-20040267404-$ or US-20050008227-$ or US-20050065651-$ or US-20050069207-$ or US-20050125099-$ or US-20060207419-$ or US-20060250101-$ or US-20070074177-$ or US-20070151389-$).did. or (US-20070200525-$ or US-20070255454-$ or US-20070260356-$ or US-20080040040-$ or US-20080097644-$ or US-20080112596-$ or US-20080140257-$ or US-20080319929-$ or US-20090037033-$ or US-20090231359-$ or US-20090234501-$ or US-20090265036-$ or US-20090272585-$ or US-20100114372-$ or US-20100152896-$ or US-20100152899-$ or US-20100228264-$ or US-20100286824-$ or US-20100305758-$ or US-20100312730-$ or US-20110026770-$ or US-20110035188-$ or US-20110060460-$ or	US-PGPUB; USPAT	OR	ON	2018/11/26 14:21

		US-20110067479-$ or US-20110144802-$ or US-20110158476-$ or US-20110160906-$).did. or (US-20110160907-$ or US-20110196199-$ or US-20110218676-$ or US-20110244919-$ or US-20110282169-$ or US-20110296944-$ or US-20120008838-$ or US-20120017232-$ or US-20120045068-$ or US-20120079670-$ or US-20120143495-$ or US-20120144242-$ or US-20120150777-$ or US-20120209432-$ or US-20120221147-$ or US-20120303091-$ or US-20120303160-$ or US-20120308076-$ or US-20120308136-$ or US-20130000480-$ or US-20130044139-$ or US-20130066468-$ or US-20130096719-$ or US-20130116827-$ or US-20130173060-$ or US-20130206170-$ or US-20130218339-$).did. or (US-20130245829-$ or US-20130274924-$ or US-20130310979-$ or US-20130325775-$ or US-20130346347-$ or US-20140016858-$ or US-20140081895-$ or US-20140089232-$ or US-20140114479-$ or US-20140187519-$ or US-20140190514-$ or US-20140276951-$ or US-20140277718-$ or US-20140350723-$ or US-20140358828-$ or US-20140371907-$ or US-20140371912-$ or US-20150032258-$ or US-20150094850-$ or US-20150094852-$ or US-20150120128-$ or US-20150127155-$ or US-20150185027-$ or US-20150204559-$ or US-20150213299-$ or US-20150306761-$ or US-20150317357-$).did. or (US-20150339589-$ or US-20160057925-$ or US-20160075026-$ or US-20180120116-$ or US-20170153646-$ or US-20140100768-$ or US-20170344013-$ or US-20160071278-$ or US-20080294338-$ or US-20180114293-$ or US-20180113469-$ or US-20180112985-$ or US-20180088597-$ or US-20180077534-$ or US-20170048816-$ or US-20160290805-$ or US-20110194755-$ or US-20130080045-$ or US-20120245844-$ or US-20120159408-$ or US-20110102545-$ or US-20080033645-$ or US-20050234679-$ or US-20130216098-$ or US-20130184865-$ or US-20120316784-$ or US-20110166737-$).did. or (US-20160271795-$ or US-20170123066-$ or US-20160259993-$ or US-20130138246-$ or US-20040073360-$ or US-20110123135-$ or US-20110010033-$ or US-20100049391-$ or US-20150161818-$ or US-20180075643-$ or US-20150172626-$ or US-20120121161-$ or US-20150304634-$ or US-20140037136-$ or US-20150213617-$ or US-20140350839-$ or US-20160091899-$ or US-20170105592-$).did. or (US-5155684-$ or US-						

		5341540-$ or US-7212651-$ or US-7576639-$ or US-8174568-$ or US-8514236-$ or US-8774970-$ or US-8843244-$ or US-9192869-$ or US-9298183-$ or US-9315192-$ or US-9746339-$ or US-9775681-$ or US-4638445-$ or US-4763276-$ or US-4852018-$ or US-5121497-$ or US-5280179-$ or US-5446356-$ or US-5602761-$ or US-5612883-$ or US-5673367-$ or US-5719480-$ or US-5841959-$ or US-5994864-$ or US-6124694-$).did. or (US-6169981-$ or US-6243622-$ or US-6366293-$ or US-6442451-$ or US-6560511-$ or US-6584375-$ or US-6636781-$ or US-6697711-$ or US-6760645-$ or US-6812846-$ or US-6961060-$ or US-7002585-$ or US-7148644-$ or US-7243334-$ or US-7342589-$ or US-7668605-$ or US-8145492-$ or US-8364314-$ or US-8380348-$ or US-8380652-$ or US-8419804-$ or US-8423225-$ or US-8452448-$ or US-8515162-$ or US-8639035-$ or US-8639644-$ or US-8679260-$).did. or (US-8793205-$ or US-8924021-$ or US-8958911-$ or US-8958912-$ or US-8958937-$ or US-9008840-$ or US-9015093-$ or US-9144907-$ or US-9242372-$ or US-9939814-$ or US-9844879-$ or US-8576235-$ or US-7634336-$ or US-9720071-$ or US-6900758-$ or US-9952053-$ or US-9741140-$ or US-9606542-$ or US-9558424-$ or US-9483879-$ or US-9910444-$ or US-9870624-$ or US-9807365-$ or US-8209144-$ or US-9802322-$ or US-9947134-$).did.				
S92	12	S90 AND S91	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:21
S93	506	S90 OR S91	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:21
S94	1	15/340807.app.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:24
S95	112	S93 AND (graph WITH (start$4 OR end OR ending OR destination OR finish$4 OR begin$4 OR origin))	US-PGPUB; USPAT; USOCR;	OR	ON	2018/11/26 14:25

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S96	166	S93 AND (graph WITH (start$4 OR end OR ending OR destination OR finish$4 OR begin$4 OR origin OR path OR pathway OR course OR segments OR trajectory OR vector))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:26
S97	95	S93 AND ((graph WITH (start$4 OR end OR ending OR destination OR finish$4 OR begin$4 OR origin OR path OR pathway OR course OR segments OR trajectory OR vector)) SAME map$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:26
S98	422	(US-20020107649-$ or US-20020158599-$ or US-20020175894-$ or US-20020198854-$ or US-20030023347-$ or US-20030025082-$ or US-20030108415-$ or US-20030144764-$ or US-20030220714-$ or US-20040030449-$ or US-20040036437-$ or US-20040051493-$ or US-20040073360-$ or US-20040167641-$ or US-20040172166-$ or US-20040172168-$ or US-20040258307-$ or US-20040267404-$ or US-20050008227-$ or US-20050035883-$ or US-20050039176-$ or US-20050065651-$ or US-20050069207-$ or US-20050086254-$ or US-20050125099-$ or US-20050159879-$).did. or (US-20050223176-$ or US-20050234679-$ or US-20050267987-$ or US-20060010141-$ or US-20060106857-$ or US-20060187017-$ or US-20060207419-$ or US-20060250101-$ or US-20060277323-$ or US-20070024624-$ or US-20070074177-$ or US-20070112708-$ or US-20070151389-$ or US-20070200525-$ or US-20070229238-$ or US-20070229522-$ or US-20070239314-$ or US-20070250463-$ or US-20070255454-$ or US-20070260356-$ or US-20080018646-$ or US-20080033645-$ or US-20080040040-$ or US-20080059015-$ or US-20080097644-$ or US-20080112596-$ or US-20080140257-$).did. or (US-20080291199-$ or US-20080294338-$ or US-20080319929-$ or US-20090037024-$ or US-20090037033-$ or US-20090112905-$ or US-20090116728-$ or US-20090150790-$ or US-20090198375-$ or US-20090216820-$ or US-20090228166-$ or US-20090231359-$ or US-20090234501-$ or US-20090272585-$ or US-20100049391-$ or US-20100114372-$ or US-20100152896-$ or US-20100152899-$ or US-20100163621-$ or US-20100228264-$ or US-20100274430-$ or US-	US-PGPUB; USPAT; FPRS; EPO; JPO; DERWENT	OR	ON	2018/11/26 14:27

