

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

AVIDBOTS CORP. and AVIDBOTS USA CORP.,
Petitioners,

v.

BRAIN CORPORATION,
Patent Owner.

Case No. IPR2025-01601
U.S. Patent No. 10,379,539

Petition for *Inter Partes* Review of U.S. Patent No. 10,379,539

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PETITIONERS' EXHIBIT LIST

Exhibit	Description
1001	U.S. Patent No. 10,379,539
1002	File History for U.S. Patent No. 10,379,539 (Appl. No. 16/011,499)
1003	Declaration of Nickolaos Papanikolopoulos
1004	U.S. Patent Appl. Pub. No. 2015/0284010 (“Beardsley”)
1005	J. Minguez, L. Montano, J. Santos-Victor, “Abstracting Vehicle Shape and Kinematic Constraints from Obstacle Avoidance Methods”, 20(1) Autonomous Robots 43-59 (2006) (“Minguez”)
1006	O. Khatib, “Real-Time Obstacle Avoidance For Manipulators and Mobile Robots,” 5 Int’l J. of Robotics Research 90–98 (1986) (“Khatib”)
1007	J.A. Castellanos, J. Montiel, J. Neira, J.D Tardos, “The SPmap: A probabilistic framework for simultaneous localization and map building,” 15(5) IEEE Trans. Robotics and Automation 948–952 (1999) (“Castellanos”)
1008	Declaration of Dr. Mary K. Bolin
1009	Maki K. Habib, “Real Time Mapping and Dynamic Navigation for Mobile Robots,” 4(3) Int’l J. of Advanced Robotic Systems 323 (2007) (“Habib”)
1010	Chang, Ya-Chun, Yamamoto, Yoshio, On-line path planning strategy integrated with collision and dead-lock voidance schemes for wheeled mobile robot in indoor environments, Industrial Robot, An International Journal 35(5) 421-34 (2008) (“Yamamoto”)
1011	Oussama Khatib et al., “Robots in Human Environments: Basic Autonomous Capabilities”, 18(7) International Journal Of Robotics Research 684-696 (1999) (“Khatib ’99”)
1012	Choset et al., “Principles of Robotic Motion Theory, Algorithms, and Implementation”, Massachusetts Institute of Technology Press (2005) (“Choset”)
1013	International Organization for Standardization, “Robots and robotic devices — Safety requirements for personal care robots” 13482 First Edition (2014)

Exhibit	Description
1014	Plaintiff Brain Corporation's Objections And Responses To Defendants' First Set Of Interrogatories (NOS. 1–9) (Redacted Excerpt)
1015	J. Scholz, S. Chitta, B. Marthi and M. Likhachev, "Cart pushing with a mobile manipulation system: Towards navigation with moveable objects," IEEE International Conference on Robotics and Automation 6115-6120 (2011)

TABLE OF ABBREVIATIONS

Abbreviation	Term
'499 Application	U.S. Patent Application No. 16/011,499
'539 Patent	U.S. Patent No. 10,379,539
Board	Patent Trial and Appeal Board
Challenged Claims	Claims 1–20 of U.S. Patent No. 10,379,539
Beardsley	U.S. Patent Appl. No. 15/0284010 (Ex1004)
Khatib	O. Khatib, “Real-Time Obstacle Avoidance For Manipulators and Mobile Robots,” 5 Int’l J. of Robotics Research 90–98 (1986) (Ex1006)
Castellanos	J.A. Castellanos, J. Montiel, J. Neira, J.D Tardos, “The SPmap: A probabilistic framework for simultaneous localization and map building,” 15(5) IEEE Trans. Robotics and Automation 948–952 (1999) (Ex1007)
Habib	Maki K. Habib, “Real Time Mapping and Dynamic Navigation for Mobile Robots,” 4(3) Int’l J. of Advanced Robotic Systems 323 (2007) (Ex1009)
Yamamoto	Chang, Ya-Chun, Yamamoto, Yoshio, “On-line path planning strategy integrated with collision and dead-lock avoidance schemes for wheeled mobile robot in indoor environments”, Industrial Robot, An International Journal 35(5) 421-34 (2008) (Ex1010)
Scholz	J. Scholz, S. Chitta, B. Marthi and M. Likhachev, “Cart pushing with a mobile manipulation system: Towards navigation with moveable objects,” IEEE International Conference on Robotics and Automation 6115-6120 (2011) (Ex1015)
Ex.	Exhibit
Fig.	Figure
IPR	<i>inter partes</i> review
Patent Office	United States Patent and Trademark Office

TABLE OF AUTHORITIES (*continued*)

Page(s)

Abbreviation	Term
Petitioners or Avidbots	Avidbots Corp. and Avidbots USA Corp.
POSITA	person of ordinary skill in the art
Board	Patent Trial and Appeal Board
Challenged Claims	Claims 1–20 of U.S. Patent No. 10,379,539
Beardsley	U.S. Patent Appl. No. 15/0284010 (Ex1004)
Khatib	O. Khatib, “Real-Time Obstacle Avoidance For Manipulators and Mobile Robots,” 5 Int’l J. of Robotics Research 90–98 (1986) (Ex1006)
Castellanos	J.A. Castellanos, J. Montiel, J. Neira, J.D Tardos, “The SPmap: A probabilistic framework for simultaneous localization and map building,” 15(5) IEEE Trans. Robotics and Automation 948–952 (1999) (Ex1007)
Habib	Maki K. Habib, “Real Time Mapping and Dynamic Navigation for Mobile Robots,” 4(3) Int’l J. of Advanced Robotic Systems 323 (2007) (Ex1009)
Scholz	J. Scholz, S. Chitta, B. Marthi and M. Likhachev, “Cart pushing with a mobile manipulation system: Towards navigation with moveable objects,” IEEE International Conference on Robotics and Automation 6115-6120 (2011) (Ex1015)

MANDATORY NOTICES

A. Real Parties-in-Interest [37 C.F.R. § 42.8(b)(1)]

The real parties-in-interest are Petitioners Avidbots Corp. and Avidbots USA Corp. (collectively, “Petitioners” or “Avidbots”). No entity not named above is funding, controlling, or directing this Petition, or otherwise has had an opportunity to control or direct this Petition or Petitioners’ participation in any resulting IPR.

B. Related Matters [37 C.F.R. § 42.8(b)(2)]

The ’539 patent is the subject of a civil action, *Brain Corp. v. Avidbots Corp. & Avidbots USA Corp.*, Case No. 24-cv-12569 (N.D. Ill.), filed December 6, 2024. Petitioner is not aware of any other disclaimers, reexamination certificates, or IPR petitions addressing the ’539 patent.

C. Lead and Back-Up Counsel [37 C.F.R. § 42.8(b)(3)]

Pursuant to 37 C.F.R. §§ 42.8(b)(3), 42.8(b)(4), and 42.10(a), Petitioners provide the following designation of counsel:

Lead Counsel for Petitioners	Back-Up Counsel for Petitioners
Brian M. Buroker (Reg. No. 39,125) Gibson, Dunn & Crutcher LLP 1050 Connecticut Ave. NW Washington, DC 20036 Phone: (202) 955-8500 Fax: (202) 467-0539 Email: bburoker@gibsondunn.com	Nathan Curtis (Reg. No. 70,471) Gibson, Dunn & Crutcher LLP 2001 Ross Avenue Suite 2100 Dallas, TX 75201 Phone: (214) 698-3423 Fax: (214) 571-2961 Email: ncurtis@gibsondunn.com L. Kieran Kieckhefer (pro hac vice forthcoming) One Embarcadero Center Suite 2600 San Francisco, CA 94111 Phone: (415) 393-8200 Email: kkieckhefer@gibsondunn.com Ahmed E. ElDessouki (pro hac vice forthcoming) Gibson, Dunn & Crutcher LLP 200 Park Avenue New York, NY 10166 Phone: (212) 351-4000 Email: aeldessouki@gibsondunn.com

A Power of Attorney accompanies this Petition in accordance with 37 C.F.R.
§ 42.10(b).

D. Service Information [37 C.F.R. § 42.8(b)(4)]

Service via hand delivery or postal mail may be made at the addresses of the
lead and back-up counsel above. Petitioners hereby consent to electronic service,
and service by electronic mail may be made at the following email address:

- GDC-AvidbotsIPR@gibsondunn.com

I. INTRODUCTION

Pursuant to 35 U.S.C. § 311, Petitioners hereby petition for IPR of U.S. Patent No. 10,379,539 (Ex. 1001) and seek cancellation of claims 1–20 as unpatentable under 35 U.S.C. §§ 102 and 103.

The '539 patent is directed to a robot and methods for autonomous navigation using sensor data to generate a map and determine a route for the robot. The robot uses simulated “forces” repel the robot away from obstacles as it navigates along a path.

Although the '539 patent was not filed until June 18, 2018, the technique of simulating forces for obstacle avoidance was known as early as 1986 (Ex1006) and its allowance reflects a clear error during examination. In the Examiner’s October 4, 2018 rejection, despite raising an objection over double patenting, the examiner allowed claims 1-20 even while acknowledging “[t]here are inventions in the field that provide similar functionality and/or have similar features.” Ex1002, 91-92; Ex1003, ¶43. Worse, the Examiner commented on none of these inventions. This glaring omission resulted in a summary and erroneous allowance.

As illustrated below, the '539 patent’s claims are directed to well-known techniques. Prior art Beardsley and Yamamoto disclose the use of sensors to detect obstacles by simulating forces. Well known map building methods are disclosed in Castellanos. Khatib—published in 1986—explains the technique of simulating

forces on multiple points to navigate the robot. Scholz discloses dynamically adjusting a robot's footprint.

Petitioners respectfully submit that it is appropriate for the Board to institute IPR to invalidate this patent that never should have issued.

II. REQUIREMENTS OF *INTER PARTES* REVIEW

A. Standing

Pursuant to 37 C.F.R. § 42.104(a), Petitioners certify that the '539 patent is available for IPR (more than nine months have passed since issuance (35 U.S.C. § 311(c)(1)) and that Petitioners are not barred or estopped from requesting an IPR on the grounds identified herein.

B. Identification of Challenge and Relief Requested

Pursuant to 37 C.F.R. § 42.104(b), Petitioners request that the Board institute IPR of claims 1–20 of the '539 Patent under pre-AIA 35 U.S.C. §§ 102 and 103.

The '539 Patent issued on August 13, 2019. Petitioners do not challenge whether the Challenged Claims are entitled to a priority date of November 2, 2016.

If review is instituted, Petitioner will not pursue in the Litigation the same grounds or any grounds that could have reasonably been raised in this Petition.

The precise relief requested by Petitioners is that claims 1-20 be canceled based on the grounds below:

Ground	Claims	Basis for Rejection¹
1	1-20	Beardsley in view of Castellanos
2	1-20	Beardsley in view of Castellanos and Khatib
3	1-20	Yamamoto in view of Khatib
4	3, 10, 16	Beardsley in view of Castellanos and Scholz

The above challenges are made in view of the following prior art references, none of which was of record during prosecution of the '539 patent:

1. Beardsley (Ex1004)

Beardsley was published on October 8, 2015, and claims priority to a non-provisional application filed on August 12, 2014. Beardsley qualifies as prior art to the '539 patent under post-AIA U.S.C. § 102(a).

2. Khatib (Ex1006)

Khatib was published in print in the International Journal of Robotics Research in 1986 and in the Sage Journals database in October 2006. Ex1008, ¶¶32-33. Khatib would have been located by POSITA exercising reasonable diligence as of October 2006, by searching on the Sage Journals database for terms including “obstacle avoidance,” “mobile robots,” or “Khatib,” which are terms synonymous and/or closely related with the concepts underlying the '539 patent. *Id.* ¶50; Ex1003,

¹ All obviousness grounds include the knowledge of a POSITA.

¶23. Khatib qualifies as prior art to the '539 patent under at least post-AIA 35 U.S.C. § 102(a).

3. Castellanos (Ex1007)

Castellanos was published in print in the IEEE journal, Transactions on Robots and Automation, in October 1999, and published on the well-known online database IEEE Xplore. Ex1008, ¶ 24, 27. Castellanos would have been located by a POSITA exercising reasonable diligence at least as of May 2000, by searching on IEEE Xplore for terms such as “localization,” “map building,” and “robotics and automation,” which are synonymous and/or closely related terms to the '539 patent. *Id.* ¶37; Ex1003, ¶26. Castellanos qualifies as prior art to the '539 patent under at least post-AIA 35 U.S.C. § 102(a).

4. Yamamoto (Ex1010)

Yamamoto was published in print and online in the journal, *Industrial Robot, an International Journal*, on August 22, 2008. Ex1008, ¶44. Yamamoto would have been located by a POSITA exercising reasonable diligence as of that date, including by searching on the database, Emerald Insights for terms such as “mobile robot”, “mobile robot in indoor environment”, or “path planning,” which are synonymous and/or closely related terms to the '539 patent. *Id.*, ¶48; Ex1003, ¶40. Yamamoto qualifies as prior art to the '530 patent under at least post-AIA 35 U.S.C. § 102(a).

5. Scholz (Ex1015)

Scholz was published in the IEEE Conference on Robotics and Automation and added to IEEE Xplore on August 18, 2011. Ex1008, ¶51. Scholz would have been located by a POSITA exercising reasonable diligence at least as of that date, by searching on IEEE Xplore for terms such as “robot sensing systems,” “robotic navigation,” “path planning,” and “mobile robots,” which are synonymous and/or closely related terms to the ’539 patent. *Id.*, ¶54; Ex1003, ¶29. Scholz qualifies as prior art to the ’539 patent under at least post-AIA 35 U.S.C. § 102(a).

C. How the Challenged Claims Are To Be Construed Under 37 C.F.R. § 42.104(b)(3)

A claim subject to IPR shall be construed using the same standard as in a civil action. 37 C.F.R. § 42.100(b). The Board need only construe terms “to the extent necessary to resolve the controversy.” *Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017). No construction of any claim term is necessary for the Board to resolve, and that the Challenged Claims would have been obvious under any reasonable construction.

D. How the Challenged Claims Are Unpatentable Under 37 C.F.R. § 42.104(b)(4)

An explanation of how the Challenged Claims are unpatentable under the statutory grounds identified above, including the identification of where each

element of the claim is found in the prior art patents or printed publications, is provided below.

E. Supporting Evidence Under 37 C.F.R. § 42.104(b)(5)

The exhibit numbers of the supporting evidence relied upon and the relevance of the evidence to the Challenged Claims, including an identification of specific portions of the evidence that support the challenge, are provided below. A list of exhibits with the exhibit number and a brief description of each exhibit is also included in this Petition pursuant to 37 C.F.R. § 42.63(e). The technical information and grounds for rejection explained in this Petition are further supported by the Declaration of Nikolaos Papanikolopoulos, Ph.D. (Ex. 1003).

F. Payment of Fees

Pursuant to 37 C.F.R. §§ 42.103 and 42.15(a), the required fee is being submitted herewith. The Office is authorized to charge any fee deficiency, or credit overpayment, to deposit account no. 50-1408, including additional fees due in connection with this Petition.

III. TECHNICAL BACKGROUND

A. Alleged Invention of the '539 Patent

The '539 patent admits that it was known for “a robot [to] plan its own route in an environment based on its knowledge of the environment (e.g., a map).” Ex1001, 1:37-39. The patent contends that “features of the environment can change” and “current robots may not be able to make real time adjustments to its planned

path in response to these changes.” *Id.* at 1:41-45. The patent concludes that prior art robots may “collide into objects, and/or make sub-optimal adjustments to its route.” *Id.* at 1:45-47.

To address this alleged problem, the patent describes a robot that implements a method 600 (Figure 6 below) that determines “forces on each of the plurality of points of each route pose” and then repositions “one or more route poses in response to forces” and generates “a collision-free path.”

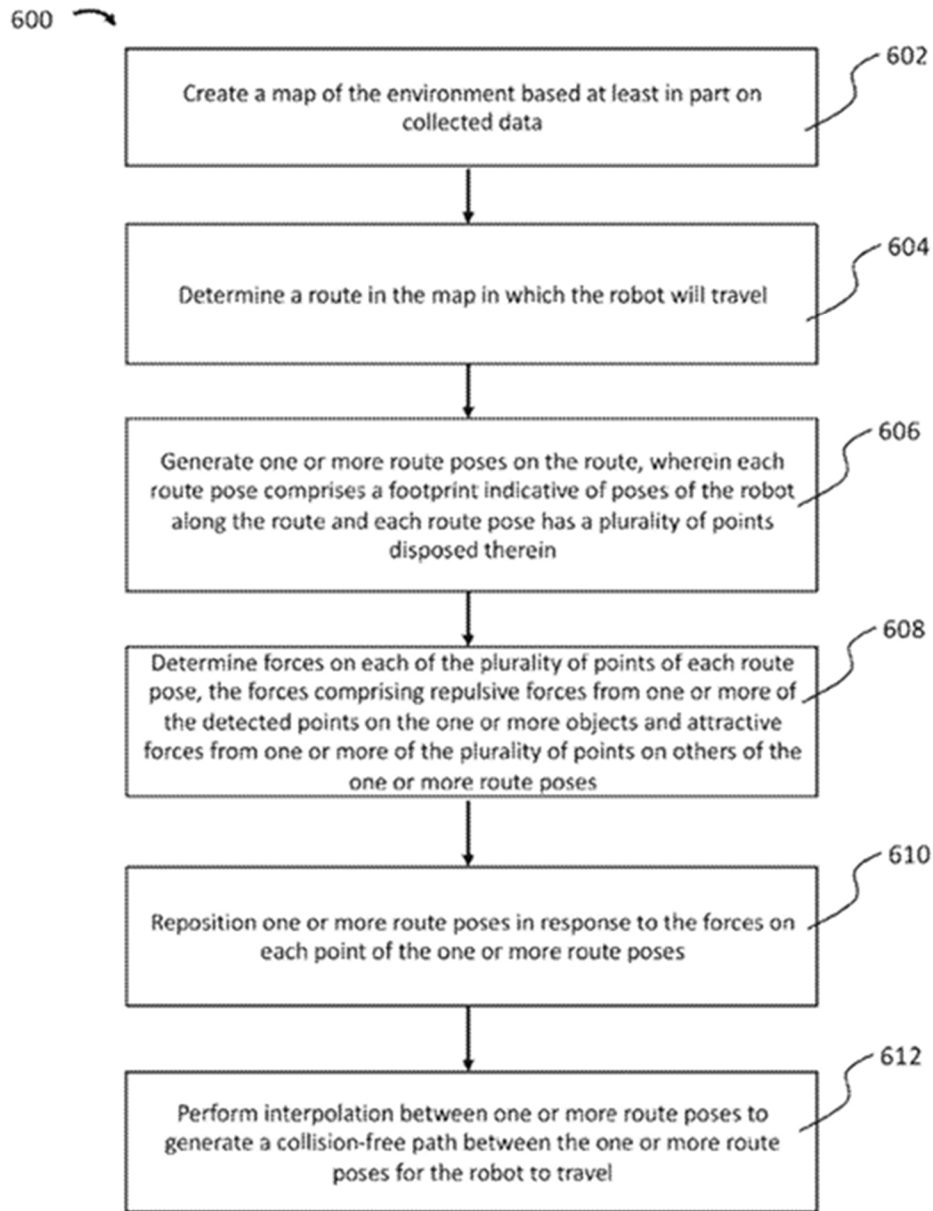


FIG. 6

Ex1001, Fig. 6.

B. State of Art Before the '539 Patent

The techniques claimed as new in the '539 patent were well-known in the art prior to its filing, including map creation and the use of forces to reposition the robot

along the route based to dynamically avoid obstacles. Ex1003, ¶23. In 2007, Habib surveyed well-known art relating to map building and localization. Ex1009, 323-324; Ex1003, ¶¶23-25. Techniques such as calculating simulated forces for real time object avoidance by robotic arms and mobile robots were well known since at least the publication of Khatib's seminal paper in 1986. Ex1006; Ex1012, 80, 101-104, 582 (applying Khatib to mobile robots); Ex1003, ¶¶23, 28. Dynamically reshaping a robot's footprint was known since at least 2011. Ex1015, 6119; Ex1003, ¶29. Selecting footprint size depending on acceptable collision risk was known since at least 2014. Ex1013, 66-70. The '539 patent is an obvious combination of routine and well-known navigation techniques for autonomous robots. *Infra* (Section IV); Ex1003, ¶23.

C. Prosecution History of the '539 Patent

The '539 patent was subject to only a single rejection. While rejected primarily on double patenting grounds, the examiner admitted the existence of "inventions in the field that provide similar functionality and/or have similar features," but failed to comment on any of them in any level of detail, including seminal disclosure on obstacle avoidance using simulated forces, a key feature of the '539 patent. Ex1002, 91-92; Ex1003 ¶43.