		20100286824-$ or US-20100305758-$ or US-20100312386-$ or US-20100312730-$ or US-20110010033-$ or US-20110026770-$).did. or (US-20110035188-$ or US-20110060460-$ or US-20110067479-$ or US-20110083125-$ or US-20110102545-$ or US-20110123135-$ or US-20110144802-$ or US-20110158476-$ or US-20110160906-$ or US-20110160907-$ or US-20110166737-$ or US-20110194755-$ or US-20110196199-$ or US-20110218676-$ or US-20110244919-$ or US-20110282169-$ or US-20110296944-$ or US-20110307685-$ or US-20120001787-$ or US-20120008838-$ or US-20120017232-$ or US-20120045068-$ or US-20120072166-$ or US-20120079670-$ or US-20120084860-$ or US-20120109150-$ or US-20120121161-$).did. or (US-20120143495-$ or US-20120144242-$ or US-20120144376-$ or US-20120150777-$ or US-20120159408-$ or US-20120194521-$ or US-20120209432-$ or US-20120221147-$ or US-20120245844-$ or US-20120303091-$ or US-20120303160-$ or US-20120306847-$ or US-20120308076-$ or US-20120308136-$ or US-20120316784-$ or US-20130000480-$ or US-20130036112-$ or US-20130044139-$ or US-20130066468-$ or US-20130080045-$ or US-20130096719-$ or US-20130116827-$ or US-20130138246-$ or US-20130173060-$ or US-20130184865-$ or US-20130206170-$ or US-20130216098-$).did. or (US-20130218339-$ or US-20130245829-$ or US-20130271468-$ or US-20130274924-$ or US-20130310979-$ or US-20130325325-$ or US-20130325775-$ or US-20130332065-$ or US-20130346347-$ or US-20140002843-$ or US-20140016858-$ or US-20140037136-$ or US-20140058563-$ or US-20140081895-$ or US-20140089232-$ or US-20140100768-$ or US-20140114479-$ or US-20140187519-$ or US-20140190514-$ or US-20140276951-$ or US-20140277718-$ or US-20140350723-$ or US-20140350839-$ or US-20140358828-$ or US-20140371907-$ or US-20140371912-$ or US-20150025714-$).did. or (US-20150032258-$ or US-20150094850-$ or US-20150094852-$ or US-20150120128-$ or US-20150120583-$ or US-20150127155-$ or US-20150145985-$ or US-20150154467-$ or US-20150161513-$ or US-20150161818-$ or US-20150172626-$ or US-20150185027-$ or US-20150199458-$ or US-20150205299-$ or US-20150206015-$ or US-20150213299-$ or US-20150213617-$ or US-20150234387-$ or						

		US-20150261223-$ or US-20150283703-$ or US-20150285644-$ or US-20150304634-$ or US-20150306761-$ or US-20150317357-$ or US-20150323197-$ or US-20150332489-$ or US-20150339589-$).did. or (US-20150362921-$ or US-20160003620-$ or US-20160045822-$ or US-20160057925-$ or US-20160065909-$ or US-20160071278-$ or US-20160075026-$ or US-20160078303-$ or US-20160086385-$ or US-20160091899-$ or US-20160121487-$ or US-20160182502-$ or US-20160259993-$ or US-20160271795-$ or US-20160282862-$ or US-20160287044-$ or US-20160290805-$ or US-20160309973-$ or US-20170048816-$ or US-20170074665-$ or US-20170105592-$ or US-20170123066-$ or US-20170139551-$ or US-20170153646-$ or US-20170168485-$ or US-20170308742-$ or US-20170310946-$).did. or (US-20170329333-$ or US-20170329347-$ or US-20170337716-$ or US-20170344013-$ or US-20180051991-$ or US-20180068658-$ or US-20180075643-$ or US-20180077534-$ or US-20180088597-$ or US-20180112985-$ or US-20180113469-$ or US-20180114293-$ or US-20180120116-$ or US-20180172450-$ or US-20180180428-$ or US-20180196702-$ or US-20180211407-$ or US-20180267162-$ or US-20180300310-$ or US-20180328738-$).did. or (US-4638445-$ or US-4763276-$ or US-4852018-$ or US-5121497-$ or US-5155684-$ or US-5280179-$ or US-5283896-$ or US-5341540-$ or US-5446356-$ or US-5602761-$ or US-5612883-$ or US-5673367-$ or US-5675720-$ or US-5719480-$ or US-5841959-$ or US-5994864-$ or US-6124694-$ or US-6169981-$ or US-6243622-$ or US-6243680-$ or US-6366293-$ or US-6442451-$ or US-6560511-$ or US-6584375-$ or US-6636781-$ or US-6760645-$).did. or (US-6812846-$ or US-6900758-$ or US-6961060-$ or US-7002585-$ or US-7243334-$ or US-7342589-$ or US-7565627-$ or US-7634336-$ or US-7668605-$ or US-7676465-$ or US-7680858-$ or US-8027945-$ or US-8145492-$ or US-8209144-$ or US-8364314-$ or US-8380348-$ or US-8380652-$ or US-8419804-$ or US-8423225-$ or US-8452448-$ or US-8515162-$ or US-8576235-$ or US-8639035-$ or US-8639644-$ or US-8679260-$ or US-8762298-$ or US-8774970-$).did. or (US-8793205-$ or US-8843244-$ or US-8868410-$ or US-8958911-$ or US-8958912-$ or US-8958937-$ or US-						