The Examiner allowed the claims on April 4, 2019. Ex1002, 118. The '539 patent issued on August 13, 2019. Ex1001. Because more than nine months have passed since issuance, the '539 Patent is eligible for IPR. 35 U.S.C. § 311(c)(1).

D. Person of Ordinary Skill in the Art

The '539 patent relates to the field of dynamic route planning. Ex1001, 1:26-29. A POSITA at the time of the earliest effective filing date of the '539 patent would have had a Bachelor's degree or higher in electrical, computer, or mechanical engineering, or computer science (or equivalent discipline) and at least two years' experience in research, design and/or development of autonomous robotics and/or robotic mapping/navigation and/or a related field. Additional education could substitute for experience, and vice versa. Ex1003, ¶57.

IV. GROUNDS OF UNPATENTABILITY

A. Ground 1: Beardsley in view of Castellanos Render Obvious Claims 1–20

Beardsley's method for control of an autonomous vehicle combined with Castellanos's map generation method disclose all elements of the Challenged Claims (Ground 1) and render the Challenged Claims obvious.

1. Overview of Ground and Prior Art

a. Summary of Beardsley

Beardsley discloses an autonomous robotic vehicle, such as a cleaning robot, that determines a collision-free route that avoids obstacles. Ex1004, [0008], [0045],

[0221]. Beardsley discloses a “potential field approach that pushes the vehicle away from both static and dynamic obstacles” through use of a “repulsive force.” *Id.* [0061]. Beardsley also discloses a “guidance trajectory” that provides “higher control over the motion,” which is created using a roadmap or grid map (400) with connected waypoints (430). *Id.* [0057], [0060], [0061]. Each waypoint has an associated arrival time and an active area (434), which is an area “where the vehicle is allowed to freely move.” *Id.* [0008], [0057], [0061]; Fig. 4.

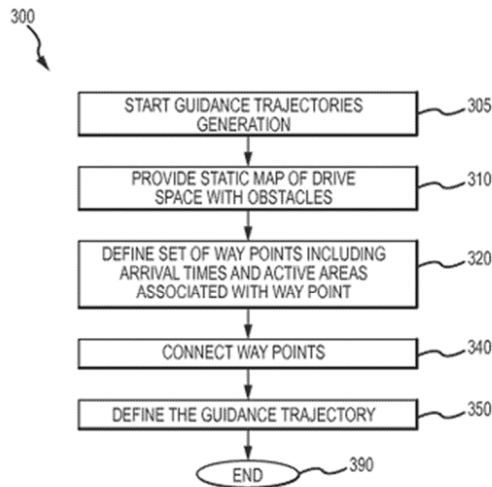


FIG.3

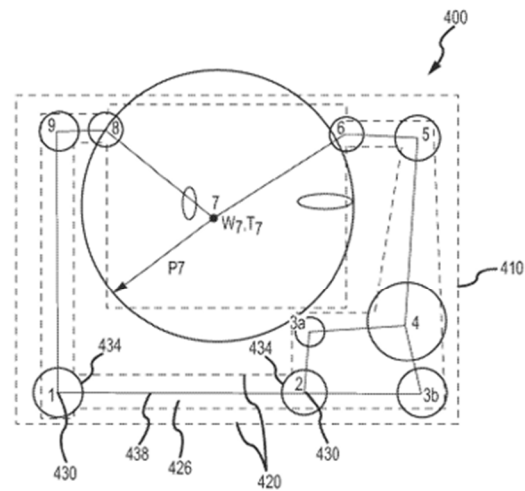


FIG.4

Id., Figs. 3, 4.

b. Summary of Castellanos

Castellanos discloses “path planning and navigation of a mobile robot.” Ex1007, 948. The method provides “automatic construction of [a] map of the environment in which the robot navigates” using laser data collected from sensors,

referred to as an SPmap. *Id.* Fig. 1 shown below depicts Castellanos' approach to SLAM.

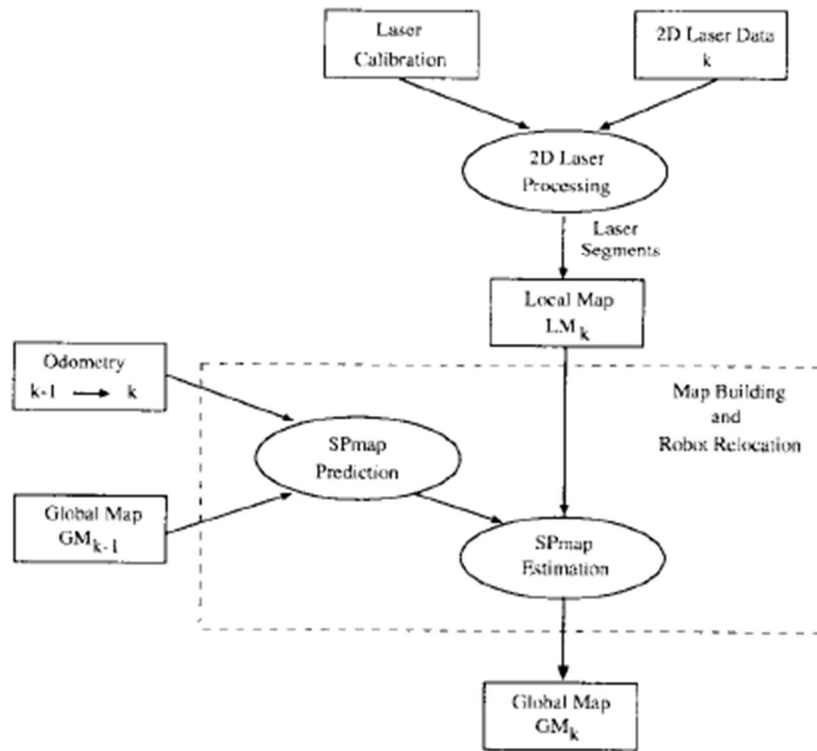
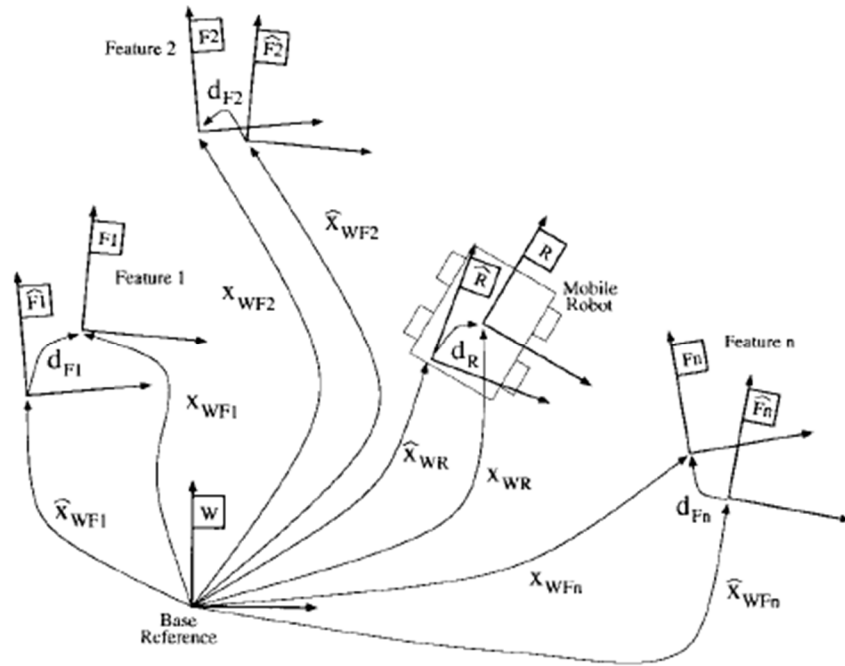


Fig. 1. Simultaneous localization and map building.

Ex1007, Fig. 1.

Castellanos maps obstacles (“geometric element” / “feature”) with respect to the base location of the mobile robot (“base reference W ”) by calculating a location vector accounting for estimation error resulting in the diagram in Fig. 2. *Id.*, 948-949.



Castellanos discloses “incremental construction of the SPmap” by using “estimation techniques based on” an “extended Kalman filter.” *Id.*, 949. Castellanos estimates “displacement of the mobile robot between two intermediate points along its trajectory” and predicts the location of a mobile robot at a particular time. *Id.* Castellanos also discloses matching local map observations with global map features and estimating extended Kalman filters by decomposing into the estimation of the mobile robot location and subsequent estimation of map features from common observations. *Id.*, Fig. 5.

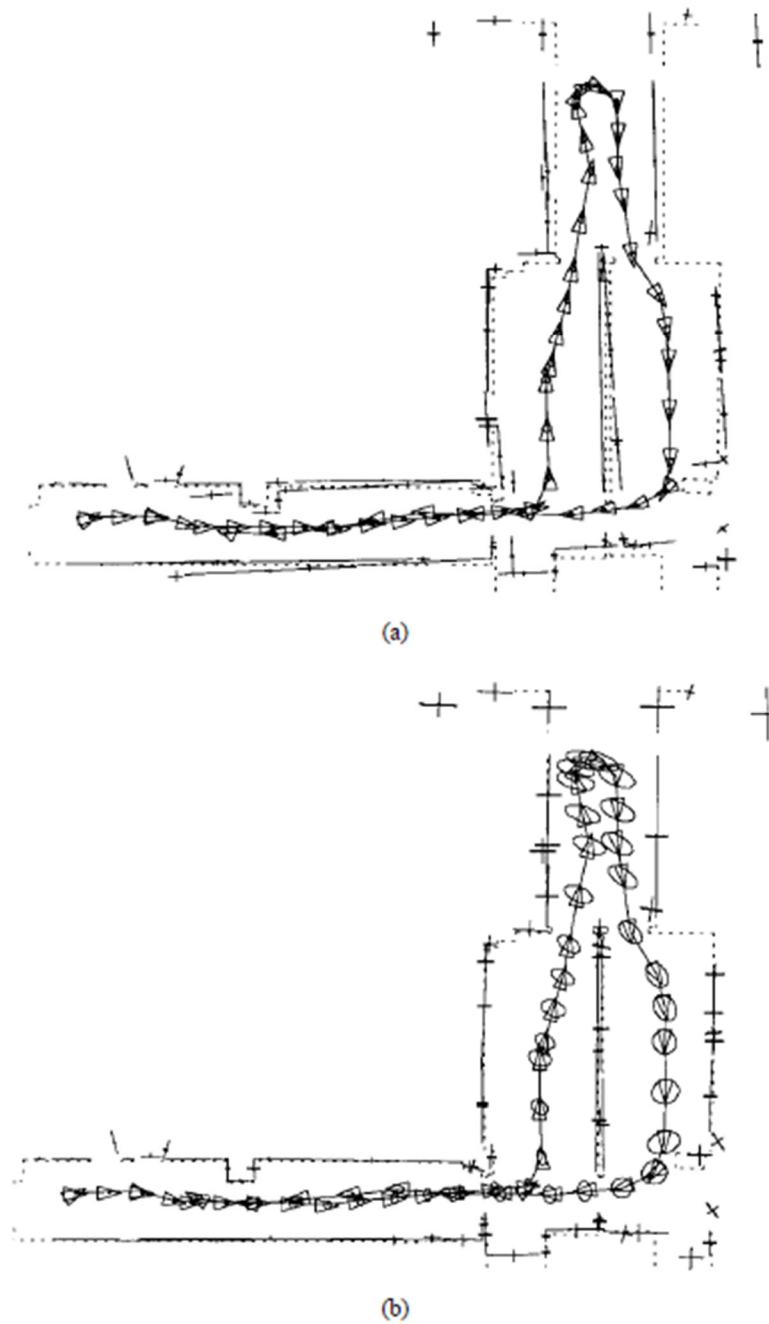


Fig. 5. Estimated robot trajectory and built map (a) neglecting correlations between entities, where the estimated solution diverges from ground-truth, and (b) using the SPmap approach. An *a priori* model map is drawn for reference purposes.

c. Motivation to Combine Beardsley and Castellanos

Well before the '539 patent, a POSITA would have been familiar with the various implementations of the potential field method of obstacle avoidance, such as Beardsley, and mapping methods, such as Castellanos. *Supra* § III.B; Ex1003, ¶54.

A POSITA would have recognized that the problems of mapping, obstacle avoidance, and navigation/motion planning are a well-known set of issues that comprise a unified challenge to creating a “complete navigation system” in the field of autonomous robotics. Ex1003, ¶55; Ex1005, 44. A complete navigation system necessarily requires combinations of methods, and a POSITA would have been motivated to combine existing methods across to improve existing total or partial solutions for a complete navigation system. Ex1003, ¶55.

First, Beardsley's robot uses a “grid map” and implements the well-known “potential field” approach of obstacle avoidance for navigation on the grid map. Ex1004, [0008], [0012], [0016], [0061], Fig. 3 (step 310); Ex1003, ¶56. However, Beardsley does not disclose how the grid map is generated. *Id.* Castellanos teaches a SLAM method for generating a map, utilizing a probabilistic model to represent the location of uncertain geometric information, and which uses route poses in a shape and size substantially the same as the robot. Ex1007, 948; Ex1003, ¶56.

A POSITA would have been motivated to combine Beardsley's potential field-based obstacle avoidance technique with the mapping technique disclosed in Castellanos to develop a complete navigation system. Ex1003, ¶56.

A POSITA seeking improved solutions to a complete navigation system in the field of autonomous robots would have combined the teachings of obstacle avoidance, map building, and localization using route poses disclosed in Beardsley and Castellanos to develop a complete solution. Ex1003, ¶56; Ex1009, 323.

Castellanos teaches generating a trajectory on the map with route poses on the route. Ex1003, ¶56. A POSITA seeking improved solutions to a complete navigation system in the field of autonomous robots would have been motivated to implement the Castellanos' trajectories with route poses onto Beardsley's robot to allow the robot to navigate static obstacles using Beardsley's attractive and repulsive forces. Ex1003, ¶56.

Second, Castellanos's localization teachings are particularly well-suited to be combined with Beardsley's obstacle avoidance and navigation teachings. Ex1003, ¶58. Each method uses sensor data. *Id.* Beardsley discloses a "vehicle 110" which relies on "sensor data 119" "to determine present locations of [other] vehicles 110 in the drive space," which allows vehicle 110 to avoid collisions. Ex1004, [0048], [0104]. However, Beardsley does not disclose which specific sensors would be suitable. Ex1003, ¶58. Castellanos discloses a robot "equipped with a rotating two-

dimensional (2-D) laser rangefinder.” Thus, a POSITA would have been motivated to combine teachings of Beardsley and Castellanos to develop a complete method for autonomous robotic navigation that could efficiently use the same sensors and sensor data for localization (Castellanos) and obstacle avoidance and navigation (Beardsley). *Id.*

A POSITA would have reasonably expected success in combining the teachings of Beardsley and Castellanos, both of which use sensors/sensor data. Ex1003, ¶59. Beardsley’s method of obstacle avoidance combined with Castellanos’s SLAM method provide solutions to complementary sub-problems in the complete navigation system. *Id.*, Ex1009, 323; Ex1005, 44.

2. Detailed Analysis of Ground 1

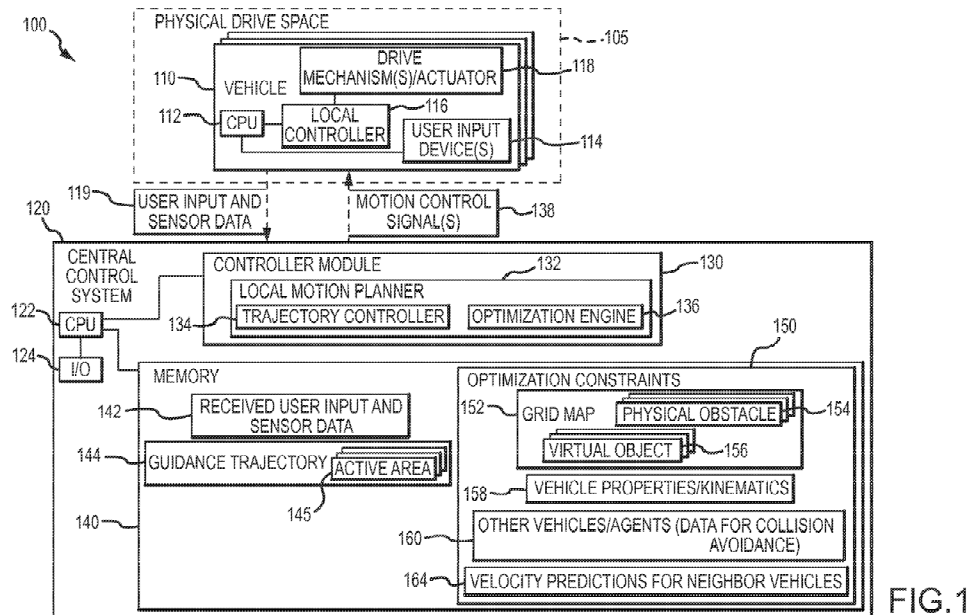
As supported by the Papanikolopoulos Declaration, the combination of Beardsley and Castellanos teaches all elements of claims 1–20 of the ’539 Patent and also renders all of those claims obvious. Ex1003, ¶64.

a. Element 1[pre]: “A robot for maneuvering along a route, comprising:”

To the extent the preamble is limiting, Beardsley/Castellanos disclose this limitation. Ex1003, ¶65.

Beardsley discloses a system 100, which is a robot, and which includes vehicle 110 and a control system 120 for controlling the vehicle 110. Ex1004, [0045], Figs. 1-2; Ex1003, ¶65. Beardsley discloses its robot is for maneuvering along a route.

Ex1004, Figs. 4, 8E-8F, 11C; Ex1004, [0057]-[0058], [0060], Figs. 1-2; *see infra* element 1[b][1].



Ex1004, Fig. 1.

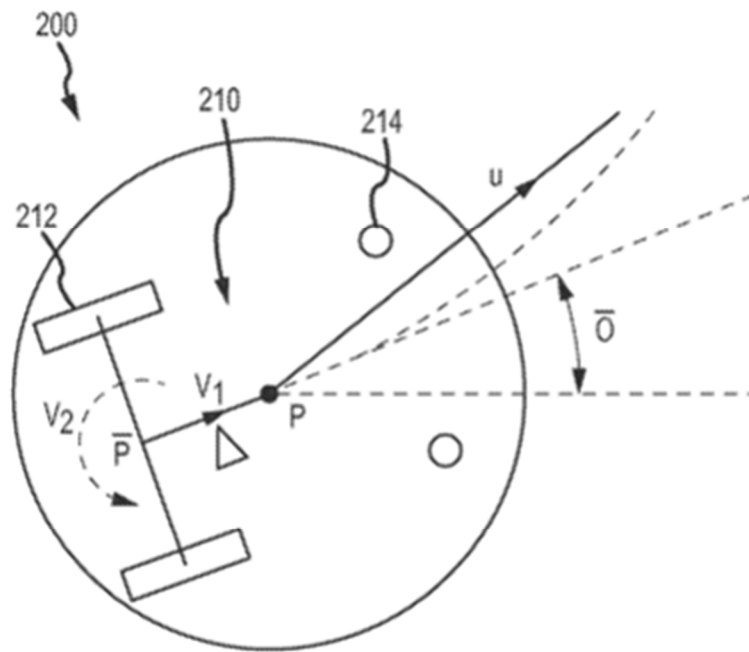


FIG.2

Id., Fig. 2.



20

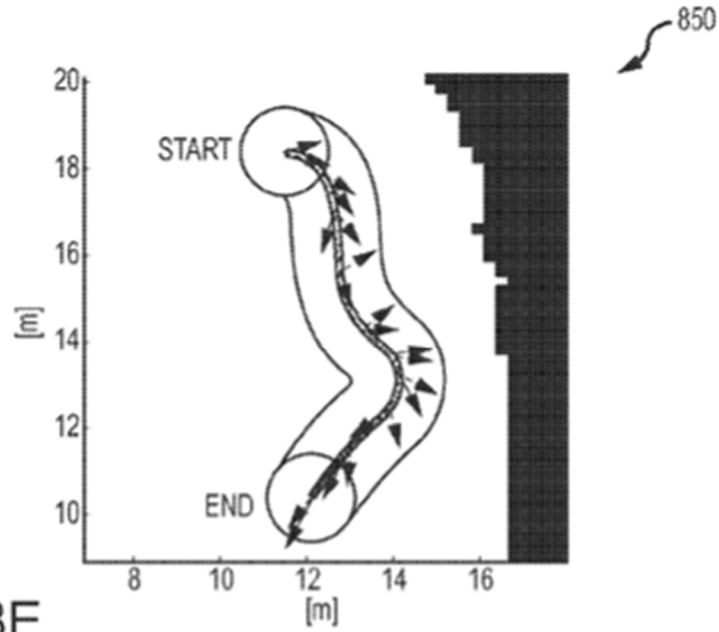


FIG. 8E

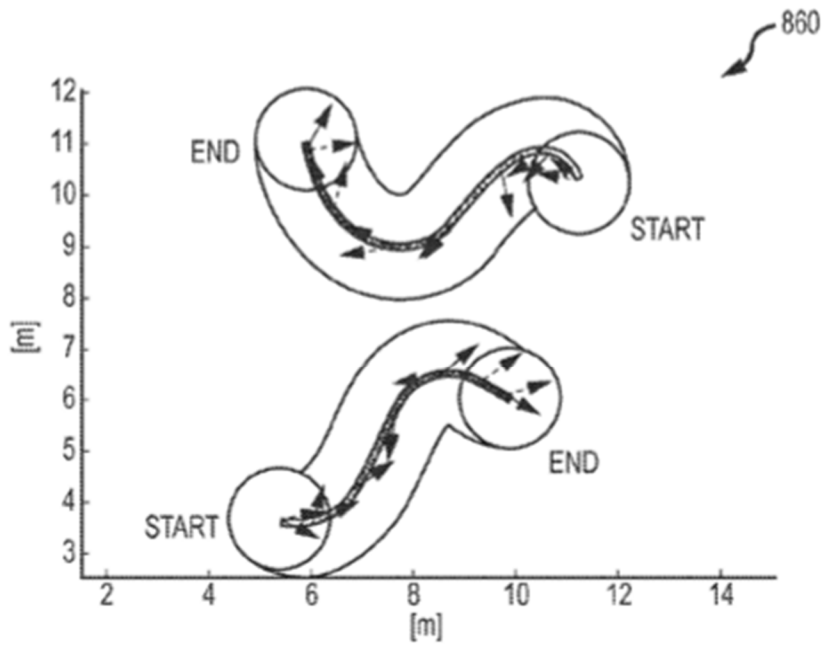
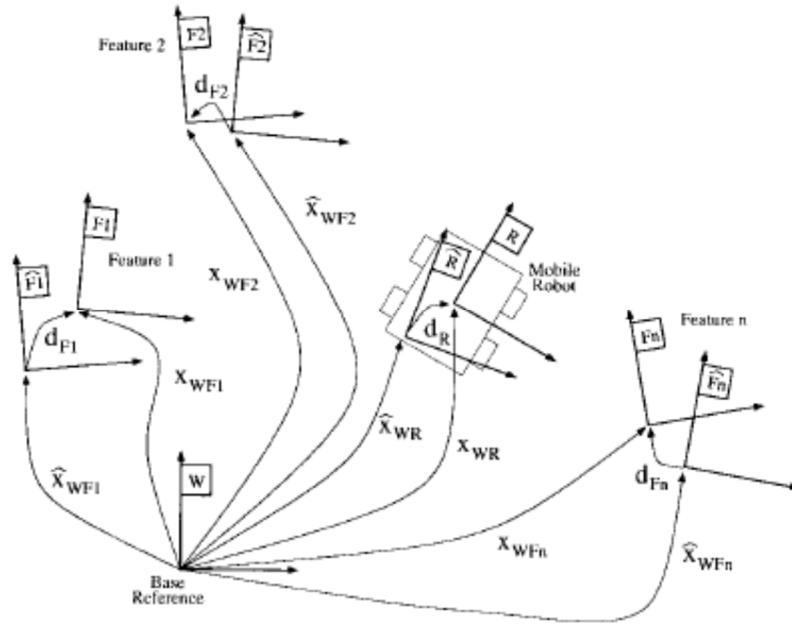


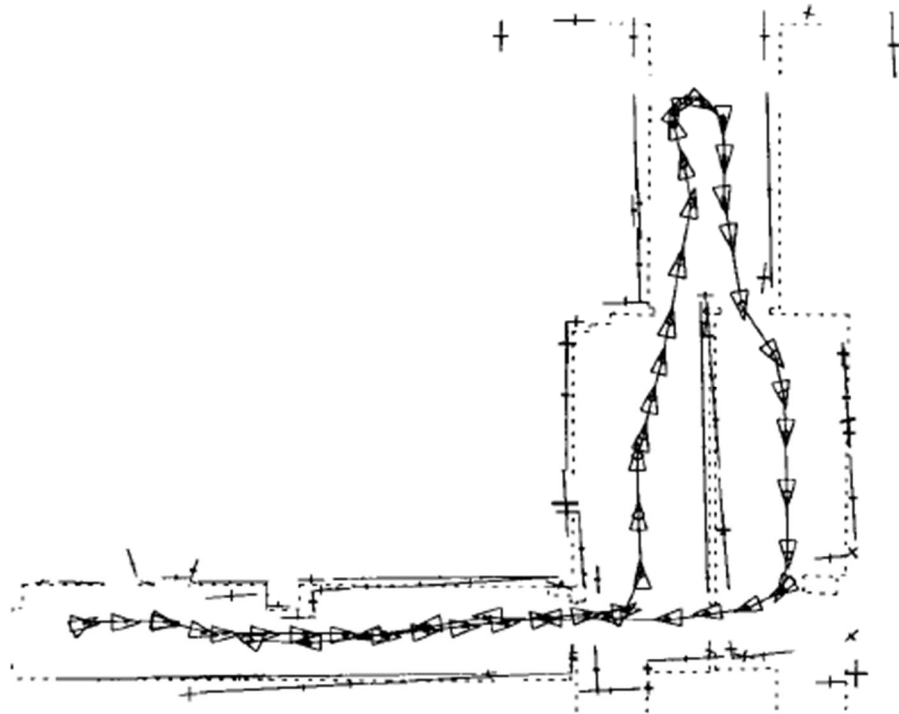
FIG. 8F

Id., Figs. 8E-8F.

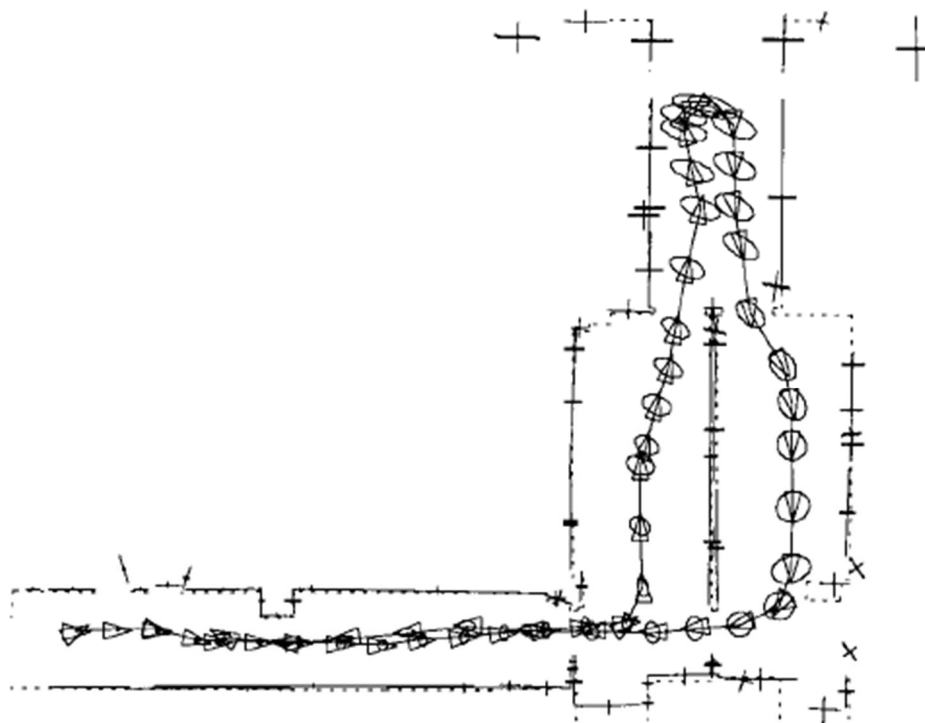
Castellanos also discloses a robot. Ex1007, 952 (“LabMate™ mobile robot”); Ex1003, ¶66. Castellanos discloses this robot is for maneuvering along a route. *Id.*, 950 (the robot is “programmed to follow a trajectory.”); *Id.*, Figs. 2, 5; Ex1003 ¶66. *See infra* element 1[b][1].



Ex1007, Fig. 2.



(a)



(b)

Id., Figs. 5(a)-(b).

- b. Element 1[a]:** “one or more sensors coupled to the robot, the one or more sensors configured to collect data about an environment proximate to the robot including detected points on one or more objects in the environment; and”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶67.

Beardsley discloses that local controller 116 of vehicle 110 transmits “sensor or tracking system data [119] . . . for determining the present location of other/neighboring vehicles.” Ex1004, [0045], Figure 1. Vehicle 110 relies on “sensor data 119” “to determine present locations of [other] vehicles 110 in the drive space,” which allows vehicle 110 to avoid collisions. *Id.* [0048]. Beardsley also discloses accounting for “sensor noise” in determining distance to objects for purposes of obstacle avoidance, further underscoring the use of sensors to detect points on objects. Ex1004, [0104]. Beardsley also discloses storing “sensor data [] from the vehicle” in memory. *Id.*, [0047]. A POSITA would have understood that Beardsley’s sensor data is obtained from sensors on vehicle 110, which correspond to the claimed “one or more sensors coupled to the robot.” Ex1003, ¶67. A POSITA would have understood that Beardsley’s sensors collect data at “detected points on one or more objects in the environment,” as was commonly known. *Id.*

To the extent a POSITA would not have understood Beardsley to have disclosed sensors on the robot, it would have been obvious to modify Beardsley to incorporate Castellanos’ teachings regarding sensors. Ex1003, ¶68. Castellanos

discloses a robot “equipped with a rotating two-dimensional (2-D) laser rangefinder,” which corresponds to the claimed “sensor.” Ex1007, 948, 952. The robot “was programmed to follow a trajectory . . . stopping at regular intervals to take measurements.” *Id.*, 950. Castellanos further discloses that its “SPmap consistently formulates the representation and integration of sensorial information gathered by different sensors.” *Id.*, 948, Fig. 1. Castellanos further discloses that its “approach can include different types of features obtained by different types of sensors, and thus it is suitable to deal with a multisensory system.” *Id.*, 949. This multisensory system, which can obtain information on “different types of features,” constitutes detecting “points” on one or more objects in the environment. Ex1003, ¶68.

c. Element 1[b]: “a controller configured to execute computer readable instructions to,”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶69.

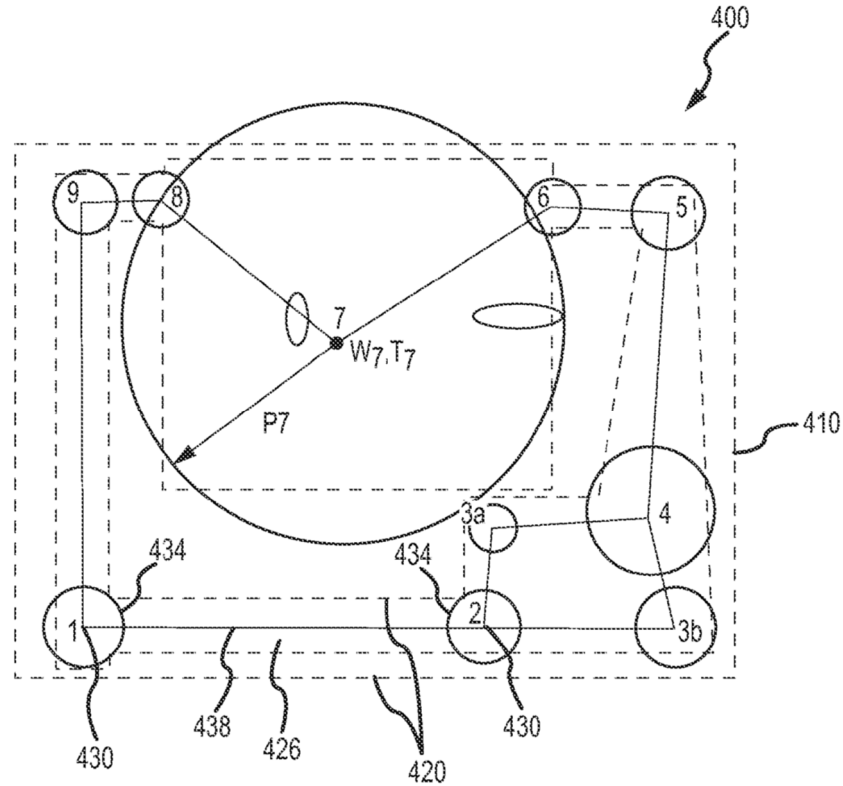
Beardsley discloses that system 100 includes (i) “a processor 112 running a local controller 116 that controls operations of a drive mechanism(s)/actuator 118 to cause the vehicle 110 to move in a particular direction and velocity within the space 105,” and (ii) a “central control system 120 that may take the form of a computer or computer-based system specially configured to control the vehicles 110 via motion control signals 138.” Ex1004, [0044], [0046]. The central control system 120 and local controller correspond to the claimed “controller.” Ex1003, ¶69.

Castellanos also discloses a “LabMate™ mobile robot” which a POSITA would have understood to feature the claimed controller. Ex1007 952, Ex1003, ¶70.

- d. **Element 1[b][1]:** “determine a route on a map for the robot to travel, the map corresponding to the environment and being generated by at least one or more sensors coupled to the robot, the route including a plurality of points such that a first point being discretized than a second point, each of the plurality of points corresponding to a respective pose of the robot, the respective pose of the robot including a plurality of points disposed therein, the respective pose corresponding to at least one of position and orientation of the robot, and”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶71.

Beardsley discloses a “roadmap or grid map” 400 of drive space 410, which “includes several rooms and corridors with these available spaces/areas for driving shown at 426 (with lighter or no shading) and occupied spaces or physical/virtual objects shown at 420 (with darker shading).” Ex1004, [0017], [0060], Fig. 4. Grid map 400 corresponds to “the map corresponding to the environment and being generated by at least one or more sensors coupled to the robot.” Ex1003, ¶71; *see supra* element 1[a].



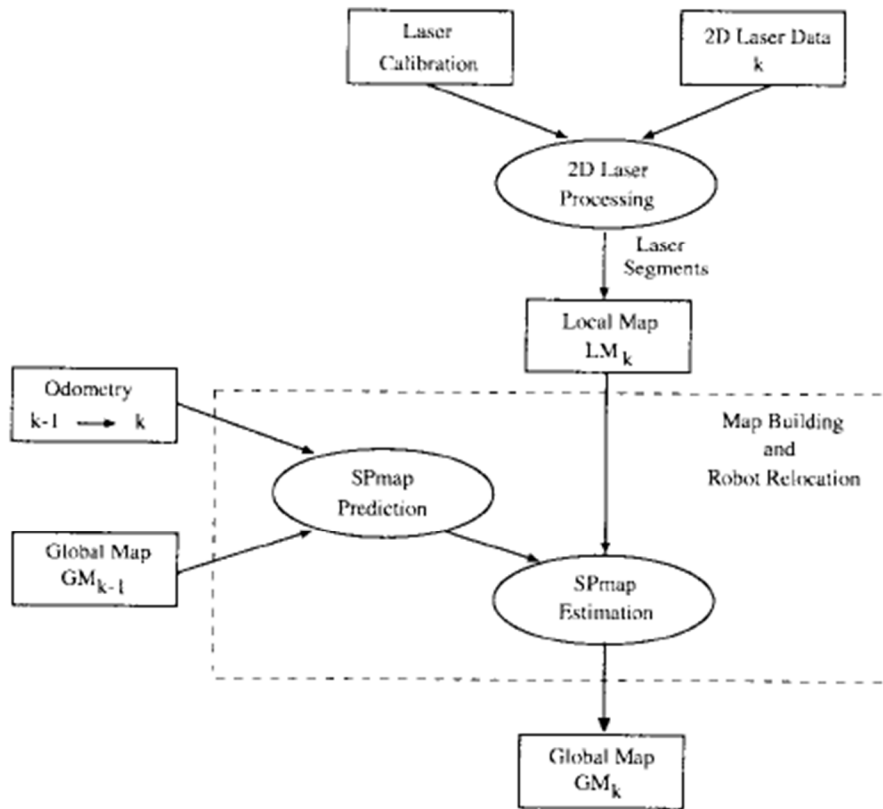
Ex1004, Fig. 4.

Grid map 400 is generated by system 100 using the method 300 of Figure 3. *Id.*, [0057]-[0060], [0160], Figure 3; Ex1003, ¶72. At step 310 of method 300, “the method 300 continues at 310 by providing a static map of the selected drive space that includes locations, shapes, and sizes of obstacles.” Ex1004, [0057].

Bearsley further explains that grid map 400 is “e.g., an image[] of space that defines locations of obstacles in the space (physical objects such as walls and also, in some cases, virtual objects that may be projected into the space or be displayed on a monitor/display device in the vehicle).” *Id.* [0012], [0047]-[0048] (explaining that “grid map 152 . . . maps physical obstacles 154” based on “sensor data 119 from

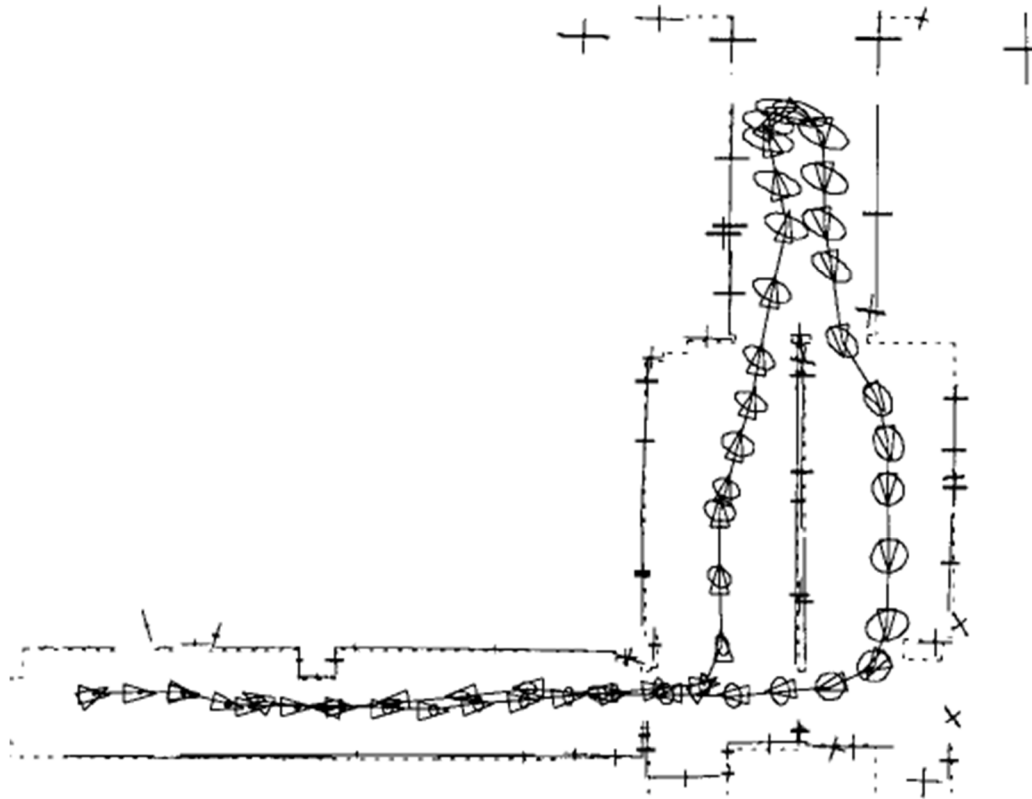
the vehicle 110.”). A POSITA would have understood that the image that forms the grid map 400 is generated using data collected by an image sensor. Ex1003, ¶73.

To the extent a POSITA would not have understood Beardsley to have disclosed map creation by the robot, it would have been obvious to modify Beardsley to use Castellanos’ map building process, to allow the robot of Beardsley to create a “static map of the selected drive space that includes locations, shapes, and sizes of obstacles,” as required by step 310 of method 300. Ex1004, [0057], Ex1003, ¶74. Castellanos discloses a method for “automatic construction of [a] map of the environment in which the robot navigates.” Ex1007, 948. Figure 1 of Castellanos illustrates a flow chart for using 2D laser data collected by the sensor to create a local map and a global map (i.e., map of the environment). Ex1003, ¶74.



Ex1007, Fig. 1.

Castellanos also discloses a method of creating a map of an environment based on collected sensor data, which it refers to as a “symmetries and perturbations map” or “SPmap.” *Id.*, 948; Ex1003, ¶75. Castellanos discloses that its “SPmap [method] consistently formulates the representation and integration of sensorial information gathered by different sensors.” Ex1007, 948. A map generated using the SPmap method disclosed in Castellanos is depicted in Figure 5(b). Ex1003, ¶75.