		9008840-$ or US-9015093-$ or US-9144907-$ or US-9188982-$ or US-9192869-$ or US-9242372-$ or US-9298183-$ or US-9315192-$ or US-9558424-$ or US-9606542-$ or US-9720071-$ or US-9741140-$ or US-9746339-$ or US-9775681-$ or US-9802322-$ or US-9807365-$ or US-9844879-$ or US-9870624-$ or US-9910444-$ or US-9912764-$ or US-9939814-$).did. or (US-9947134-$ or US-9952053-$).did. or (CN-100582650-$ or CN-101319875-$ or CN-101398907-$ or CN-101398907-$ or CN-103268729-$ or CN-103268729-$ or CN-103528585-$ or CN-103528585-$ or CN-103674015-$ or CN-103674015-$ or CN-103970135-$ or CN-104374395-$ or CN-105547301-$ or CN-105547301-$ or CN-105843222-$ or CN-105843223-$ or CN-105856230-$ or CN-105856230-$ or CN-106094834-$ or CN-106227724-$ or CN-106408601-$ or CN-106556341-$ or CN-106643721-$ or CN-106843211-$ or CN-106909149-$ or CN-106931975-$).did. or (CN-106971144-$ or CN-107193279-$ or CN-107491070-$ or CN-107944443-$ or CN-107992038-$ or CN-108107895-$ or CN-205403803-$ or EP-1411450-$ or EP-3074955-$ or JP-2827895-$ or KR-101490055-$ or WO-2018085291-$).did. or (WO-2008048260-$).did. or (JP-07281748-$ or JP-07287617-$ or JP-10063327-$ or JP-2005032196-$ or JP-2007249632-$ or JP-2014222550-$ or JP-2014222551-$).did. or (AU-2017201409-$ or CN-102831446-$ or CN-103268729-$ or CN-103712617-$ or CN-105093934-$ or CN-106094834-$ or CN-106225788-$ or CN-106272423-$ or CN-106312397-$ or CN-106325266-$ or CN-106779251-$ or CN-106815843-$ or CN-106914899-$ or CN-106931975-$ or CN-107063258-$ or CN-107193279-$ or CN-107303678-$ or CN-107356230-$ or CN-107436148-$ or CN-107450535-$ or CN-107992038-$ or CN-108062097-$ or CN-108195375-$ or CN-108415445-$ or CN-108510012-$ or CN-108638071-$).did. or (CN-206194076-$ or CN-206628891-$ or EP-1411450-$ or EP-2063363-$ or JP-07281748-$ or JP-2005032196-$ or JP-2009207319-$ or KR-1490055-$ or KR-2018076815-$ or KR-816269-$ or US-20080001948-$ or US-20090228474-$ or US-20130267178-$ or US-20130283926-$ or US-20140025201-$ or US-20140058563-$ or US-20150332489-$ or US-20170061828-$ or US-20170348851-$ or US-20180120116-$ or US-20180161986-$ or US-8723870-$ or WO-2008048260-$ or WO-2010013205-$ or WO-2011156247-$ or WO-2012040644-$ or WO-				

		2014000090-$).did. or (WO-2015121677-$ or WO-2018006469-$ or WO-2018072563-$ or WO-2018078107-$).did.				
S99	28	S98 AND ((graph WITH (start$4 OR end OR ending OR destination OR finish$4 OR begin$4 OR origin OR path OR pathway OR course OR segments OR trajectory OR vector)) SAME map$4) AND @ad<"20161101"	US-PGPUB; USPAT	OR	ON	2018/11/26 14:28
S100	272	(US-20020107649-$ or US-20040258307-$ or US-20060187017-$ or US-20070229238-$ or US-20070229522-$ or US-20080059015-$ or US-20090228166-$ or US-20120001787-$ or US-20120072166-$ or US-20120109150-$ or US-20130325325-$ or US-20130332065-$ or US-20140002843-$ or US-20150199458-$ or US-20150205299-$ or US-20150234387-$ or US-20150261223-$ or US-20150283703-$ or US-20150323197-$ or US-20150362921-$ or US-20160065909-$ or US-20160078303-$ or US-20160121487-$ or US-20160182502-$ or US-20160282862-$ or US-20160287044-$).did. or (US-20160309973-$ or US-20170139551-$ or US-20170329333-$ or US-20170329347-$ or US-20020158599-$ or US-20020175894-$ or US-20020198854-$ or US-20030023347-$ or US-20030025082-$ or US-20030108415-$ or US-20030144764-$ or US-20030220714-$ or US-20040030449-$ or US-20040036437-$ or US-20040051493-$ or US-20040167641-$ or US-20040172166-$ or US-20040172168-$ or US-20040267404-$ or US-20050008227-$ or US-20050065651-$ or US-20050069207-$ or US-20050125099-$ or US-20060207419-$ or US-20060250101-$ or US-20070074177-$ or US-20070151389-$).did. or (US-20070200525-$ or US-20070255454-$ or US-20070260356-$ or US-20080040040-$ or US-20080097644-$ or US-20080112596-$ or US-20080140257-$ or US-20080319929-$ or US-20090037033-$ or US-20090231359-$ or US-20090234501-$ or US-20090265036-$ or US-20090272585-$ or US-20100114372-$ or US-20100152896-$ or US-20100152899-$ or US-20100228264-$ or US-20100286824-$ or US-20100305758-$ or US-20100312730-$ or US-20110026770-$ or US-20110035188-$ or US-20110060460-$ or US-20110067479-$ or US-20110144802-$ or US-20110158476-$ or US-20110160906-$).did. or (US-20110160907-$ or US-20110196199-$ or US-20110218676-$ or US-20110244919-$ or US-20110282169-$ or US-20110296944-$ or US-20120008838-$ or US-20120017232-$ or US-20120045068-	US-PGPUB; USPAT	OR	ON	2018/11/26 14:34

		$ or US-20120079670-$ or US-20120143495-$ or US-20120144242-$ or US-20120150777-$ or US-20120209432-$ or US-20120221147-$ or US-20120303091-$ or US-20120303160-$ or US-20120308076-$ or US-20120308136-$ or US-20130000480-$ or US-20130044139-$ or US-20130066468-$ or US-20130096719-$ or US-20130116827-$ or US-20130173060-$ or US-20130206170-$ or US-20130218339-$).did. or (US-20130245829-$ or US-20130274924-$ or US-20130310979-$ or US-20130325775-$ or US-20130346347-$ or US-20140016858-$ or US-20140081895-$ or US-20140089232-$ or US-20140114479-$ or US-20140187519-$ or US-20140190514-$ or US-20140276951-$ or US-20140277718-$ or US-20140350723-$ or US-20140358828-$ or US-20140371907-$ or US-20140371912-$ or US-20150032258-$ or US-20150094850-$ or US-20150094852-$ or US-20150120128-$ or US-20150127155-$ or US-20150185027-$ or US-20150204559-$ or US-20150213299-$ or US-20150306761-$ or US-20150317357-$).did. or (US-20150339589-$ or US-20160057925-$ or US-20160075026-$ or US-20180120116-$ or US-20170153646-$ or US-20140100768-$ or US-20170344013-$ or US-20160071278-$ or US-20080294338-$ or US-20180114293-$ or US-20180113469-$ or US-20180112985-$ or US-20180088597-$ or US-20180077534-$ or US-20170048816-$ or US-20160290805-$ or US-20110194755-$ or US-20130080045-$ or US-20120245844-$ or US-20120159408-$ or US-20110102545-$ or US-20080033645-$ or US-20050234679-$ or US-20130216098-$ or US-20130184865-$ or US-20120316784-$ or US-20110166737-$).did. or (US-20160271795-$ or US-20170123066-$ or US-20160259993-$ or US-20130138246-$ or US-20040073360-$ or US-20110123135-$ or US-20110010033-$ or US-20100049391-$ or US-20150161818-$ or US-20180075643-$ or US-20150172626-$ or US-20120121161-$ or US-20150304634-$ or US-20140037136-$ or US-20150213617-$ or US-20140350839-$ or US-20160091899-$ or US-20170105592-$ or US-20180051991-$ or US-20170074665-$ or US-20160003620-$ or US-20150332489-$ or US-20140058563-$ or US-20120306847-$ or US-20120194521-$ or US-20120144376-$ or US-20100274430-$).did. or (US-20090216820-$ or US-20090198375-$ or US-20070024624-$ or US-20050267987-$).did. or (US-5155684-$ or US-						