Ex1007, Fig. 5(b).

Beardsley discloses a method 300 for “creating a roadmap or set of guidance trajectories,” which correspond to the claimed “route on a map for the robot to travel.” Ex1004, [0057], Fig. 3; Ex1003, ¶76. The set of guidance trajectories “(1) guide the motion of the vehicle; (2) limit its movements; (3) guarantee that the vehicle has a certain performance even in the case where the driver does not specify a velocity; and (4) control the throughput of vehicles throughout a drive space or ride area.” *Id.*, [0051].

Method 300 includes steps 305, 310, 320, 340, and 350, which illustrate the process for determining the set of guidance trajectories. *Id.* [0057]-[0059]; Ex1003, ¶77.

Beardsley discloses that its method 300 roadmap is “created via waypoints connected by straight lines.” *Id.* [0057]. At step 320 of method 300, “set of waypoints is specified, and, for each waypoint, an arrival time, T_i , (or, alternatively, a speed over the segment) and an active area (where the vehicle is allowed to freely move) of a predefined radius, ρ_i , around the waypoint is provided.” *Id.* [0058]. This is illustrated in Figure 4, which shows “nine waypoints, w_i ” (labeled 1 through 9), “with arrival times, T_i , and a number of different radii, ρ_i , for their associated active areas 434.” *Id.* [0057], [0060], Figs. 3, 4 (illustrating exemplary waypoints 430); Ex1003, ¶78.

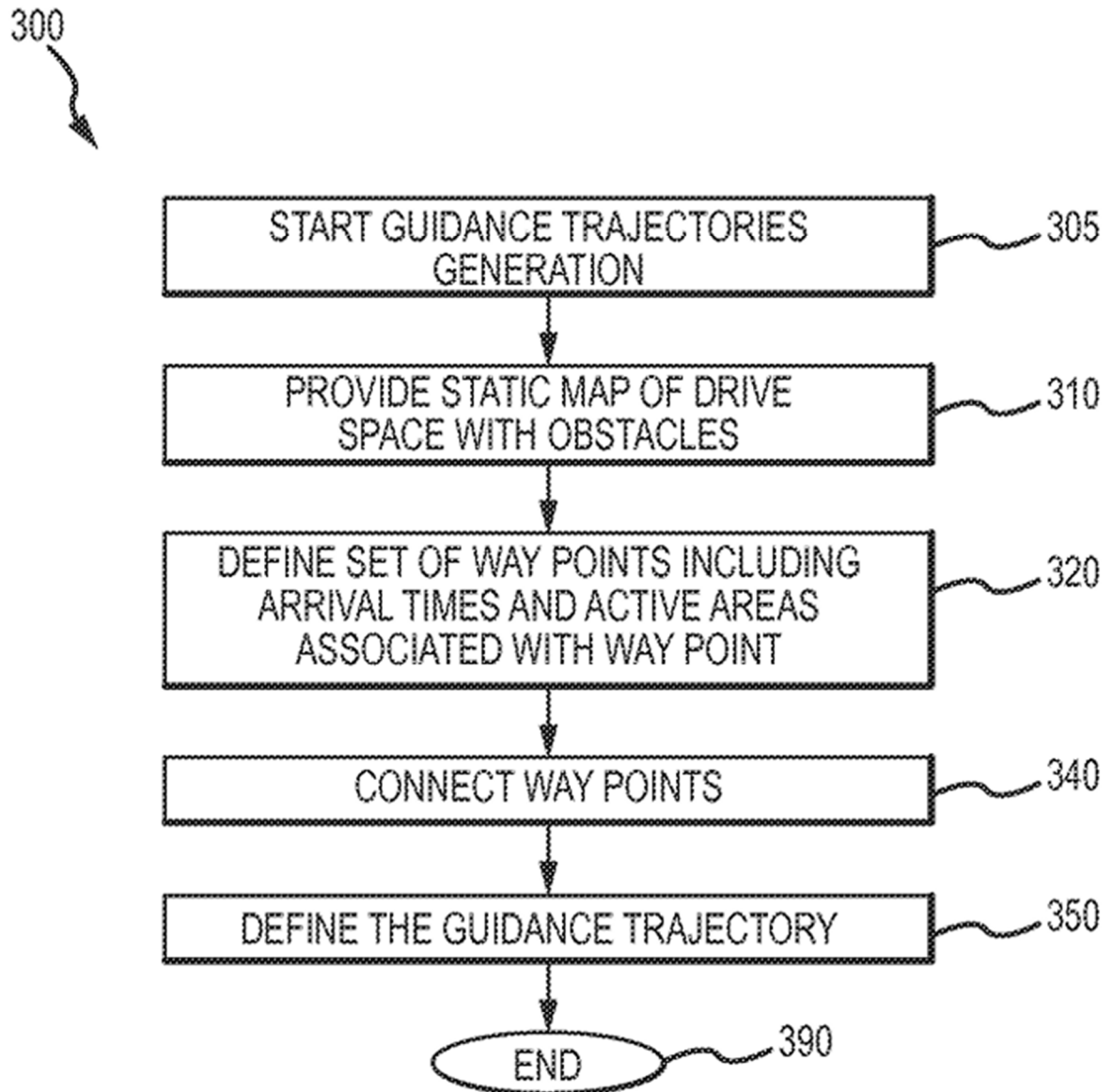
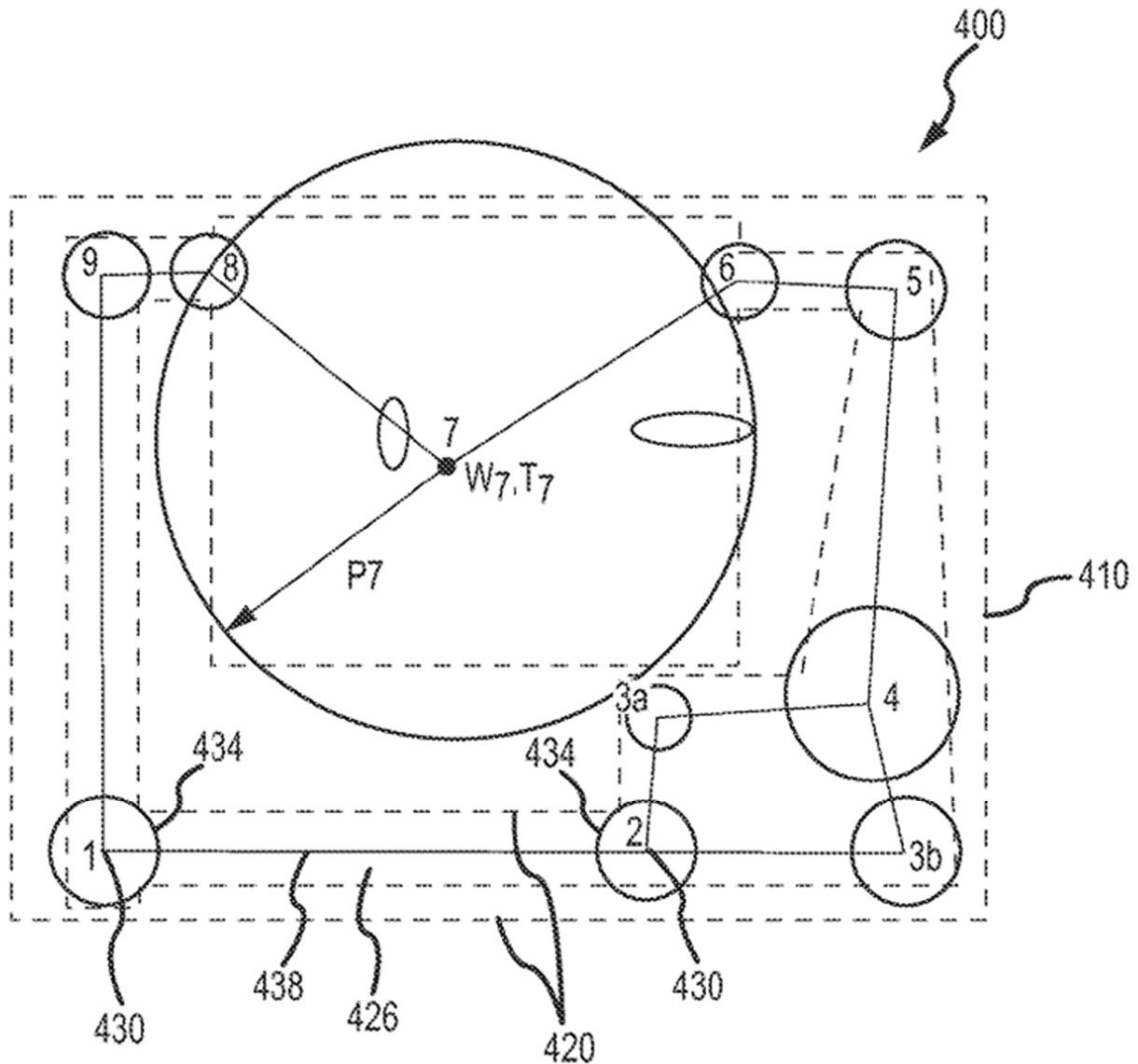


FIG.3

Ex1004, Fig. 3.



Id., Fig. 4.

The roadmap generated by method 300, including each waypoint and associated active areas corresponds to the claimed “route including a plurality of points such that a first point being discretized than a second point.” Ex1003, ¶79.

Each waypoint and/or “active area” corresponds to the claimed “respective pose of the robot including a plurality of points disposed therein.” Ex1003, ¶80; Ex1004 Fig. 2.

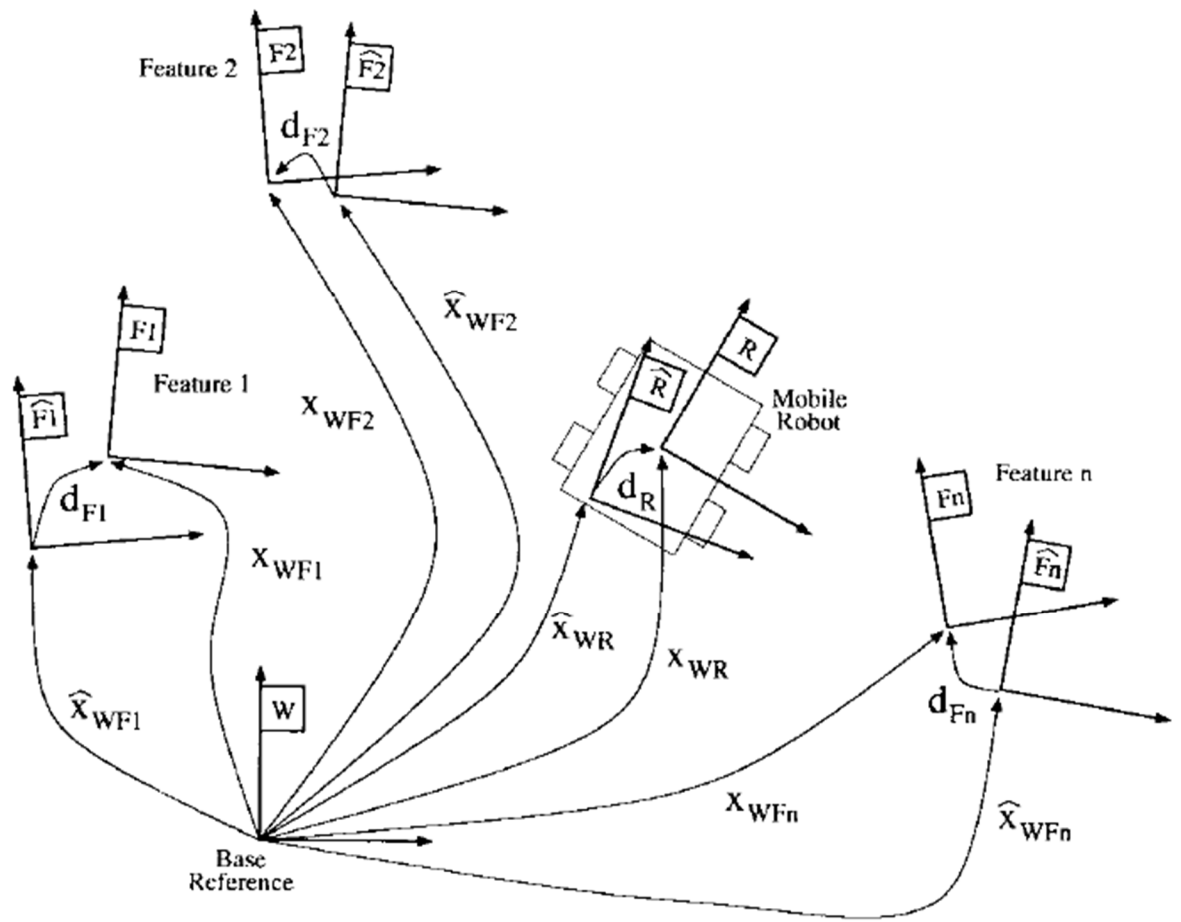
Each waypoint has a “plurality of points disposed therein,” as claimed. Ex1003, ¶81, Ex1004. Fig. 2. Beardsley discloses that “[w]ith regard to wheelchair (vehicle, in this example) kinematics, the unicycle model is used, with p the point in-between both tractor wheels, δ the orientation of the vehicle, and $v1$, $v2$ the linear and angular speed of the platform.” The “local trajectory is applied at this point $[p]$, and a circle of radius r is considered as the enveloping shape of the vehicle.” *Id.* [0056], [0050] (“A disk, $D(p,r)$, of radius r_i centered at p_i defines its enveloping shape. The enlarged obstacle map is given by a static grid map O_r of the positions p where a disk $D(p,r)$ is in collision with a static obstacle.”).

A POSITA would have understood that each waypoint has multiple points, including point p , and points around the circle of the radius that envelopes the shape of the vehicle. Ex1003, ¶82.

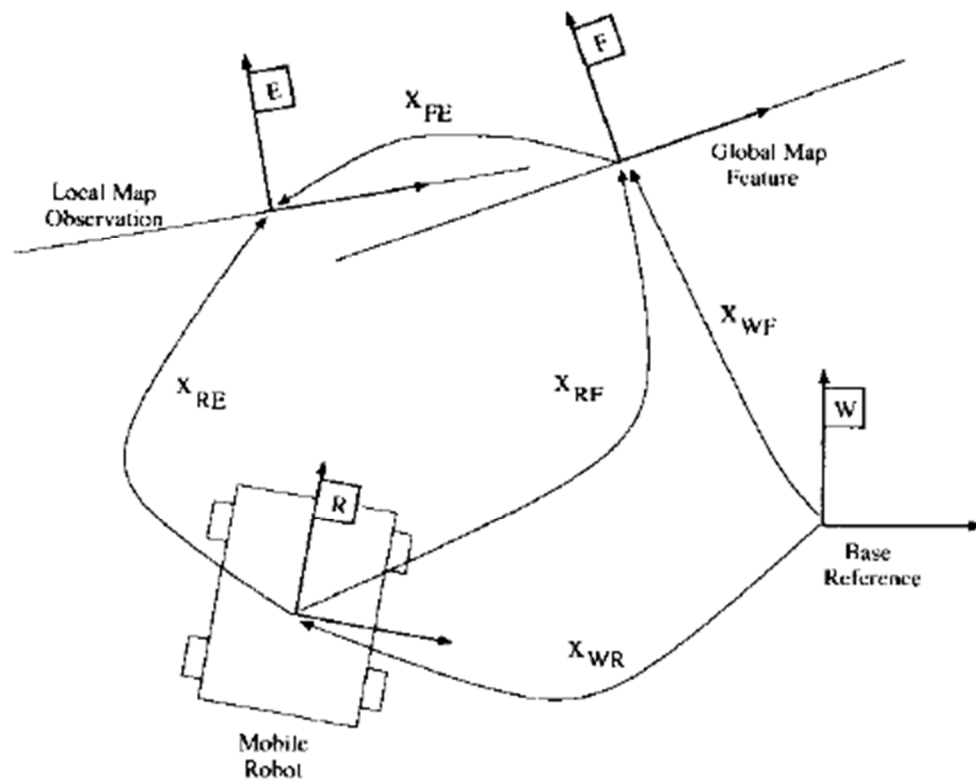
In Beardsley, each waypoint and/or active area corresponds to the claimed “position and orientation of the robot” Ex1003, ¶83; Ex1004, [0012] (“The processing of the user input includes searching the grid map (e.g., with the vehicle's current position in the space) to identify the obstacles and to define a path from the first position to the second position in the space that avoids the obstacles.”), [0050]

(“Consider a group of n vehicles of which m are controlled, either in a distributed or centralized way. The position, velocity, and acceleration of a robot, i , are denoted”) [0056] (“With regard to . . . kinematics, the unicycle model is used, with p the point in-between both tractor wheels, δ the orientation of the vehicle . . .”), Figs. 2, 4; Ex1003, ¶83.

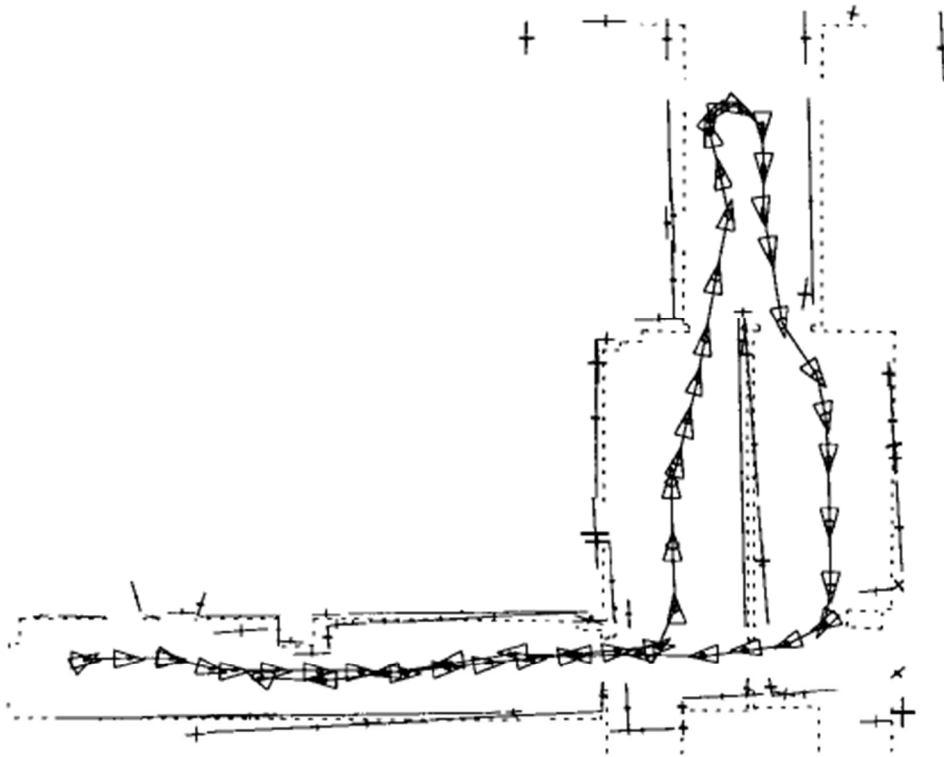
To the extent a POSITA would not have understood Beardsley to have disclosed a “pose of the robot”, it would have been obvious to modify Beardsley to incorporate Castellanos’ route poses. Ex1003, ¶84. Castellanos discloses “estimation of the mobile robot location and . . . the estimation of the map features [] from a common set of observations.” Ex1007, 951. Each such robot location constitutes a pose of the robot corresponding to at least one position and orientation of the robot. Ex1003, ¶84. Castellanos further depicts poses for the mobile robot along the route in Figures 2, 3, and 5, each of which also depicts the pose of the robot along the route. *Id.* As illustrated in the figures, a POSITA would have understood that each pose comprises a plurality of points on the map disposed therein. Ex1003, ¶84.



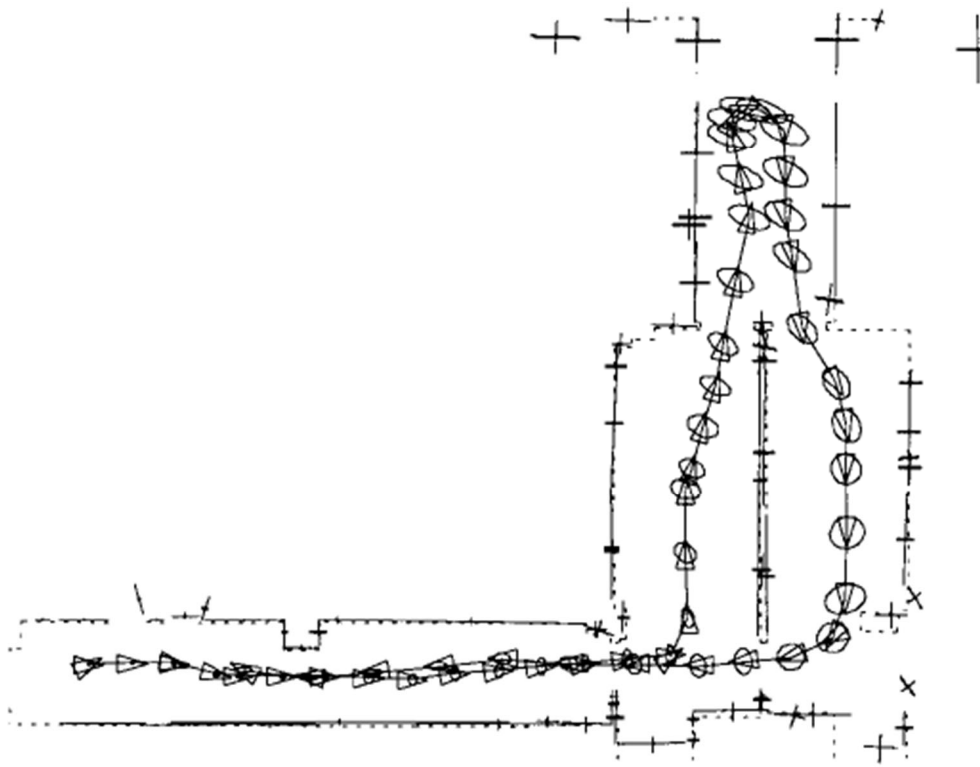
Ex1007, Fig. 2.



Id., Fig. 3.



(a)



(b)

Id., Fig. 5.

- e. **Element 1[b][2]:** “compute repulsive forces from a point on an object onto the plurality of points of the respective pose, the object being on the map.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶85.

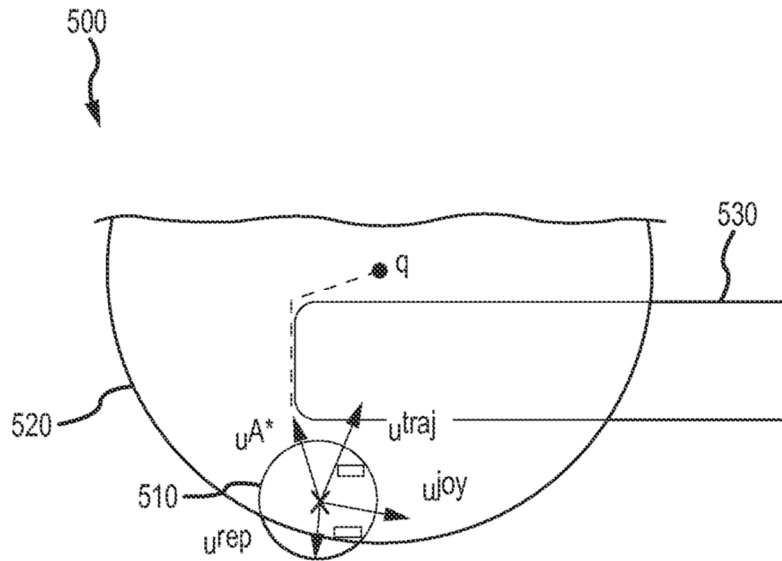
Beardsley discloses computing “repulsive forces from a point on an object onto the plurality of points of the respective pose” as claimed. Ex1003, ¶85. For example, Beardsley discloses computing a “repulsive velocity u_i^{rep} ” for each time step, for each vehicle i , using “a potential field approach that pushes the vehicle away from both static and dynamic obstacles.” Ex1004, [0061]; Ex1003, ¶85. Beardsley’s Equation (8) provides an example of such a function. Ex1003, ¶85.

$$u_i^{rep} = Vr \frac{\bar{D} - d(p_i O)}{\bar{D}} n_{i,O} + \sum_{j|p_{ij} < D} Vr \frac{D - p_{ij}}{D - r_i - r_j} \frac{p_{ij}}{p_{ij}}$$

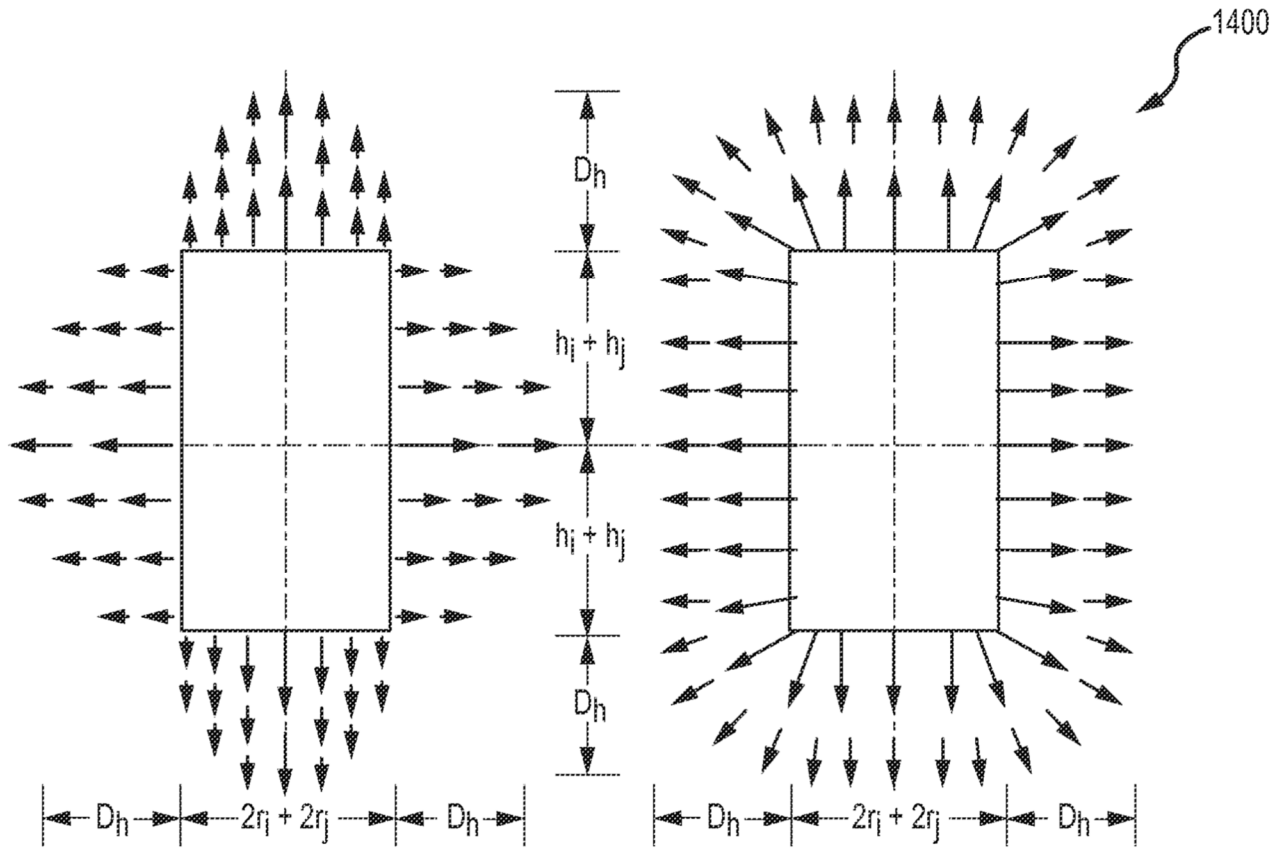
Ex1004, Equation (8).

Beardsley further explains that “[t]o appropriately maintain a minimum inter-agent distance, the preferred velocity, $\bar{u}$, is corrected by adding a repulsive velocity [] given by a vector field such as those shown in one of the two examples of repulsive velocities shown in the graph 1400 of FIG. 14 and that pushes agents apart from each other when at a certain distance.” Ex1004, [0104], Figures 5 (repulsive force u^{rep}) and 14. A POSITA would have understood that Figure 14 illustrates examples

of repulsive velocities “from a point on an object,” which affect “the plurality of points of the respective pose,” as claimed. Ex1003, ¶86.



Ex1004, Fig. 5.



Id., Fig. 14.

Beardsley further discloses that the object in question is on the map. *See supra* 1[a], 1[b][1]; Ex1004, [0008] (“Collision-free local motions are achieved with an extension of velocity obstacles that takes into account dynamic constraints and also a grid-based map representation of the space through which the vehicle is traveling under share controlled.”), [0042] (“a grid map defining the location, size, and shape of static obstacles”). Ex1003, ¶87.

- f. **Claim 2:** “The robot of claim 1, wherein the respective pose of the robot and a subsequent respective pose of the robot being regularly or irregularly spaced apart from each other on the route such that the respective pose and the

subsequent respective pose form a sequence along the route.”

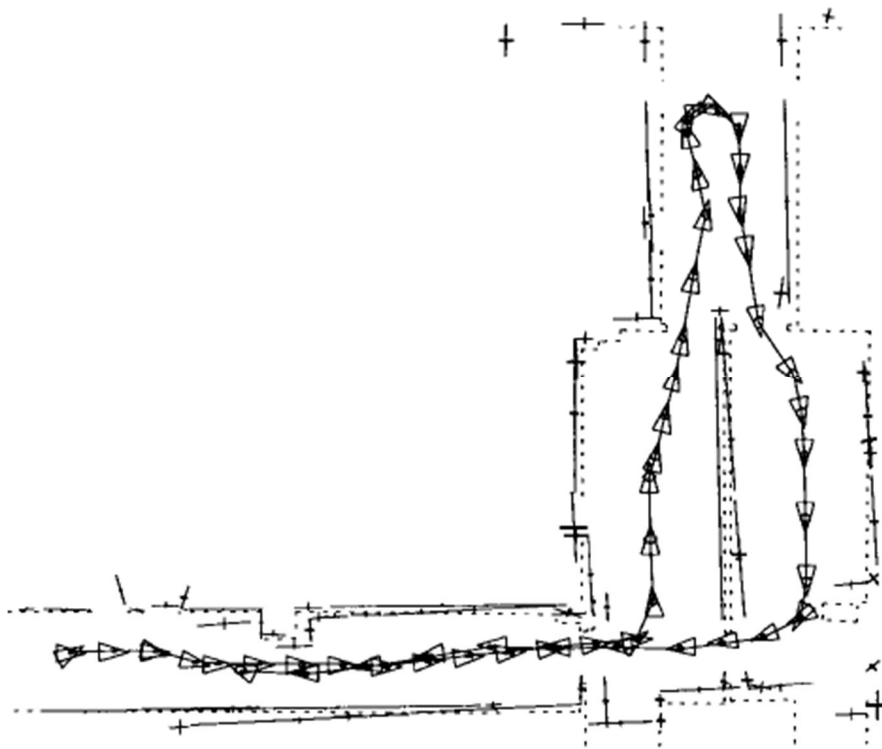
The Beardsley/Castellanos combination discloses this limitation. Ex1003,

¶88. *See supra* element 1[b][1].

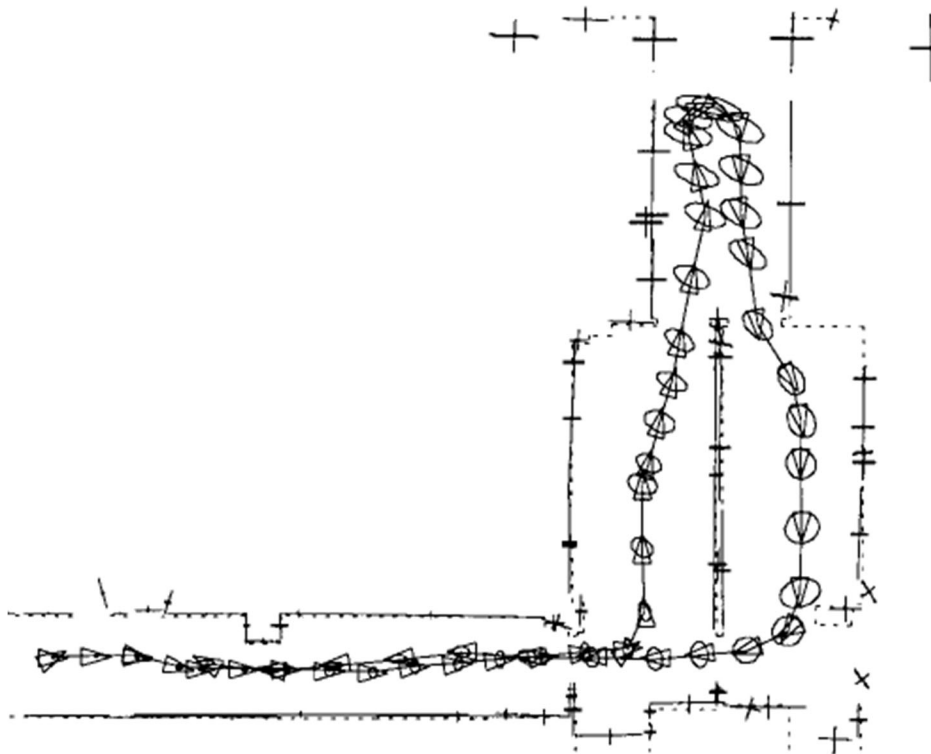
Beardsley discloses that its method comprises “connecting consecutive waypoints.” Ex1004, [0058]. Beardsley also discloses “arrival times” “for each waypoint,” which is a sequence in which the robot travels the route. *Id.*; Ex1003,

¶89. Beardsley Figure 4 also shows the waypoints as the sequence of travel for the robot. *Id.*

To the extent a POSITA would not have understood Beardsley to have disclosed poses forming a sequence along the route, it would have been obvious to modify Beardsley to use Castellanos’ route poses. Ex1003, ¶90. Castellanos’s Figure 5 depicts the poses forming a sequence in which the robot travels along the route. *Id.*; Ex1007, Fig. 5.



(a)



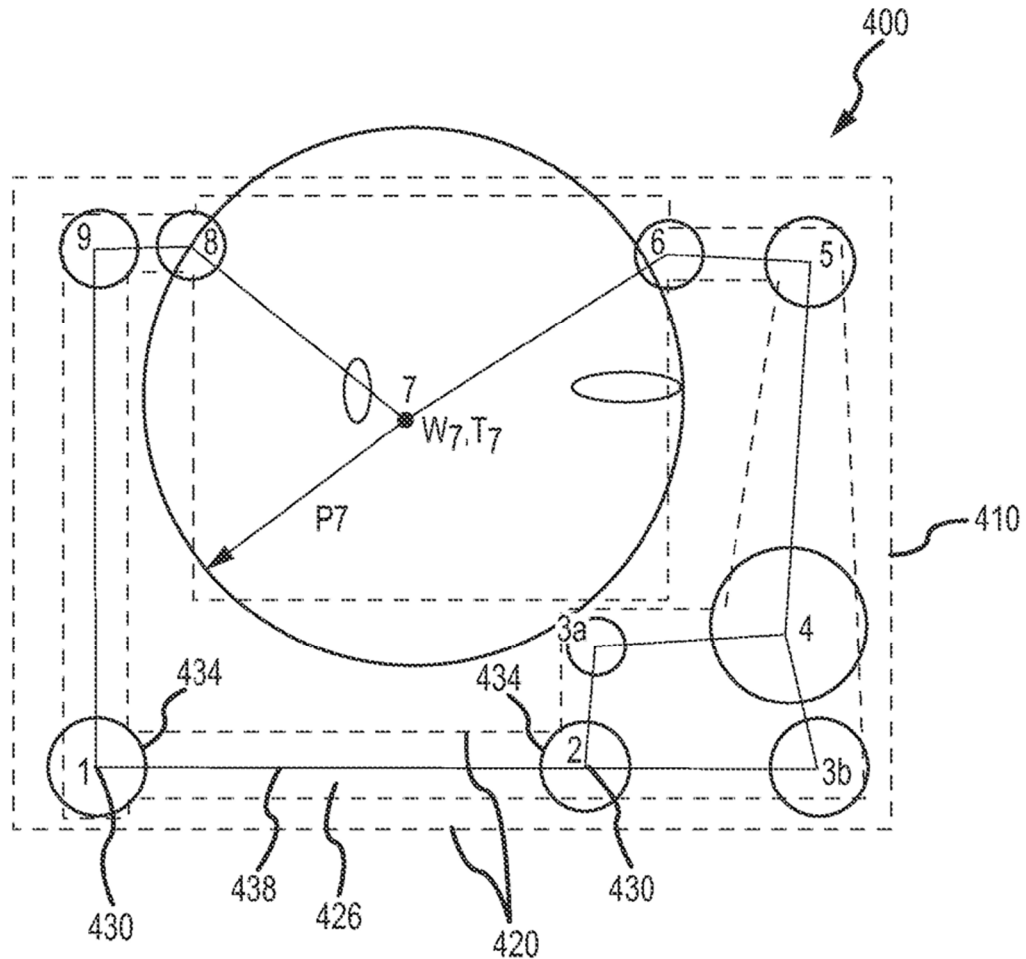
(b)

Id., Fig. 5.

- g. Claim 3:** “The robot of claim 1, wherein the respective pose corresponds to a footprint of the robot, the footprint configured to be adjustable between a small footprint and a large footprint, the small footprint having a high likelihood of collision with the object, and the large footprint having a low likelihood of collision with the object, the footprint of the robot configured to be dynamically reshaped.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶91. *See supra* element 1[b][1].

As explained above (Element 1[b][1]), Beardsley discloses for each waypoint, an active area (where the vehicle is allowed to freely move) of a predefined radius, ρ_i , around the waypoint is provided.” Ex1004. [0058]. This is illustrated in Figure 4, which shows “nine waypoints, w_i ” (labeled 1 through 9), “with arrival times, T_i , and a number of different radii, ρ_i , for their associated active areas 434.” *Id.* [0060]; Ex1003, ¶92. Beardsley discloses “[a]t least some of the active areas differ in size or shape defining differing areas in which the vehicle may move within the space.” *Id.*, [0013]. The “active area” associated with each waypoint corresponds to the claimed “footprint of the robot,” “configured to be adjustable between a small footprint and a large footprint” Ex1003, ¶92.



Ex1004, Fig. 4.

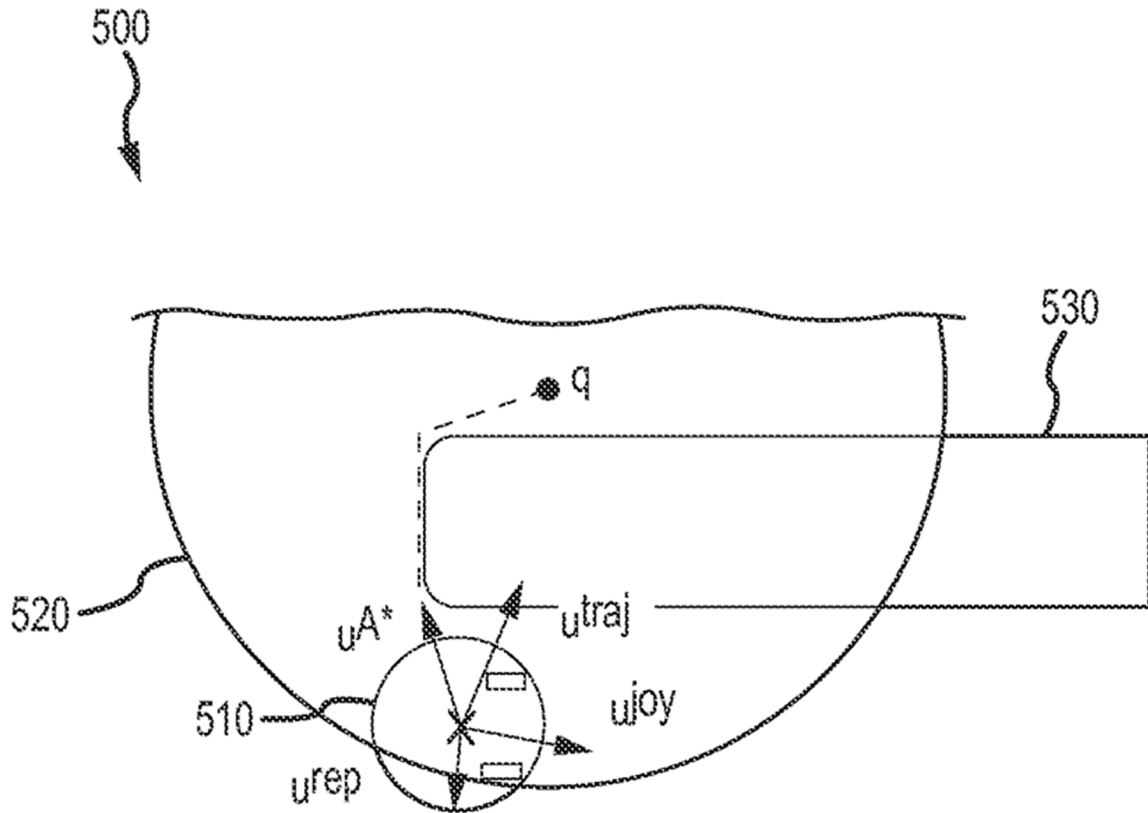
A POSITA would have found it obvious to define active areas for a desired size or configurable between two desired sizes. Ex1004, [1013]; Ex1003, ¶93. Moreover, a POSITA would have understood that using a small footprint would have a higher risk of collision with objects than a larger footprint, and that it would be desirable to be able to set the footprint size based on acceptable or otherwise specified collision risk. Ex1004, [1013]; Ex1003, ¶93.