		5341540-$ or US-7212651-$ or US-7576639-$ or US-8174568-$ or US-8514236-$ or US-8774970-$ or US-8843244-$ or US-9192869-$ or US-9298183-$ or US-9315192-$ or US-9746339-$ or US-9775681-$ or US-4638445-$ or US-4763276-$ or US-4852018-$ or US-5121497-$ or US-5280179-$ or US-5446356-$ or US-5602761-$ or US-5612883-$ or US-5673367-$ or US-5719480-$ or US-5841959-$ or US-5994864-$ or US-6124694-$).did. or (US-6169981-$ or US-6243622-$ or US-6366293-$ or US-6442451-$ or US-6560511-$ or US-6584375-$ or US-6636781-$ or US-6697711-$ or US-6760645-$ or US-6812846-$ or US-6961060-$ or US-7002585-$ or US-7148644-$ or US-7243334-$ or US-7342589-$ or US-7668605-$ or US-8145492-$ or US-8364314-$ or US-8380348-$ or US-8380652-$ or US-8419804-$ or US-8423225-$ or US-8452448-$ or US-8515162-$ or US-8639035-$ or US-8639644-$ or US-8679260-$).did. or (US-8793205-$ or US-8924021-$ or US-8958911-$ or US-8958912-$ or US-8958937-$ or US-9008840-$ or US-9015093-$ or US-9144907-$ or US-9242372-$ or US-9939814-$ or US-9844879-$ or US-8576235-$ or US-7634336-$ or US-9720071-$ or US-6900758-$ or US-9952053-$ or US-9741140-$ or US-9606542-$ or US-9558424-$ or US-9483879-$ or US-9910444-$ or US-9870624-$ or US-9807365-$ or US-8209144-$ or US-9802322-$ or US-9947134-$ or US-9188982-$).did.				
S101	27	S99 AND S100	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:34
S102	715	((G06K9/6224).CPC.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:37
S103	0	((G06K9/6224).CPC.) AND B25J.cpcl.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:37
S104	51	(directed ADJ graph).bi. AND B25J.cpcl.	US-PGPUB; USPAT;	OR	ON	2018/11/26 14:38

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S105	98	(directed ADJ graph).bi. AND G05D.cpcl.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:39
S106	353	(directed ADJ graph).bi. AND G05B.cpcl.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 14:39
S107	1	("20120121161").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/11/26 15:38
S108	15	S101 AND match$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 15:47
S109	9	blanche WITH navigation	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 15:57
S110	289	graph AND ((G01C21/30).CPC.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 16:00
S111	226	graph AND ((G01C21/30).CPC.) AND match$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 16:02
S112	5	graph AND ((G01C21/30).CPC.) AND (scan$4 NEAR2 match$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/11/26 16:03
S113	276	(US-20020107649-$ or US-20040258307-$ or US-20060187017-$ or US-20070229238-$ or US-20070229522-$ or US-20080059015-$ or US-	US-PGPUB; USPAT	OR	ON	2018/12/06 10:50

		20090228166-$ or US-20120001787-$ or US-20120072166-$ or US-20120109150-$ or US-20130325325-$ or US-20130332065-$ or US-20140002843-$ or US-20150199458-$ or US-20150205299-$ or US-20150234387-$ or US-20150261223-$ or US-20150283703-$ or US-20150323197-$ or US-20150362921-$ or US-20160065909-$ or US-20160078303-$ or US-20160121487-$ or US-20160182502-$ or US-20160282862-$ or US-20160287044-$).did. or (US-20160309973-$ or US-20170139551-$ or US-20170329333-$ or US-20170329347-$ or US-20020158599-$ or US-20020175894-$ or US-20020198854-$ or US-20030023347-$ or US-20030025082-$ or US-20030108415-$ or US-20030144764-$ or US-20030220714-$ or US-20040030449-$ or US-20040036437-$ or US-20040051493-$ or US-20040167641-$ or US-20040172166-$ or US-20040172168-$ or US-20040267404-$ or US-20050008227-$ or US-20050065651-$ or US-20050069207-$ or US-20050125099-$ or US-20060207419-$ or US-20060250101-$ or US-20070074177-$ or US-20070151389-$).did. or (US-20070200525-$ or US-20070255454-$ or US-20070260356-$ or US-20080040040-$ or US-20080097644-$ or US-20080112596-$ or US-20080140257-$ or US-20080319929-$ or US-20090037033-$ or US-20090231359-$ or US-20090234501-$ or US-20090265036-$ or US-20090272585-$ or US-20100114372-$ or US-20100152896-$ or US-20100152899-$ or US-20100228264-$ or US-20100286824-$ or US-20100305758-$ or US-20100312730-$ or US-20110026770-$ or US-20110035188-$ or US-20110060460-$ or US-20110067479-$ or US-20110144802-$ or US-20110158476-$ or US-20110160906-$).did. or (US-20110160907-$ or US-20110196199-$ or US-20110218676-$ or US-20110244919-$ or US-20110282169-$ or US-20110296944-$ or US-20120008838-$ or US-20120017232-$ or US-20120045068-$ or US-20120079670-$ or US-20120143495-$ or US-20120144242-$ or US-20120150777-$ or US-20120209432-$ or US-20120221147-$ or US-20120303091-$ or US-20120303160-$ or US-20120308076-$ or US-20120308136-$ or US-20130000480-$ or US-20130044139-$ or US-20130066468-$ or US-20130096719-$ or US-20130116827-$ or US-20130173060-$ or US-20130206170-$ or US-20130218339-$).did. or (US-20130245829-$ or US-20130274924-$ or US-20130310979-$ or US-20130325775-$ or US-20130346347-					

		$ or US-20140016858-$ or US-20140081895-$ or US-20140089232-$ or US-20140114479-$ or US-20140187519-$ or US-20140190514-$ or US-20140276951-$ or US-20140277718-$ or US-20140350723-$ or US-20140358828-$ or US-20140371907-$ or US-20140371912-$ or US-20150032258-$ or US-20150094850-$ or US-20150094852-$ or US-20150120128-$ or US-20150127155-$ or US-20150185027-$ or US-20150204559-$ or US-20150213299-$ or US-20150306761-$ or US-20150317357-$).did. or (US-20150339589-$ or US-20160057925-$ or US-20160075026-$ or US-20180120116-$ or US-20170153646-$ or US-20140100768-$ or US-20170344013-$ or US-20160071278-$ or US-20080294338-$ or US-20180114293-$ or US-20180113469-$ or US-20180112985-$ or US-20180088597-$ or US-20180077534-$ or US-20170048816-$ or US-20160290805-$ or US-20110194755-$ or US-20130080045-$ or US-20120245844-$ or US-20120159408-$ or US-20110102545-$ or US-20080033645-$ or US-20050234679-$ or US-20130216098-$ or US-20130184865-$ or US-20120316784-$ or US-20110166737-$).did. or (US-20160271795-$ or US-20170123066-$ or US-20160259993-$ or US-20130138246-$ or US-20040073360-$ or US-20110123135-$ or US-20110010033-$ or US-20100049391-$ or US-20150161818-$ or US-20180075643-$ or US-20150172626-$ or US-20120121161-$ or US-20150304634-$ or US-20140037136-$ or US-20150213617-$ or US-20140350839-$ or US-20160091899-$ or US-20170105592-$ or US-20180051991-$ or US-20170074665-$ or US-20160003620-$ or US-20150332489-$ or US-20140058563-$ or US-20120306847-$ or US-20120194521-$ or US-20120144376-$ or US-20100274430-$).did. or (US-20090216820-$ or US-20090198375-$ or US-20070024624-$ or US-20050267987-$).did. or (US-5155684-$ or US-5341540-$ or US-7212651-$ or US-7576639-$ or US-8174568-$ or US-8514236-$ or US-8774970-$ or US-8843244-$ or US-9192869-$ or US-9298183-$ or US-9315192-$ or US-9746339-$ or US-9775681-$ or US-4638445-$ or US-4763276-$ or US-4852018-$ or US-5121497-$ or US-5280179-$ or US-5446356-$ or US-5602761-$ or US-5612883-$ or US-5673367-$ or US-5719480-$ or US-5841959-$ or US-5994864-$ or US-6124694-$).did. or (US-6169981-$ or US-6243622-$ or US-6366293-$ or US-				