Beardsley also discloses “enveloping the shape of the vehicle” in “a circle of radius r .” Ex1004 [0056], [0050] (“A disk, $D(p,r)$, of radius r_i centered at p_i defines its enveloping shape. The enlarged obstacle map is given by a static grid map or of the positions p where a disk $D(p,r)$ is in collision with a static obstacle.”). A POSITA would have understood that the radius of the enveloping circle could easily be adjusted based on desired size and corresponding collision risk. Ex1003, ¶94.

- h. Element 4[a]:** “The robot of claim 1, wherein, the repulsive forces from the point on the object prevent the robot from colliding with the object,”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶95. *See supra* 1[b][2].

Beardsley discloses using repulsive forces from the point on the object to prevent the robot from colliding with the object. Ex1004, [0063] (“An obstacle 530 is shown in the graph with the shared control functioning to avoid collision with the obstacle.”), Fig. 5. Ex1003, ¶96.



Ex1004, Fig. 5.

- i. **Element 4[b]:** “the repulsive forces from the object is uniform on the respective pose,”

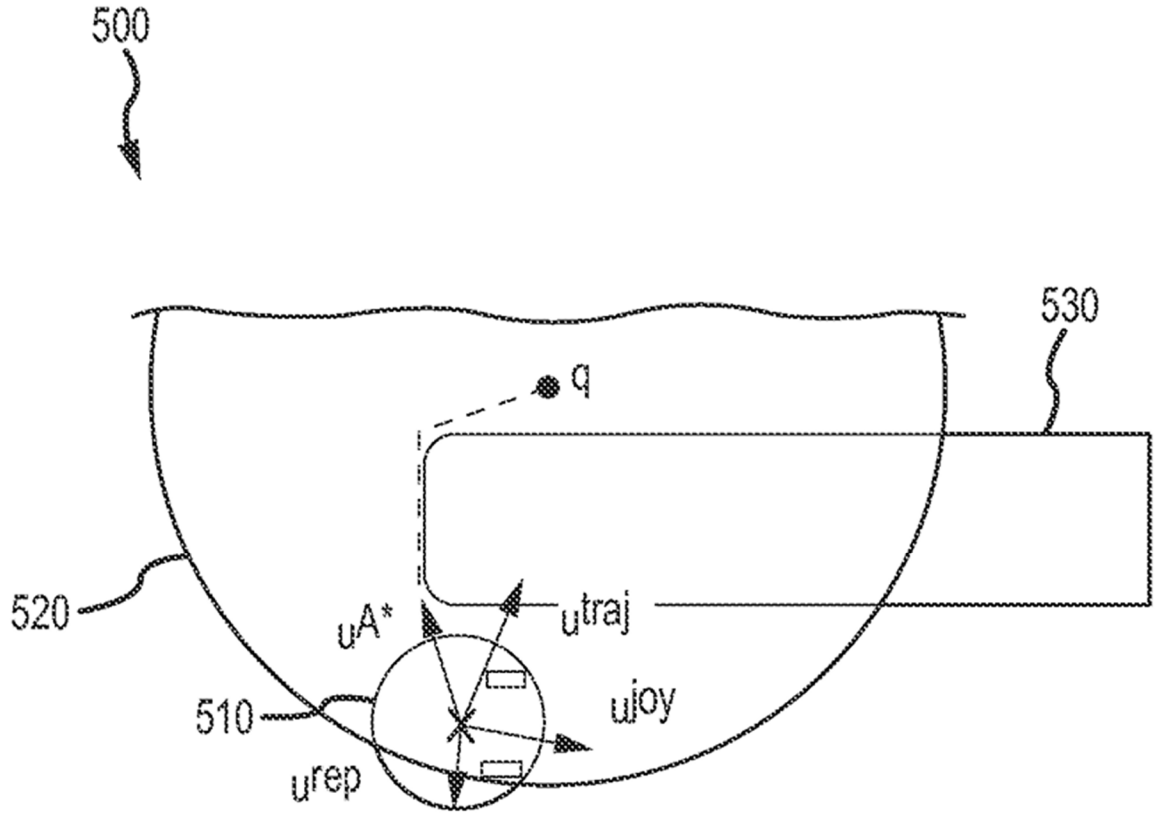
The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶97; *See supra* 1[b][2].

Equation 8 discloses a maximum repulsive velocity, “ v_r ” Ex1004, [0061]. A POSITA would understand that repulsive forces from the object would be uniform on the route pose where the repulsive forces are at their maximum. Ex1003, ¶98.

- j. **Element 4[c]:** “and the repulsive forces is dependent on characteristics of where the object is positioned relative to the respective pose.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶99. *See supra* 1[b][2].

Beardsley discloses repulsive forces from an object on a pose are calculated dependent on the distance between the pose and the object. Ex1003, ¶100; Ex1004, [0061] (“The repulsive velocity u_i^{rep} is computed with a potential field approach that pushes the vehicle away from both static and dynamic obstacles. A linear function weighting the distance to other vehicles is used . . . where V_r is the maximum repulsive velocity, D and $\bar{D}$ are the maximum distance from which a repulsive force is added.”) (emphasis added), *id.* (“[T]he guidance trajectory, and the neighboring obstacles as follows . . . where $\mu_2=1$ if the vehicle is inside the active area and $\mu_2=0$ otherwise, and $\mu_1=1$ if q is in line of sight of the vehicle and $\mu_1=0$ otherwise.” (emphasis added)). The distance threshold used by the force function constitutes the dependency on the “characteristics of where the object is positioned relative to the respective pose” of Claim 4. Ex1003, ¶100.



Ex1004, Fig. 5.

$$u_i^{rep} = V_r \frac{\bar{D} - d(p_i O)}{\bar{D}} n_{i,O} + \sum_{j|p_{ij} < D} V_r \frac{D - p_{ij}}{D - r_i - r_j} \frac{p_{ij}}{p_{ij}}$$

Id., Equation (8).

Moreover, Equation (8) is based on “the distance to the closest static obstacle.”

Ex1004, [0061]; Ex1003, ¶101. Beardsley therefore computes the magnitude of repulsive force relative to the distance of an object from the pose. *Id.*

- k. Claim 5:** “The robot of claim 1, wherein the plurality of points of the respective pose configured to experience the repulsive forces, the plurality of points capable of

translating and rotating in response to repositioning of the respective pose.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶102.

Petitioner incorporates by reference the disclosures provided for elements 1[b][1], 1[b][2]. Beardsley discloses applying its method to quadrotors and accounting for translation and rotation. *Id.*; Ex1004, [0135] (defining a rotation matrix RI). In the context of an obstacle avoidance method such as Beardsley, this translation and rotation constitute the translation and rotation of route poses in response to repositioning of a pose. Ex1003, ¶103. A POSITA would have understood that this technique could also be applied to ground robots to also determine translation and rotation. *Id.*

1. **Claim 6:** “The robot of claim 1, wherein the controller is further configured to execute the computer readable instructions to, perform interpolation between the respective pose and a subsequent respective route pose to generate a collision-free route between the respective pose and the subsequent respective route pose for the robot to travel.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶104.

Petitioner incorporates by reference the disclosures provided under elements 1[b], 1[b][1], 1[b][2], claim 5. Beardsley illustrates “a grid map 400 of a drive space 410 that may be generated with the method 300 of Fig. 3.” Ex1004, [0060], Fig. 4. Step 350 of method 300 “involves generating or defining the guidance trajectory

along with the active area around it (e.g., by interpolation or the like).” *Id.* [0058]. Beardsley further explains that “waypoints 430 [marked 1 through 9] are connected by straight lines as shown at 438, and, in between waypoints, the ideal trajectory and active area is given by interpolation.” *Id.* The trajectory generated is a collision-free path between the route poses—including between each respective route pose and a subsequent route pose—for the robot to travel because it avoids “occupied spaces or physical/virtual objects shown at 420.” *Id.*; Ex1003, ¶105.

- m. Claim 7:** “The robot of claim 1, wherein the controller is further configured to execute the computer readable instructions to, reposition the respective pose and a subsequent respective pose in response to the repulsive forces on each point of the plurality of points.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶106.

Petitioner incorporates by reference the disclosures provided under elements 1[b], 1[b][1], 1[b][2]. Beardsley discloses using the “potential field approach that pushes the vehicle away from both static and dynamic obstacles.” Ex1004, [0061]. Beardsley applies this approach to “local motion planning,” *id.* [0096], including through “selectively adjusting the velocity and direction . . . to generate a trajectory . . . for the vehicle in the space,” *id.* [0011]. Ex1003, ¶108. A POSITA would have understood that the use of potential fields to adjust velocity would result in the repositioning of the route poses, including the respective pose and any

subsequent respective poses, in response to the repulsive forces on each point of the plurality of points. Ex1003, ¶108.

- n. **Element 8[pre]:** “A method for dynamic navigation and route planning of a robot in an environment, comprising:”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶109.

See supra 1[b][1]; Ex1004, [0008], [0010], [0160], [0221].

- o. **Element 8[a]:** “determining a route on a map for the robot, the route including one or more route poses, each route pose comprising a footprint indicative at least in part of a pose and a shape of the robot along the route and each route pose having a plurality of points disposed therein, the map corresponding to an environment and being generated by at least one sensor on the robot, the route including a plurality of points such that a first point being discretized than a second point, each of the plurality of points corresponding to a respective pose of the robot, the respective pose of the robot including a plurality of points disposed therein, the respective pose corresponding to at least one of position and orientation of the robot; and”

The Beardsley/Castellanos combination discloses this limitation. Ex1003,

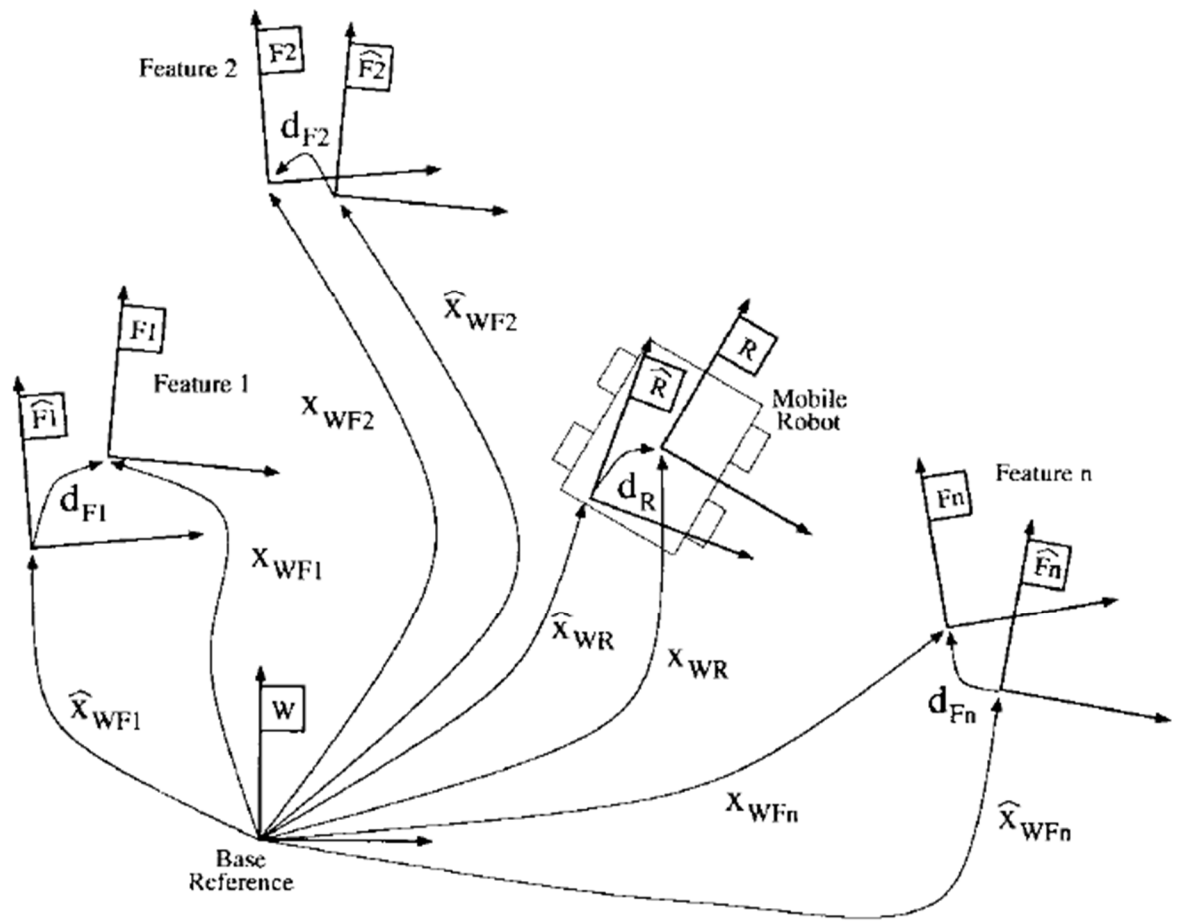
¶110. *See supra* elements 1[a], 1[b][1], 1[b][2], claim 3.

Each of Beardsley’s waypoints and/or active areas corresponds to the claimed “route poses on the route.” Ex1003, ¶112. Beardsley accounts for the “kinematic constraints of the vehicle,” such as the “vehicle’s radius.” Ex1004, [0065]; Ex1003, ¶112. Beardsley discloses modeling the shape of each vehicle as an enveloping cylinder or circle with a given radius centered at the vehicle.

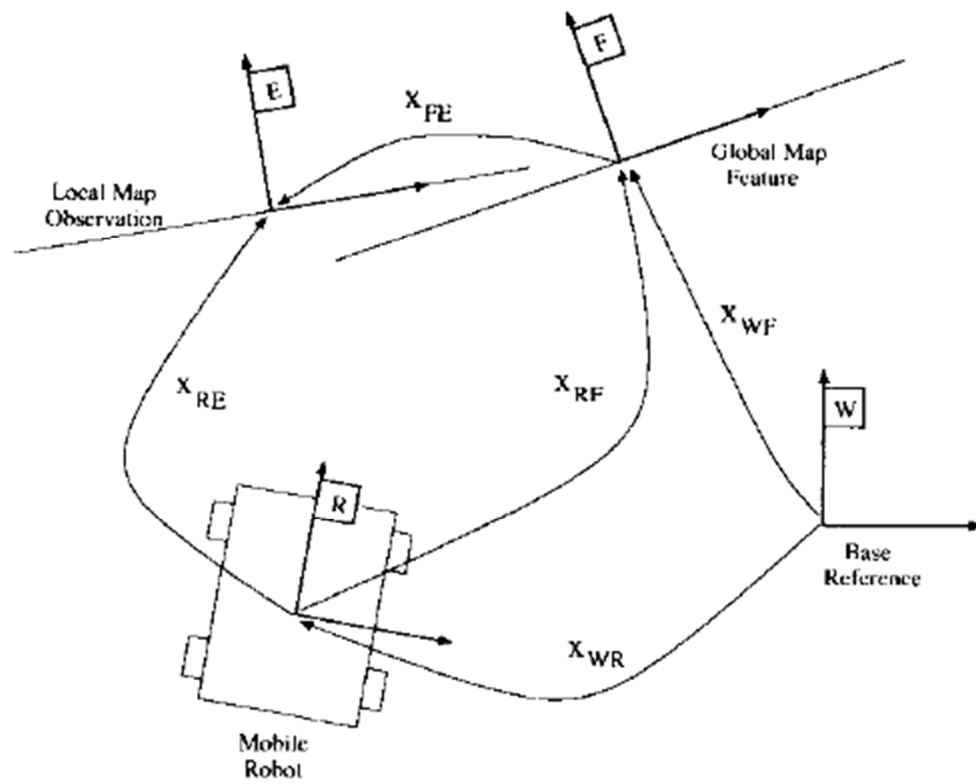
Ex1004, [0095] (“The shape of each agent or vehicle is modeled by an enveloping

cylinder of radius, r_i , and height, $2h_i$, centered at the agent or vehicle”), and in another example Beardsley considers an enveloping circle, *id.* [0056] (“a circle of radius r is considered as the enveloping shape of the vehicle”). Beardsley’s enveloping cylinder or circle is a “indicative at least in part of a . . . shape of the robot”, and coupled with Beardsley’s use of waypoints and “active areas,” *supra* element 1[b][2], constitute the use of these footprints in the selection of waypoints (i.e., route poses). Ex1003, ¶112.

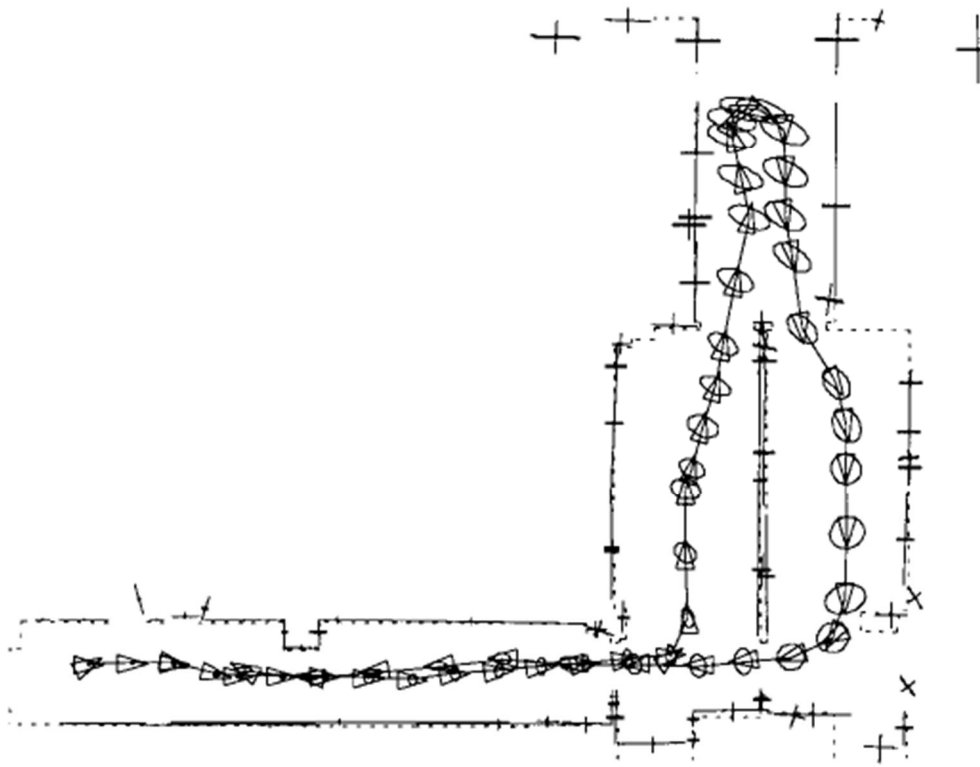
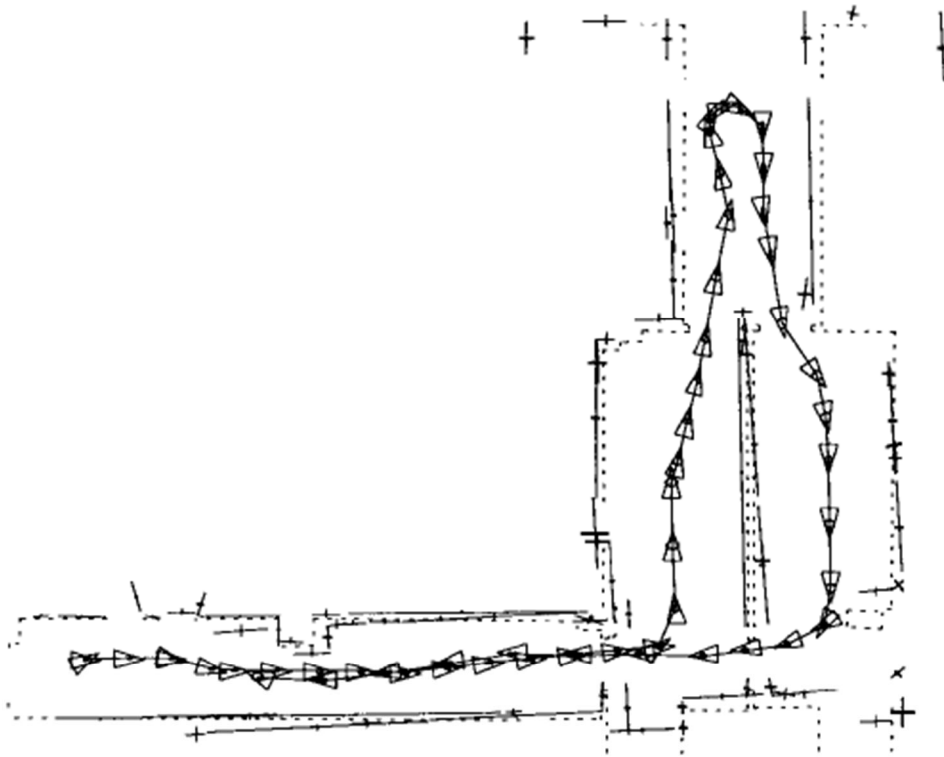
To the extent a POSITA would not have understood Beardsley to have disclosed route poses on the route, it would have been obvious to modify Beardsley to use Castellanos’ route poses. Ex1003, ¶113. Castellanos discloses “estimation of the mobile robot location and . . . the estimation of the map features [] from a common set of observations.” Ex1007, 951. Each such robot location constitutes a route pose indicative of the footprint of a robot pose and shape. Ex1003, ¶113. Castellanos further depicts poses for the mobile robot along the route in Figures 2, 3, and 5, each of which also depicts the route pose comprising a footprint of the robot along the route. *Id.*



Ex1007, Fig. 2.