		6442451-$ or US-6560511-$ or US-6584375-$ or US-6636781-$ or US-6697711-$ or US-6760645-$ or US-6812846-$ or US-6961060-$ or US-7002585-$ or US-7148644-$ or US-7243334-$ or US-7342589-$ or US-7668605-$ or US-8145492-$ or US-8364314-$ or US-8380348-$ or US-8380652-$ or US-8419804-$ or US-8423225-$ or US-8452448-$ or US-8515162-$ or US-8639035-$ or US-8639644-$ or US-8679260-$).did. or (US-8793205-$ or US-8924021-$ or US-8958911-$ or US-8958912-$ or US-8958937-$ or US-9008840-$ or US-9015093-$ or US-9144907-$ or US-9242372-$ or US-9939814-$ or US-9844879-$ or US-8576235-$ or US-7634336-$ or US-9720071-$ or US-6900758-$ or US-9952053-$ or US-9741140-$ or US-9606542-$ or US-9558424-$ or US-9483879-$ or US-9910444-$ or US-9870624-$ or US-9807365-$ or US-8209144-$ or US-9802322-$ or US-9947134-$ or US-9188982-$).did. or (US-8209143-$ or US-9310807-$ or US-9366540-$ or US-9880002-$).did.				
S114	8	graph AND S113 AND (scan$4 NEAR2 match$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 10:54
S115	3	graph AND S113 AND (scan$4 NEAR2 match$4) AND @AD<"20161101"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 10:54
S116	284	901/1.ccls. AND vacuum.ti,ab,bsum.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 11:44
S117	6893	((G05D2201/0215 OR G05D2201/0203).CPC.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 11:52
S118	3348	((G05D1/0225).CPC.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	ON	2018/12/06 12:07

			IBM_TDB			
S119	278	((B25J9/0003 AND B25J11/0085).CPC.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:09
S120	35696	(robot WITH (clean$4 OR vacuum)).ti,ab,bsum.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:54
S121	6893	(G05D2201/0215 OR G05D2201/0203).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:54
S122	1047	(A47L2201/04 OR A47L2201/00).cpc. AND (navigat$4 OR graph)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:54
S123	1426	(A47L2201/04 AND A47L2201/00).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:54
S124	278	(B25J9/0003 AND B25J11/0085).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:54
S125	1443	B25J9/0003.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:55
S126	558	B25J11/0085.cpc. AND (901/1.ccls. OR (autonomous$2 OR travel$4 OR (mobile ADJ2 (robot OR vehicle))).ti,ab.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:55
S127	40457	S120 S121 S122 S123 S124 S125 S126	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2018/12/06 12:55

			EPO; JPO; DERWENT; IBM_TDB			
S128	70	S127 AND (graph.ti,ab.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:56
S129	253	S127 AND (SLAM.ti,ab,bsum.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:56
S130	26	S128 AND S129	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:56
S131	31740	S127 AND @AD<"20161101"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:56
S132	62	S131 AND (graph.ti,ab.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:57
S133	227	S131 AND (SLAM.ti,ab,bsum.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:57
S134	25	S132 AND S133	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:57
S135	2214	S131 AND (match$4)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 12:57
S136	22	S134 AND S135	US-PGPUB; USPAT;	OR	ON	2018/12/06 12:57

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S137	8	S134 AND S135	US-PGPUB; USPAT	OR	ON	2018/12/06 12:59
S138	35696	(robot WITH (clean$4 OR vacuum)).ti,ab,bsum.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 14:58
S139	6893	(G05D2201/0215 OR G05D2201/0203).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 14:58
S140	1047	(A47L2201/04 OR A47L2201/00).cpc. AND (navigat$4 OR graph)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 14:58
S141	1426	(A47L2201/04 AND A47L2201/00).cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 14:58
S142	278	(B25J9/0003 AND B25J11/0085).CPC.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 14:58
S143	1443	B25J9/0003.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 14:58
S144	558	B25J11/0085.cpc. AND (901/1.ccls. OR (autonomous$2 OR travel$4 OR (mobile ADJ2 (robot OR vehicle))).ti,ab.)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 14:58
S145	40457	S138 S139 S140 S141 S142 S143 S144	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	ON	2018/12/06 14:58

			DERWENT; IBM_TDB			
S146	31740	S145 AND @AD< "20161101"	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 14:58
S147	1510	S146 AND graph$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 14:59
S148	473	S146 AND SLAM!	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 15:00
S149	2214	S146 AND match$4	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2018/12/06 15:00
S150	129	S147 AND S148 AND S149	US-PGPUB; USPAT	OR	ON	2018/12/06 15:00
S151	0	S146 AND ((rout$4 NEAR2 search$4) WITH (graph OR node OR SLAM))	US-PGPUB; USPAT	OR	ON	2018/12/06 15:02
S152	123	S146 AND ((rout$4 OR search$4) WITH (graph OR node OR SLAM))	US-PGPUB; USPAT	OR	ON	2018/12/06 15:02
S153	38	S150 AND S152	US-PGPUB; USPAT	OR	ON	2018/12/06 15:02
S154	16	(US-20140129027-$ or US-20180120116-$ or US-20160071278-$ or US-20080294338-$ or US-20160290805-$ or US-20120316784-$ or US-20130138246-$ or US-20100049391-$ or US-20120121161-$ or US-20160091899-$ or US-20170105592-$ or US-20110125323-$).did. or (US-9910444-$ or US-8209144-$ or US-9310807-$ or US-9366540-$).did.	US-PGPUB; USPAT	OR	ON	2018/12/06 15:04
S155	12	(US-20160071278-$ or US-20140129027-$ or US-20130138246-$ or US-20120316784-$ or US-20120121161-$ or US-20110125323-$ or US-20100049391-$ or US-20080294338-$).did. or (US-9910444-$ or US-9366540-$ or US-9310807-$ or US-8209144-$).did.	US-PGPUB; USPAT	OR	ON	2018/12/06 15:06
S156	4	S155 AND search$4	US-PGPUB; USPAT	OR	ON	2018/12/06 15:06
S157	1690	S146 AND search$4	US-PGPUB; USPAT	OR	ON	2018/12/06 15:08