Id., Fig. 3.



(b)

Id., Fig. 5.

As illustrated in the figures, a POSITA would have understood that each pose comprises a plurality of points on the map disposed therein. Ex1003, ¶114. Moreover, Castellanos Figures 2, 3, and 5 all depict poses on a route wherein the footprints of route poses have substantially similar size and shape as the footprint of the robot. Ex1007, Figs. 2-3, 5; Ex1003, ¶114.

- p. Element 8[b]:** “computing repulsive forces from a point on an object in the environment onto the plurality of points of a first route pose of the one or more route poses.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶115. *See* element 1[b][2]; Ex1004 Fig. 14.

- q. Claim 9:** “The method of claim 8, wherein the respective pose of the robot and a subsequent respective pose of the robot being regularly or irregularly spaced apart from each other on the route such that the respective pose and the subsequent respective pose form a sequence along the route.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶116.

See supra elements 1[b][2], claim 2. IV.A.2.e-f.

- r. Claim 10:** “The method of claim 8, wherein the respective pose corresponds to a footprint of the robot, the footprint configured to be adjustable between a small footprint and a large footprint, the small footprint having a high likelihood of collision with the object, and the large footprint having a low likelihood of collision with the

object, the footprint of the robot configured to be dynamically reshaped.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶118.

See supra claim 3. IV.A.2.g.

- s. **Element 11[a]:** “The method of claim 8, wherein, the repulsive forces from the point on the object prevent the robot from colliding with the object,”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶¶119-

121. *See supra* element 4[a]. IV.A.2.h.

- t. **Element 11[b]:** “the repulsive forces from the object is uniform on the respective pose, and”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶122.

See supra elements 1[b][2], 4[b]. IV.A.2.e, i.

- u. **Element 11[c]:** “the repulsive forces is dependent on characteristics of where the object is positioned relative to the respective pose.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶123.

See supra elements 1[b][2], 4[c]. IV.A.2.e, j.

- v. **Claim 12:** “The method of claim 8, wherein the plurality of points of the respective pose configured to experience the repulsive forces, the plurality of points capable of translating and rotating in response to repositioning of the respective pose.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶124.

See supra elements 1[b][2], 8[b], claim 5.

Beardsley discloses applying its method to quadrotors and accounting for translation and rotation. *Id.*; Ex1004, [0135] (defining a rotation matrix RI). In the context of an obstacle avoidance method such as Beardsley, this translation and rotation constitute the translation and rotation of route poses. Ex1003, ¶125. A POSITA would have understood that this technique could also be applied to ground robots to also determine translation and rotation. *Id.* Beardsley discloses using the “potential field approach that pushes the vehicle away from both static and dynamic obstacles.” Ex1004, [0061]. Beardsley applies this approach to “local motion planning,” *id.* [0096], including through “selectively adjusting the velocity and direction . . . to generate a trajectory . . . for the vehicle in the space,” *id.* [0011]. Ex1003, ¶125. A POSITA would have understood that the use of potential fields to adjust velocity would result in the repositioning of the route poses in response to the forces on each point of the route poses. Ex1003, ¶125.

- w. **Claim 13:** “The method of claim 8, further comprising: performing interpolation between the respective pose and a subsequent respective route pose to generate a collision-free route between the respective pose and the subsequent respective route pose for the robot to travel.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶126.

See supra claims 6-7. IV.A.2.1-m.

- x. **Element 14[pre]:** “A non-transitory computer-readable storage apparatus having a plurality of instructions stored

thereon, that when executed by at least one processor configure the at last one processor to:”

The Beardsley/Castellanos combination discloses this limitation. Ex1003,

¶¶128-129. *See supra* element 1[b]. IV.A.2.c.

See also Ex1004, [0044] (“The vehicle 110 may include a processor 112 running a local controller”), [0046] (“The system 100 further includes a central control system 120 that may take the form of a computer or computer-based system specially configured to control the vehicles 110 via motion control signals 138. Particularly, the control system 120 includes one or more processors The processor 122 also runs or executes code in a computer readable medium to provide a controller module 130, which provides all or a large portion of the shared motion control described herein.”). Ex1003, ¶129

- y. **Element 14[a]:** “determine a route on a map for a robot, the route comprising one or more route poses, each route pose comprising a footprint indicative at least in part of a pose and a shape of the robot along the route and each route pose having a plurality of points disposed therein, the map corresponding to the environment and being generated by at least one sensor on the robot, the route including a plurality of points such that a first point being discretized than a second point, each of the plurality of points corresponding to a respective pose of the robot, the respective pose of the robot including a plurality of points disposed therein, the respective pose corresponding to at least one of position and orientation of the robot; and”

The Beardsley/Castellanos combination discloses this limitation. Ex1003,

¶130. *See supra* elements 8[pre], 8[a]. IV.A.2.n-o.

- z. Element 14[b]:** “compute repulsive forces from a point on an object in the environment onto the plurality of points of a first route pose of the one or more route poses.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003,

¶131. *See supra* elements 1[b][2], 8[b]. IV.A.2.e, p.

- aa. Claim 15:** “The non-transitory computer readable medium of claim 14, wherein the respective pose of the robot and a subsequent respective pose of the robot being regularly or irregularly spaced apart from each other on the route such that the respective pose and the subsequent respective pose form a sequence along the route.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003,

¶¶132-133. *See supra* elements 1[b], 14[pre], claim 2. IV.A.2.c, f, x.

- bb. Claim 16:** “The non-transitory computer readable medium of claim 14, wherein the respective pose corresponds to a footprint of the robot, the footprint configured to be adjustable between a small footprint and a large footprint, the small footprint having a high likelihood of collision with the object, and the large footprint having a low likelihood of collision with the object, the footprint of the robot configured to be dynamically reshaped.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003,

¶¶134-135. *See supra* elements 1[b], 14[pre], claims 3, 10. IV.A.2.c, f-g, r, x.

- cc. Element 17[a]:** “The non-transitory computer readable medium of claim 14, wherein, the repulsive forces from

the point on the object prevent the robot from colliding with the object,”

The Beardsley/Castellanos combination discloses this limitation. Ex1003,

¶¶136-137. *See supra* elements 1[b], 4[a], 14[pre]. IV.A.2.c, h, x.

dd. Element 17[b]: “the repulsive forces from the object is uniform on the respective pose, and”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶138.

See supra elements 1[b][2], 4[b]. IV.A.2.e, i.

ee. Element 17[c]: “the repulsive forces is dependent on characteristics of where the object is positioned relative to the respective pose.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003,

¶139. *See supra* elements 1[b][2]. 4[c]. IV.A.2.e, j.

ff. Claim 18: “The non-transitory computer readable medium of claim 14, wherein the plurality of points of the respective pose configured to experience the repulsive forces, the plurality of points capable of translating and rotating in response to repositioning of the respective pose.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003,

¶¶140-141. *See supra* elements 1[b], 1[b][2], 14[pre], claims 5, 7. IV.A.2.c, e, k,

m, x.

gg. Claim 19: “The non-transitory computer readable medium of claim 14, wherein the at least one processor is further configured to execute the computer readable instructions to, perform interpolation between the respective pose and a subsequent respective route pose to

generate a collision-free route between the respective pose and the subsequent respective route pose for the robot to travel.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003,

¶¶142-143. *See supra* elements 1[b], 14[pre], claim 6. IV.A.2.c, l, x.

hh. Claim 20: “The non-transitory computer readable medium of claim 14, wherein the at least one processor is further configured to execute the computer readable instructions to, reposition the respective pose and a subsequent respective pose in response to the repulsive forces on each point of the plurality of points.”

The Beardsley/Castellanos combination discloses this limitation. Ex1003, ¶¶144-

145. *See supra* elements 1[b], 1[b][2], 14[pre], claim 7. IV.A.2.c, e, m, x.

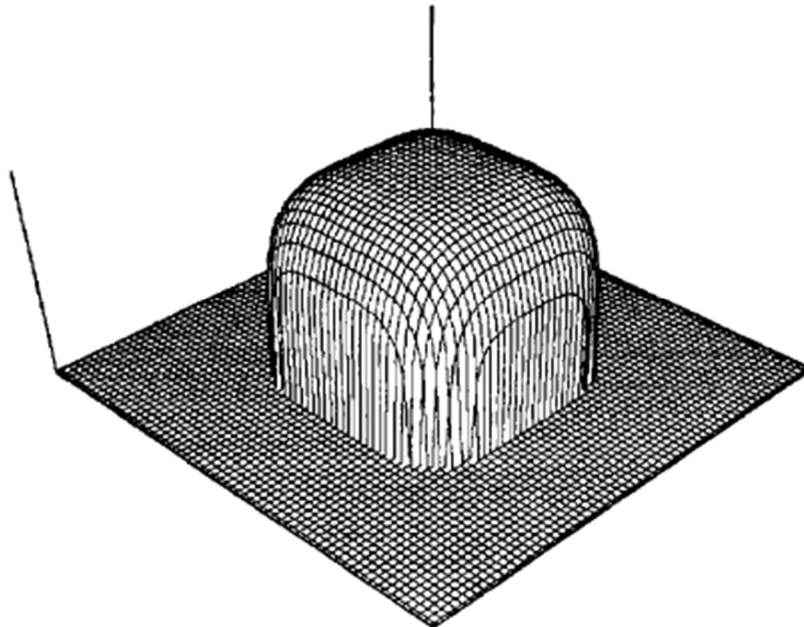
B. Ground 2: Beardsley in view of Castellanos and Khatib Render Obvious Claims 1–20

1. Overview of Ground and Prior Art

a. Summary of Khatib

Khatib is a seminal paper disclosing the real-time obstacle avoidance method using artificial potential fields. Ex1006, 90; Ex1003, ¶49. The method moves a robot (manipulator) based on simulated forces acting upon the robot. *Id.* The “manipulator moves in a field of forces. The position to be reached is an attractive pile . . . and obstacles are repulsive surfaces for the manipulator parts.” Ex1006, 90. Khatib explains that “any point of the robot can be subjected to the artificial potential field” and such a point is called a “Point Subjected to the Potential” or “PSP.” *Id.*, 93. The method “enables control of a given point of the manipulator with respect to

[an] obstacle” and specifying “an adequate number of PSPs enables the protection of all of the manipulator’s parts.” *Id.*, 94. The potential field accounts for a “limit distance” at which the influence of the potential field ceases and a “shortest distance to the obstacle” at which repulsive force is greatest. *Id.*, 93. Khatib also discloses that the potential field method can be used to account for various obstacle shapes. *Id.*, Fig. 1 (below); Ex1003, ¶49.



Ex1006, Fig. 1.

b. Motivation to Combine Beardsley, Castellanos, and Khatib

As discussed in Ground 1 (IV.A.1c), a POSITA would have been motivated to combine Beardsley with Castellanos. A POSITA would have further been motivated to modify that combination further in view of Khatib. Ex.1003, ¶146.

Khatib discloses a “real-time obstacle avoidance approach for manipulators and mobile robots.” Ex1006, 90. Khatib discloses computing the potential field multiple points to “enable protection of all of the manipulator’s part.” *Id.*, 94. Khatib presents “this method in the context of manipulator collision avoidance,” and explains that the “application to mobile robots is straightforward.” *Id.*, 91. Indeed, in a 2005 textbook, Choset disclosed an application of Khatib’s method to “rigid-body robots” using “control points.” Ex1012, 80, 101-104, 582; Ex.1003, ¶147. A POSITA would have found it advantageous to compute forces at multiple points of a rigid-body robot to account for the entire body of the robot and to enable protection of the entire body. *Id.*

A POSITA would have recognized that Khatib’s use of “PSPs” (IV.1.a) for every point of a manipulator (robot) and Beardsley’s use of waypoints and “active areas” (IV.A.1.a) were complimentary solutions to the problem of accounting for the footprint of a robot to avoid obstacles. Ex1003, ¶147. Khatib discloses computing forces at each PSP of the manipulator (which is a type of robot) and further discloses that “*n* PSPs have to be considered” to reposition the manipulator, which are essential to protect all parts of the manipulator. Ex1006, 94. Khatib’s PSPs provide a more granular method of accounting for a robot’s footprint for use in Beardsley, because additional PSPs can be specified to accurately account for, and protect, a particular robot’s parts. *Id.*; Ex1003, ¶147. A POSITA would have found it obvious

to apply Khatib's teachings to an adequate number of PSPs at each route pose to Beardsley's robot so as to ensure all parts of Beardsley's robot are protected at each pose along its route. *Id.*

A POSITA would have found it obvious and beneficial to apply Khatib's teachings concerning computing forces on more than one point of a route pose of Beardsley's robot. *Id.*, ¶148. While Khatib explains that doing so would "require[] the solution of a complicated system of equations," it also presents a technique that "avoids this costly computation." Ex1006, 94. This technique would therefore provide the benefits of improved obstacle avoidance whilst avoiding costly computations. Ex1003, ¶148. Moreover, Khatib is a seminal paper from 1986. *Id.* A POSITA would have known that computing power has increased significantly between 1986 and the filing of the '539 patent over 30 years later in 2018 and therefore could accommodate the computations of forces using the techniques proposed by Khatib. *Id.*

A POSITA would have been motivated to combine Beardsley and Khatib with Castellanos because, as noted above, § IV.A.1.c (incorporated by reference) solutions to the complete navigation system in autonomous robotics *requires* utilizing a method of localization, like that disclosed in Castellanos. *Id.*, ¶149. A POSITA seeking improved solutions to a complete navigation system in the field of autonomous robots would need to combine methods of obstacle avoidance, map

building, and localization (Ex1009, 323), like the combination of Beardsley, Khatib, and Castellanos. Ex1003, ¶149.

Khatib, like Beardsley and Castellanos, discloses the use of sensors and sensor data. Ex1006, 96 (“producing the appropriate commands . . . [involves] making use of real time obstacle sensing (low level vision and proximity sensors)”). *Supra* § IV.A.1.c (describing use of sensors by methods in Beardsley and Castellanos). A POSITA would have had an expectation of success combining Beardsley, Khatib, and Castellanos. Ex1003, ¶150. As noted, both Khatib and Beardsley disclose the use of potential field methods based on sensor data for obstacle avoidance, Khatib provides additional granularity as to accounting for the robot’s footprint, and Castellanos provides a method of localization. *Id.* These methods collectively thus provide an improved solution to a complete navigation system. *Id.* Further, because all three utilize sensors and sensor data, this underscores the reasonable likelihood of success in combining the teachings. *Id.*

2. Detailed Analysis of Ground 2

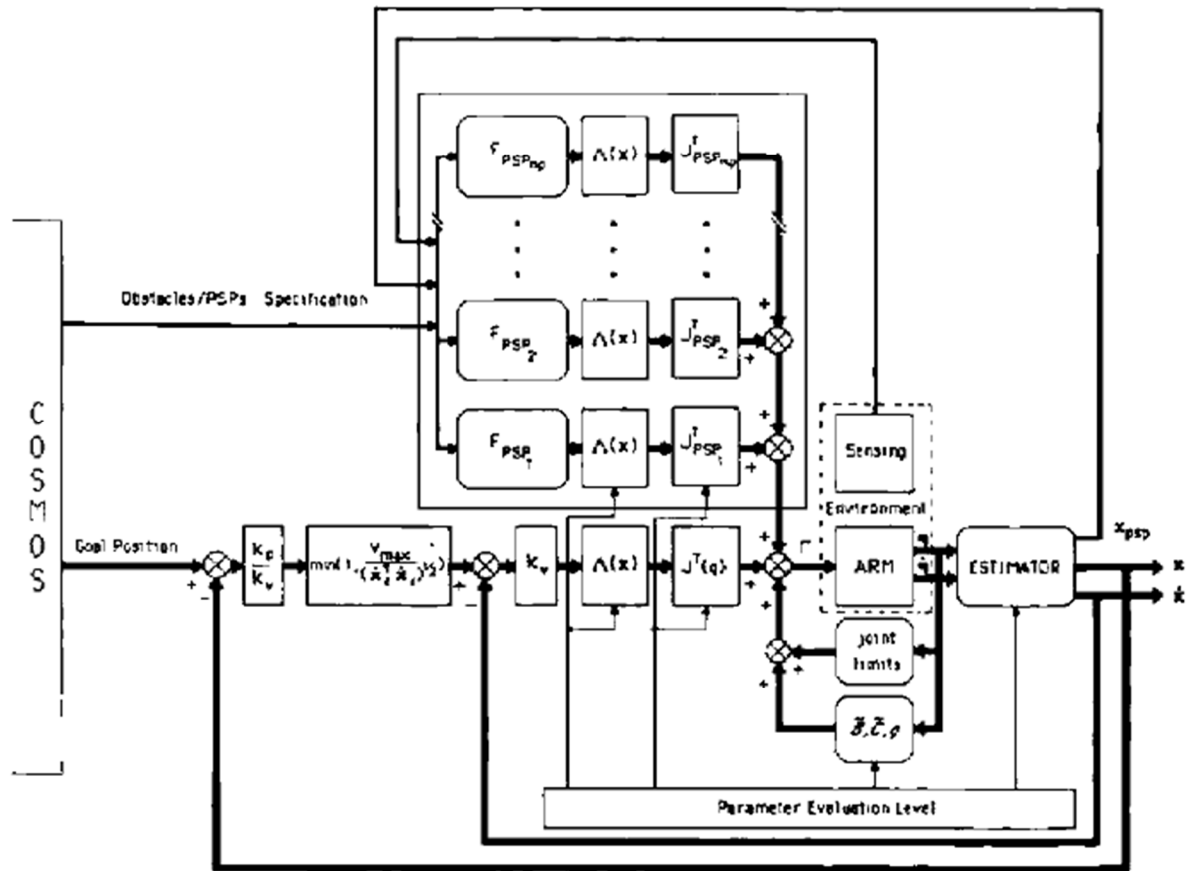
As supported by the Papanikolopoulos Declaration, Beardsley/Castellanos/Khatib combination teaches all elements of claims 1–20 of the ’539 Patent and also renders all of those claims obvious. *Supra* §§ IV.A.2.a-hh. Ex1003, ¶¶152-194.

c. Element 1[b][2]:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶157.

Khatib discloses a PUMA 560 robot that implements methods for real-time collision avoidance, where there are moving obstacles, using “visual sensing.” Ex1006, 90, Abstract. Khatib also discloses “taking into account the detailed geometry and motion of manipulator and obstacle, and making use of real-time obstacle sensing (low level vision and proximity sensors).” *Id.*, 96; Ex1003, ¶158.

Khatib discloses implementation of its technique on a “Control System Architecture,” in Fig. 3 (shown below), which is a controller. Ex1006, Fig. 3; Ex1003, ¶159.



Ex1006, Fig. 3.