S158	79	S146 AND ((route OR path) NEAR2 search$4).bi.	US-PGPUB; USPAT	OR	ON	2018/12/06 15:08
S159	31	S146 AND ((route OR path) NEAR2 search$4).bi. AND (graph OR SLAM)	US-PGPUB; USPAT	OR	ON	2018/12/06 15:09
S160	576	S147 AND (S148 OR S149)	US-PGPUB; USPAT	OR	ON	2018/12/06 15:13
S161	146	S160 AND dock$4	US-PGPUB; USPAT	OR	ON	2018/12/06 15:13
S162	111	S160 AND dock$4 AND navigat$4	US-PGPUB; USPAT	OR	ON	2018/12/06 15:13
S163	52	S160 AND dock$4 AND navigat$4 AND node	US-PGPUB; USPAT	OR	ON	2018/12/06 15:14
S164	1	S160 AND dock$4 AND navigat$4 AND (graph WITH node)	US-PGPUB; USPAT	OR	ON	2018/12/06 15:14
S165	1	S160 AND dock$4 AND (graph WITH node)	US-PGPUB; USPAT	OR	ON	2018/12/06 15:14
S166	20	S160 AND (graph WITH node)	US-PGPUB; USPAT	OR	ON	2018/12/06 15:14
S167	10	S160 AND (graph WITH node) AND pose	US-PGPUB; USPAT	OR	ON	2018/12/06 15:17
S168	1	("7774158").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2018/12/06 15:27
S169	1	(10/739935).APP.	US-PGPUB; USOCR	OR	ON	2018/12/06 15:27
S170	16	(US-20140129027-$ or US-20180120116-$ or US-20160071278-$ or US-20080294338-$ or US-20160290805-$ or US-20120316784-$ or US-20130138246-$ or US-20100049391-$ or US-20120121161-$ or US-20160091899-$ or US-20170105592-$ or US-20110125323-$).did. or (US-9910444-$ or US-8209144-$ or US-9310807-$ or US-9366540-$).did.	US-PGPUB; USPAT	OR	ON	2018/12/06 18:24
S171	14	S170 AND match$4	US-PGPUB; USPAT	OR	ON	2018/12/06 18:24
S172	10	S170 AND match$4 AND (scans! OR images!)	US-PGPUB; USPAT	OR	ON	2018/12/06 18:25

EAST Search History (Interference)

< This search history is empty>

12/ 8/ 2018 9:08:31 PM
C:\ Users\ dmoyer\ Documents\ My Docket\ 15340807\ EAST Search.wsp

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/340,807	11/01/2016	Jaldert Rombouts	P23291US00	3030

26418 7590 01/23/2019
REED SMITH LLP
P.O. BOX 488 (NYC)
PITTSBURGH, PA 15230-0488

EXAMINER
MOYER, DALE S

ART UNIT	PAPER NUMBER
3664	

NOTIFICATION DATE	DELIVERY MODE
01/23/2019	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

ptoipinbox@reedsmith.com
nycipdocketing@reedsmith.com

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

Application No. : 15340807
Applicant : Rombouts
Filing Date : 11/01/2016
Date Mailed : 01/23/2019

NOTICE TO FILE CORRECTED APPLICATION PAPERS

Notice of Allowance Mailed

This application has been accorded an Allowance Date and is being prepared for issuance. The application, however, is incomplete for the reasons below.

Applicant is given two (2) months from the mail date of this Notice within which to respond. This time period for reply is extendable under 37 CFR 1.136(a) for only TWO additional MONTHS.

The informalities requiring correction are indicated in the attachment(s). If the informality pertains to the abstract, specification (including claims) or drawings, the informality must be corrected with an amendment in compliance with 37 CFR 1.121 (or, if the application is a reissue application, 37 CFR 1.173). Such an amendment may be filed after payment of the issue fee if limited to correction of informalities noted herein. See Waiver of 37 CFR 1.312 for Documents Required by the Office of Patent Publication, 1280 Off. Gaz. Patent Office 918 (March 23, 2004). In addition, if the informality is not corrected until after payment of the issue fee, for purposes of 35 U.S.C. 154(b)(1)(iv), "all outstanding requirements" will be considered to have been satisfied when the informality has been corrected. A failure to respond within the above-identified time period will result in the application being ABANDONED.

See attachment(s).

A copy of this notice MUST be returned with the reply. Please address response to "Mail Stop Issue Fee, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450".

/Chris Harmon/
Publication Branch
Office of Data Management
(571) 272-4200

Application No. 15340807 **Drawings filed: 11/01/2016**

IDENTIFICATION OF DRAWING DEFICIENCIES

- [ ] There is a hole or the image thereof within the illustration. FIG(s)
- [ ] The illustration is penetrated or traversed by a solid or broken line that is not intended to be part of the drawing, such as a dark line caused by a flaw in the copying process. FIG(s)
- [ ] An ink stamp or the image thereof obscures part of the illustration. FIG(s)
- [ ] The drawing is marred by black smudges, obliterations, or fax/copier marks (for example, speckles or dots in a substantial portion of the drawing). FIG(s)
- [ ] Figure numbers are duplicated or missing. FIG(s)
- [ ] Drawing sheet or figure is missing. FIG(s)
- [ ] Numbers, letters, or reference characters in the drawing have been crossed out or are illegibly handwritten. FIG(s)
- [ ] The character of the lines, numbers, and letters is poor. FIG(s)
- [ ] The drawing's background shows that the original drawing was made on graph paper or other paper with a pattern or decoration. FIG(s)
- [ ] The FIG. number label is placed in a location that causes the drawing to be read upside down. FIG(s)
- [ ] Data, a reference number, or part of the drawing is truncated or missing, or a lead line has no reference number. FIG(s)
- [ ] The drawing and/or the FIG. label contain(s) foreign language. FIG(s)
- [X] This utility application contains a photograph of a view that is capable of being illustrated as a line drawing. FIG(s) 1
- [ ] A petition under 37 CFR 1.84(a)(2) to accept color drawings has been granted, but the brief description of the drawings in the specification does not contain (or has not been amended to contain) the paragraph required by 37 CFR 1.84(a)(2)(iii).
- [ ] This reissue application contains added and/or amended drawings that are not labeled as “New” or “Amended” or “Canceled” as required by 37 CFR 1.173(b)(3). FIG(s)
- [ ] This Design reissue application contains a drawing that is labeled as “Canceled” but is not surrounded by brackets, or a drawing that is surrounded by brackets but is not labeled as “Canceled.” See 37 CFR 1.173(b)(3). FIG(s)
- [ ] OTHER:
- [ ] COMMENTS:

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Jaldert Rombouts et al. Serial No. 15/340,807 Filing Date: November 1, 2016	Confirmation No. 3030 **SYSTEMS AND METHODS FOR ROBOTIC MAPPING**

RESPONSE TO NOTICE TO FILE CORRECTED APPLICATION PAPERS

Mail Stop Issue Fee
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

This is in response to the Notice To File Corrected Application Papers mailed by the U.S. Patent Office on January 23, 2019. This paper is being timely filed by March 23, 2019.

Applicant submits herewith the corrected drawing figure 1.

The Commissioner is hereby authorized to charge the fees and to credit any overpayment to Deposit Account No. 18-0586.

Date: March 1, 2019

Respectfully submitted,

/Sidarth Kapoor /
Sidarth Kapoor
Registration No. 68,159
REED SMITH LLP
136 Main Street
Suite 250
Princeton, NJ 08540
T – 609-524-2077
Attorney for Applicant

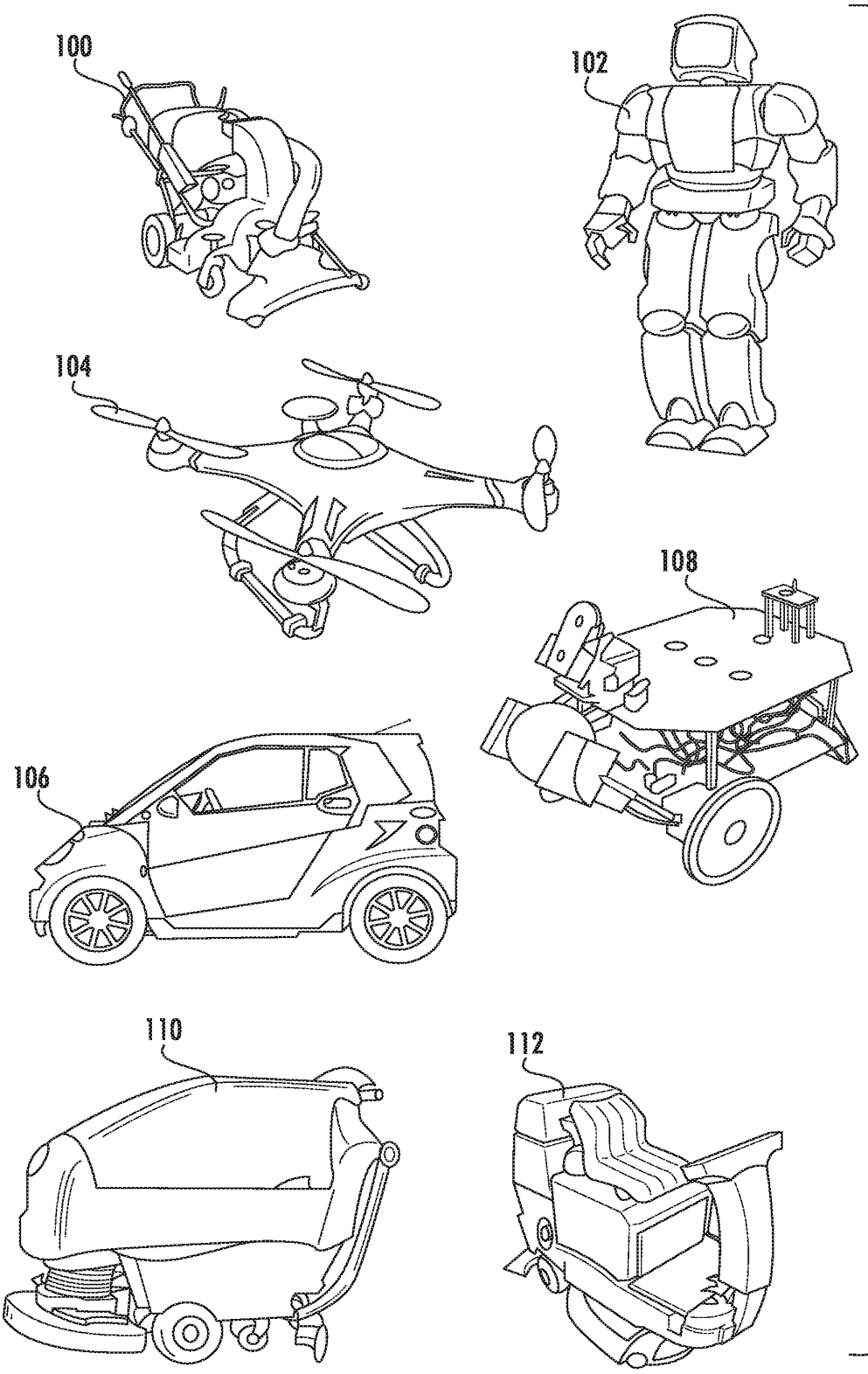


FIG. 1

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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/340,807	11/01/2016	Jaldert Rombouts	P23291US00	3030

26418 7590 01/23/2019
REED SMITH LLP
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PITTSBURGH, PA 15230-0488

EXAMINER
MOYER, DALE S

ART UNIT	PAPER NUMBER
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www.uspto.gov

Application No. : 15340807
Applicant : Rombouts
Filing Date : 11/01/2016
Date Mailed : 01/23/2019

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See attachment(s).

A copy of this notice MUST be returned with the reply. Please address response to "Mail Stop Issue Fee, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450".

/Chris Harmon/
Publication Branch
Office of Data Management
(571) 272-4200

Application No. 15340807 **Drawings filed: 11/01/2016**

IDENTIFICATION OF DRAWING DEFICIENCIES

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- [ ] The drawing is marred by black smudges, obliterations, or fax/copier marks (for example, speckles or dots in a substantial portion of the drawing). FIG(s)
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- [X] This utility application contains a photograph of a view that is capable of being illustrated as a line drawing. FIG(s) 1
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- [ ] This Design reissue application contains a drawing that is labeled as “Canceled” but is not surrounded by brackets, or a drawing that is surrounded by brackets but is not labeled as “Canceled.” See 37 CFR 1.173(b)(3). FIG(s)
- [ ] OTHER:
- [ ] COMMENTS:

Electronic Acknowledgement Receipt	
EFS ID:	35302121
Application Number:	15340807
International Application Number:	
Confirmation Number:	3030
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Customer Number:	26418
Filer:	Sidharth Kapoor/Cody Nye
Filer Authorized By:	Sidharth Kapoor
Attorney Docket Number:	P23291US00
Receipt Date:	01-MAR-2019
Filing Date:	01-NOV-2016
Time Stamp:	15:50:57
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Post Allowance Communication - Incoming	P23291US00_-_2019-03-01_-_Response_to_Notice_to_File_Corrected_Papers.pdf	489915 d057d57aa9d67956442b540bed26a586786de463	no	1
Warnings:					

Information:					
2	Drawings-only black and white line drawings	P23291US00_-_Revised_Figure_1.PDF	38494 d7bb4ab5ccc5438c0525f4c65268d0d16b36bf45	no	1
Warnings:					
Information:					
3	Post Allowance Communication - Incoming	P23291US00_-_Notice_to_File_Corrected_Application_Papers.PDF	115080 9c5e5ca8490a5cb4e8c6da4285855c77412020f2	no	3
Warnings:					
Information:					
		Total Files Size (in bytes):	643489		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
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.
<u>National Stage of an International Application under 35 U.S.C. 371</u>
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.
<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), by mail or fax, or via EFS-Web.

By mail, send to: Mail Stop ISSUE FEE
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

By fax, send to: (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

26418 7590 12/18/2018
REED SMITH LLP
P.O. BOX 488 (NYC)
PITTSBURGH, PA 15230-0488

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being transmitted to the USPTO via EFS-Web or by facsimile to (571) 273-2885, on the date below.

(Typed or printed name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/340,807	11/01/2016	Jaldert Rombouts	P23291US00	3030

TITLE OF INVENTION: SYSTEMS AND METHODS FOR ROBOTIC MAPPING

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$500	$0.00	$0.00	$500	03/18/2019

EXAMINER	ART UNIT	CLASS-SUBCLASS
MOYER, DALE S	3664	700-258000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-09 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Reed Smith LLP
2 Sidharth Kapoor
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document must have been previously recorded, or filed for recordation, as set forth in 37 CFR 3.11 and 37 CFR 3.81(a). Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Brain Corporation

(B) RESIDENCE: (CITY and STATE OR COUNTRY): San Diego, CA

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ☒ Corporation or other private group entity ❑ Government

4a. Fees submitted: ☒ Issue Fee ❑ Publication Fee (if required) ❑ Advance Order - # of Copies _____

4b. Method of Payment: *(Please first reapply any previously paid fee shown above)*

☒ Electronic Payment via EFS-Web ❑ Enclosed check ❑ Non-electronic payment by credit card (Attach form PTO-2038)

☒ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment to Deposit Account No. 18-0586

5. **Change in Entity Status** (from status indicated above)

❑ Applicant certifying micro entity status. See 37 CFR 1.29

❑ Applicant asserting small entity status. See 37 CFR 1.27

❑ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Sidharth Kapoor/ Date March 18, 2019

Typed or printed name Sidharth Kapoor Registration No. 68,159

PTOL-85 Part B (08-18) Approved for use through 01/31/2020 OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Electronic Patent Application Fee Transmittal

Application Number:	15340807
Filing Date:	01-Nov-2016
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Filer:	Sidharth Kapoor/Cody Nye
Attorney Docket Number:	P23291US00

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
UTILITY APPL ISSUE FEE	2501	1	500	500

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**500**

Electronic Acknowledgement Receipt	
EFS ID:	35450301
Application Number:	15340807
International Application Number:	
Confirmation Number:	3030
Title of Invention:	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
First Named Inventor/Applicant Name:	Jaldert Rombouts
Customer Number:	26418
Filer:	Sidharth Kapoor/Cody Nye
Filer Authorized By:	Sidharth Kapoor
Attorney Docket Number:	P23291US00
Receipt Date:	18-MAR-2019
Filing Date:	01-NOV-2016
Time Stamp:	13:37:07
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	$500
RAM confirmation Number	031819INTEFSW13375000
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	P23291US00_-_2019-03-18_-_Issue_Fee_Transmittal.PDF	89776 dbbd457c8661521dea357ffaead3afaec7198064	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30502 e56bdb7b0fe60b76f8707b7f394eb9e074f2538c	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	120278		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
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United States Patent and Trademark Office
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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
15/340,807	04/30/2019	10274325	P23291US00	3030

26418 7590 04/10/2019

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P.O. BOX 488 (NYC)
PITTSBURGH, PA 15230-0488

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 89 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Jaldert Rombouts, San Diego, CA;
BRAIN CORPORATION, San Diego, CA
Borja Ibarz Gabardos, La Jolla, CA;
Jean-Baptiste Passot, Solana Beach, CA;
Andrew Smith, San Diego, CA;

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Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82A (07-13)
Approved for use through 09/30/2025. OMB 0651-0035
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TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	15/340,807
Filing Date	11/01/2016
First Named Inventor	Jaldert Rombouts
Title	SYSTEMS AND METHODS FOR ROBOTIC MAPPING
Art Unit	3664
Examiner Name	DALE S MOYER
Attorney Docket Number	035471.075US1

SIGNATURE of Applicant or Patent Practitioner

Signature	/Sidharth Kapoor/	Date (Optional)	
Name	Sidharth Kapoor	Registration Number	68,159
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)			

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ *Total of 1 forms are submitted.

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If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82B (07-13)
Approved for use through 09/30/2025. OMB 0651-0035
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POWER OF ATTORNEY BY APPLICANT

I hereby revoke all previous powers of attorney given in the application identified in either the attached transmittal letter or the boxes below.

Application Number	Filing Date

(Note: The boxes above may be left blank if information is provided on form PTO/AIA/82A.)

☑ I hereby appoint the Patent Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above: 197519

OR

☐ I hereby appoint Practitioner(s) named in the attached list (form PTO/AIA/82C) as my/our attorney(s) or agent(s), and to transact all business in the United States Patent and Trademark Office connected therewith for the patent application referenced in the attached transmittal letter (form PTO/AIA/82A) or identified above. (Note: Complete form PTO/AIA/82C.)

Please recognize or change the correspondence address for the application identified in the attached transmittal letter or the boxes above to:

☑ The address associated with the above-mentioned Customer Number

OR

☐ The address associated with Customer Number:

OR

☐ Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

Brain Corporation

☐ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☑ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	Andy Ng	Date (Optional)	
Name	Andy Ng		
Title	General Counsel		

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

☑ Total of 1 forms are submitted.

A Federal agency may not conduct or sponsor, and a person is not required to respond to, nor shall a person be subject to a penalty for failure to comply with an information collection subject to the requirements of the Paperwork Reduction Act of 1995, unless the information collection has a currently valid OMB Control Number. The OMB Control Number for this information collection is 0651-0035. Public burden for this form is estimated to average 3 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the information collection. Send comments regarding this burden estimate or any other aspect of this information collection, including suggestions for reducing this burden to the Chief Administrative Officer, United States Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450 or email InformationCollection@uspto.gov. **DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS.** If filing this completed form by mail, send to: **Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PATENT AND TRADEMARK OFFICE

P.O. Box 1450
Alexandria, VA 22313 - 1450
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ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #	RECEIPT DATE / TIME	ATTORNEY DOCKET #
15/340,807	**01/08/2025 02:15:08 AM Z ET**	**P23291US00**

Title of Invention

SYSTEMS AND METHODS FOR ROBOTIC MAPPING

Application Information

APPLICATION TYPE	Utility - Nonprovisional Application under 35 USC 111(a)	PATENT #	10274325
CONFIRMATION #	3030	FILED BY	Sidharth Kapoor
PATENT CENTER #	68642674	FILING DATE	11/01/2016
CUSTOMER #	26418	FIRST NAMED INVENTOR	Jaldert Rombouts
CORRESPONDENCE ADDRESS	-	AUTHORIZED BY	-

Documents

TOTAL DOCUMENTS: 1

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
15-340807- POA.pdf	2	Power of Attorney	414 KB

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
15-340807- POA.pdf	D1975562A5404932021A7D81F3930D485CD72FAAD313578BC C9CAC3970C866EE20F402C44AA35D866278C6BB7A88BFB09 7DFB701F5A4EFD8706CC4383494437E

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for 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.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/340,807	11/01/2016	Jaldert Rombouts	P23291US00

CONFIRMATION NO. 3030

26418
Reed Smith LLP (New York)
P.O. BOX 488
PITTSBURGH, PA 15230-0488

POWER OF ATTORNEY NOTICE

OC000000083692558

Date Mailed: 01/30/2025

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 01/08/2025.

- The Power of Attorney to you in this application has been revoked by the applicant. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/hsarwari/

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
15/340,807	11/01/2016	Jaldert Rombouts	P23291US00

CONFIRMATION NO. 3030

197519
Pierson Ferdinand, LLP
1101 Pennsylvania Avenue N.W.
Suite 300
Washington, DC 20005

POA ACCEPTANCE LETTER

OC000000083692595

Date Mailed: 01/30/2025

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 01/08/2025.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/hsarwari/