Khatib discloses that its controller determines forces on a robot/manipulator, including repulsive forces from a detected point on an object. Ex1006, 91 (“The manipulator moves in a field of forces. The position to be reached is an attractive pole . . . and obstacles are repulsive surfaces for the manipulator parts.”); Ex1003, ¶160. F_{xd} in Equation (10) is the attractive force from a goal point and F_o in equation 10 is the repulsive force originating from the surface of the obstacle—thus Khatib

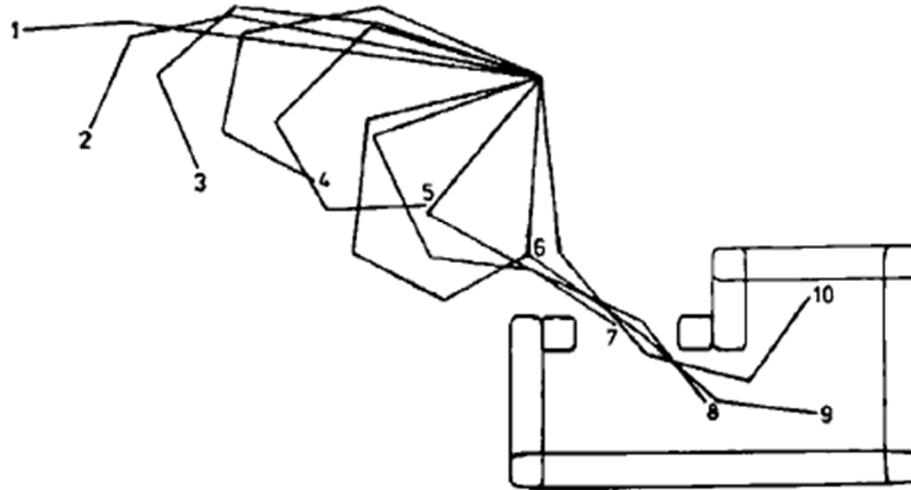
discloses computing repulsive forces from a point on an object. Ex1006, 92; Ex1003, ¶160.

$$\begin{aligned} F_{x_d}^* &= -\text{grad}[U_{x_d}(x)], \\ F_o^* &= -\text{grad}[U_o(x)]. \end{aligned}$$

Ex1006, Equation (10).

Khatib also discloses that the potential field approach “enables the control of a given point of the robot with respect to the obstacle by using the sum of the relevant gradients.” Ex1006, 94. Khatib discloses that it is possible to control a given point of a robot with respect to several obstacles, or to control different points of the robot with respect to different obstacles. Ex1003, ¶161. For example, Khatib explains that “[a]ny point of the robot can be subjected to the artificial potential field,” and defines a “Point Subjected to the Potential” as “PSP.” *Id.*, 93. Khatib discloses equations (18), (23), (24), (25) for calculating the potential field at each PSP. *Id.*, 93-94; Ex1003, ¶161. Further, Khatib recommends that “specifying an adequate number of PSPs enables the protection of all of the manipulator’s parts.” Ex1006 at 93. A POSITA would have found it obvious to apply Khatib’s teachings concerning the manipulator, which is a type of robot with a fixed base, to a mobile robot. Ex1003, ¶161. A POSITA would have therefore understood Khatib to disclose this claim element. *Id.* Khatib recommends calculating the forces for “an adequate number of PSP” to protect all of the manipulator’s parts at each position of the

manipulator (Fig. 2). *Id.* A POSITA would also have found it desirable and obvious to apply this teaching to Beardsley's robot to calculate forces for the plurality of points on a route poses of the Beardsley robot to protect all parts of the robot. *Id.*



Ex1006, Fig. 2.

- d. Element 4[c]:** “and the repulsive forces is dependent on characteristics of where the object is positioned relative to the respective pose.”

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶167. *See supra* element 1[b][2].

Khatib discloses that repulsive force “should be a nonnegative continuous and differentiable function whose value tends to infinity as the end effector approaches the obstacle’s surface. To avoid undesirable perturbing forces beyond

the obstacle's vicinity, the influence of this potential field must be limited to a given region surrounding the obstacle.” Ex1006, 92.

Khatib discloses setting repulsive force as zero where the distance to an obstacle is greater than the “limit distance of the potential field influence.”

Ex1006, 93 (Equations 16, 17); Ex1003, ¶169.

$$U_o(x) = \begin{cases} \frac{1}{2} \eta \left(\frac{1}{f(x)} - \frac{1}{f(x_0)} \right)^2 & \text{if } f(x) \leq f(x_0), \\ 0 & \text{if } f(x) > f(x_0). \end{cases}$$

Ex1006, Equation (16).

$$U_o(x) = \begin{cases} \frac{1}{2} \eta \left(\frac{1}{\rho} - \frac{1}{\rho_0} \right)^2 & \text{if } \rho \leq \rho_0, \\ 0 & \text{if } \rho > \rho_0, \end{cases}$$

Ex1006, Equation (17).

The “limit distance” and Equation (17) constitute a force function wherein the repulsive force from a first detected point (an obstacle) is “zero” on a point on a route pose (i.e., the robot) beyond the limit distance. Ex1006, 92 (“the influence of this potential field must be limited to a given region surrounding the obstacle”); Ex1003, ¶170.

A POSITA would have found it obvious and beneficial to apply Khatib's technique for computing forces to a robot that implements the teachings of Beardsley/Castellanos. *Id.*, ¶171. As Khatib explains, “[t]his potential function

can be obtained very simply in real-time since it does not require any distance calculations.” *Id.*

Accordingly, Khatib discloses that repulsive forces depend on where the object is positioned relative to the pose. Ex1003, ¶171.

e. Element 8[b]:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶176. *See supra* elements 1[b], 1[b][2].

f. Element 11[b]:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶180. *See supra* elements 1[b], 1[b][2].

g. Element 11[c]:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶181. *See supra* elements 1[b], 1[b][2], 4[c].

h. Claim 13:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶183. *See supra* element 1[b][2].

i. Element 14[b]:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶186. *See supra* elements 1[b], 1[b][2], 8[b].

j. Element 17[a]:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶189. *See supra* elements 1[b], 1[b][2], 4[a].

k. Element 17[b]:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶190. *See supra* elements 1[b], 1[b][2], 4[b].

l. Element 17[c]:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶191. *See supra* elements 1[b], 1[b][2], 4[c].

m. Claim 18:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶192 *See supra* elements 1[b], 1[b][2], claim 12.

n. Claim 20:

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Khatib combination teaches it. Ex1003, ¶194. *See supra* elements 1[b], 1[b][2].

C. Ground 3: Yamamoto in view of Khatib Render Obvious Claims 1–20

1. Overview of Ground and Prior Art

a. Summary of Yamamoto

Yamamoto discloses an autonomous robot for indoor environments that combines known path planning, map building, and obstacle avoidance techniques. Ex1010, 422 (“we propose our potential field-based path planner within topological map building ability which enables the robot . . . to build a reliable and compact map between targets (a start and goal). . .”); Ex1003, ¶53.



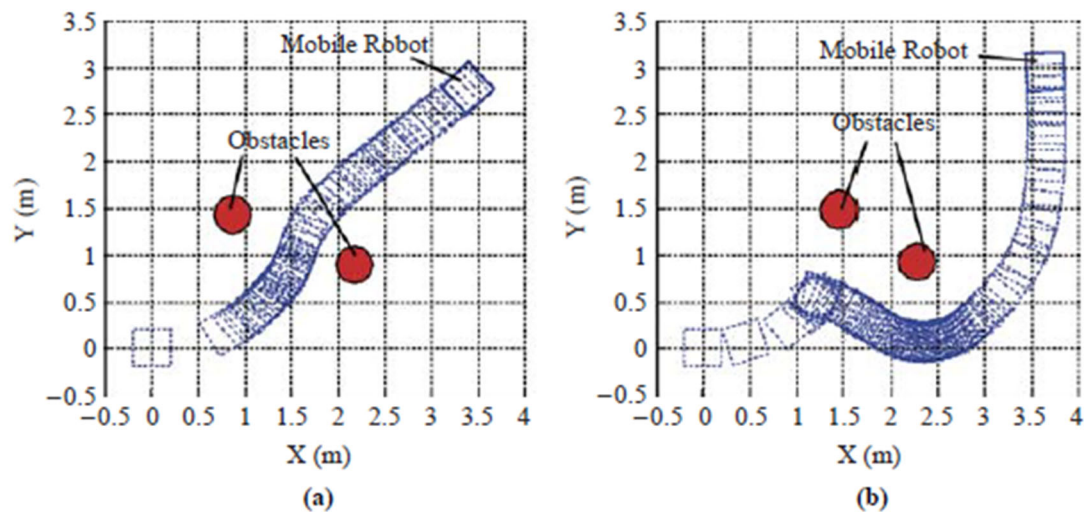
Ex1010, Fig. 4.

Yamamoto uses the potential field method of Khatib for obstacle avoidance and the Voronoi diagram method for map creation. *Id.*, 421 (“The hybrid path planner is composed of potential field method (Khatib, 1986) (Volpe and Khosla, 1990) and Voronoi diagram approach”); Ex1003, ¶54.

b. Motivation to Combine Yamamoto and Khatib

A POSITA would have been motivated to combine Yamamoto and Khatib. Ex1003, ¶195. Yamamoto uses Khatib’s technique in its proposed method in a robot. *Id.*, 421 (“In this paper, we propose a hybrid path planner . . . composed of

potential field method (Khatib, 1986)"); *id.* at 433-434; Fig. 24 (showing a “real robot in an environment where two circular obstacles are located as to generate artificial potentials . . . ”). Because Yamamoto relies on Khatib’s technique, a POSITA would have studied Khatib and applied its techniques for computing forces to the Yamamoto robot. Ex1003, ¶195.



Ex1010, Fig. 24.

Yamamoto describes Khatib as “straightforward” and that it “guarantees a safe navigation under dynamic environment[s].” Ex1010, 421. Yamamoto explains Khatib is “widely used in decades for autonomous mobile robot planning because of its simplicity.” Ex1010, 425. A POSITA familiar would be inclined to combine the teachings of Khatib because Khatib is used by Yamamoto, and because Khatib is a seminal paper that provides a simple solution for obstacle avoidance in dynamic environments. Ex1003, ¶196.

It would have been obvious to modify Yamamoto to use Khatib's route poses. Ex1003, ¶197. Khatib discloses route poses that have substantially similar footprints to the footprint of each route pose in Figure 2 thereof, which shows a "dynamic simulation for a redundant 4 *dof* manipulator operating." Ex1006, 94. As explained by Khatib, this would "enables the protection of all of the manipulator's parts." *Id.* As such, a POSITA would have been motivated to apply Khatib's route poses to Yamamoto's robot's planning trajectory to ensure that all parts of Yamamoto's robot can avoid collisions.

A POSITA would have reasonably expected success in combining Yamamoto and Khatib. Yamamoto successfully experimented using Khatib's potential field approach. Ex1010, 433 ("The collision avoidance algorithm presented has demonstrated its flexibility in both dynamically controlling the output equation and changing the shape of the repulsive potential field."). Accordingly, a POSITA would also have reasonably expected success in combining Yamamoto and Khatib. Ex1003, ¶198.

2. Detailed Analysis of Ground 3

a. Element 1[pre]

To the extent the preamble is limiting, it is disclosed by Yamamoto/Khatib. Yamamoto discloses a real robot, the Pioneer 3-DX. Ex1010, 423 ("The mobile

robot we use for experiments is an ActivMedia product, Pioneer 3-DX”); Ex1003, ¶199.

b. Element 1[a]

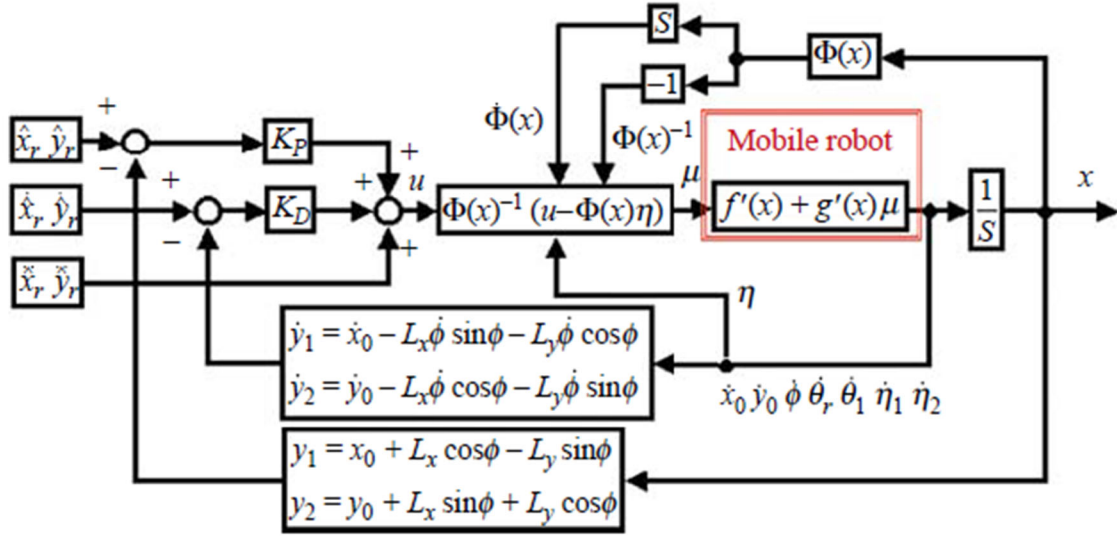
Yamamoto/Khatib discloses this limitation. Ex1003, ¶201. Yamamoto discloses that its robot “generat[es] a map model of its environment via sensory data.” Ex1010, 421. Yamamoto discloses that it uses “the closest sensory measurement from the obstacle surface, and define[s] a smallish particle obstacle at the closest location which generates a small repulsive potential as well.” *Id.*, 426. Yamamoto’s sensory measurement of the obstacle surface and definition of a small particle corresponds to this limitation’s “configured to collect data about an environment proximate to the robot including detected points on one or more objects in the environment.” Ex1003, ¶201. Additionally, the real robot is equipped with a laser, which is a sensor. *Id.*; Ex1010, Fig. 4.



Ex1010, Fig. 4.

c. Element 1[b]

Yamamoto/Khatib discloses this limitation. Ex1003, ¶202. Yamamoto discloses a system controller for its robot, which discloses the controller configured to execute computer readable instructions required by this limitation. *Id.*; Ex1010, 422 (describing “system controller.”). Yamamoto Figure 3 depicts Yamamoto’s controller.

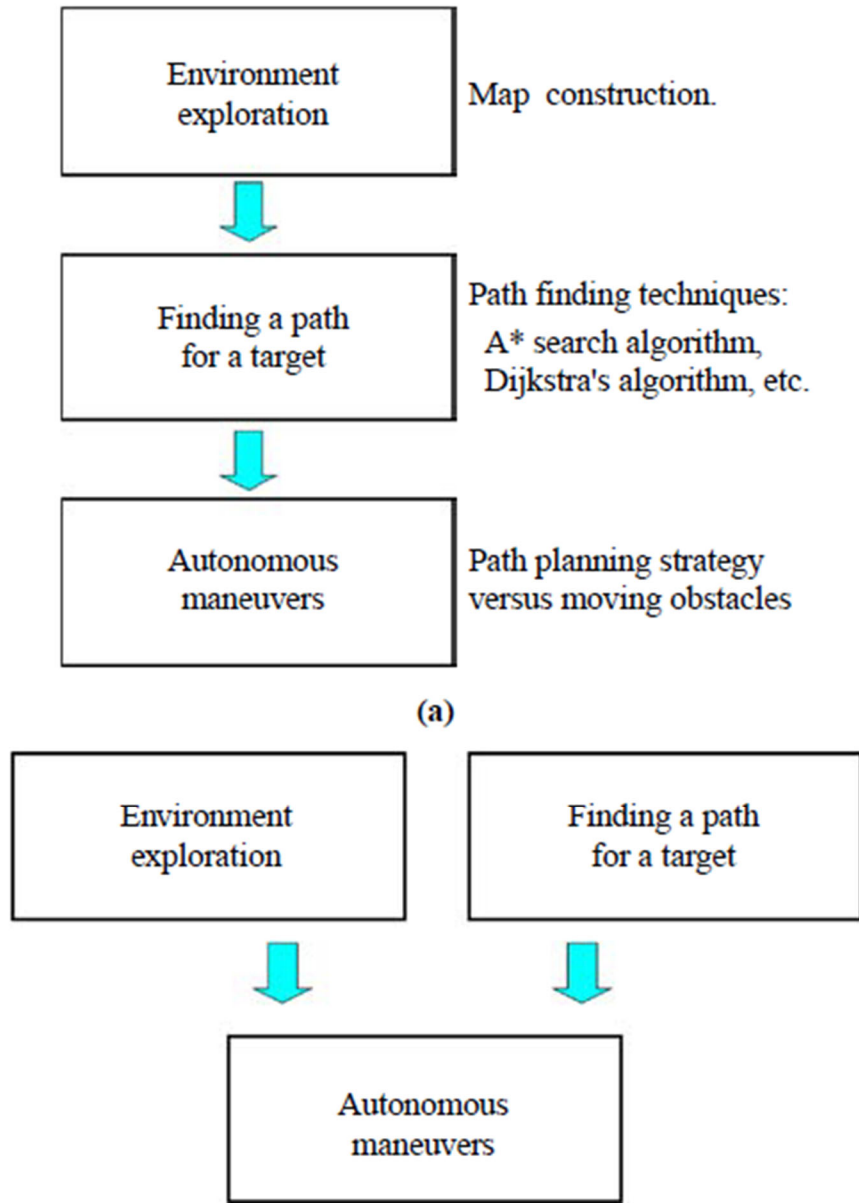


Id., Fig. 3.

d. Element 1[b][1]

Yamamoto/Khatib discloses this limitation. Ex1003, ¶203; *see supra* element 1[a].

Yamamoto discloses creating a map of the environment using the collected sensory data. Ex1010, Fig. 1 (“Map construction”); Ex1003, ¶203.



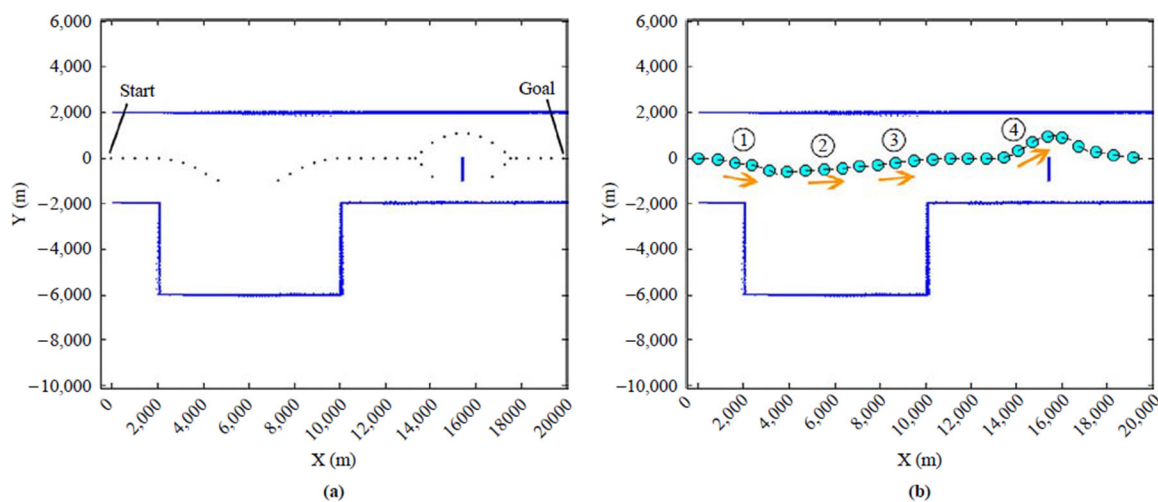
Ex1010, Fig. 1.

Yamamoto discloses a “path planner with both navigation and map building abilities.” *Id.*, 424. Yamamoto further discloses that “[b]ased on the constructed map, the robot is able to seamlessly start autonomous maneuvers between any targets.” *Id.* Yamamoto discloses that it uses “sensory data to allow the robot to

generate an approximate Voronoi structure such as a representation of free space of its environment,” i.e., a map. *Id.*, 429; Ex1003, ¶204. Yamamoto discloses that “[f]irst, the robot gathers information of its vicinity and creates a finite set P of points which approximates the sensory data from each laser scan” and then “[b]ased on each local scan, the robot accumulates the approximate sensory data for incrementally building an approximate Voronoi structure of its workspace while moving towards a target.” Ex1010, 429. Yamamoto’s map corresponds to the environment and is generated by sensors coupled to the robot. Ex1003 ¶204. Yamamoto Figure 1 discloses determining a path (route) on the map for the robot to travel, “Finding a path for a target.” *Id.*

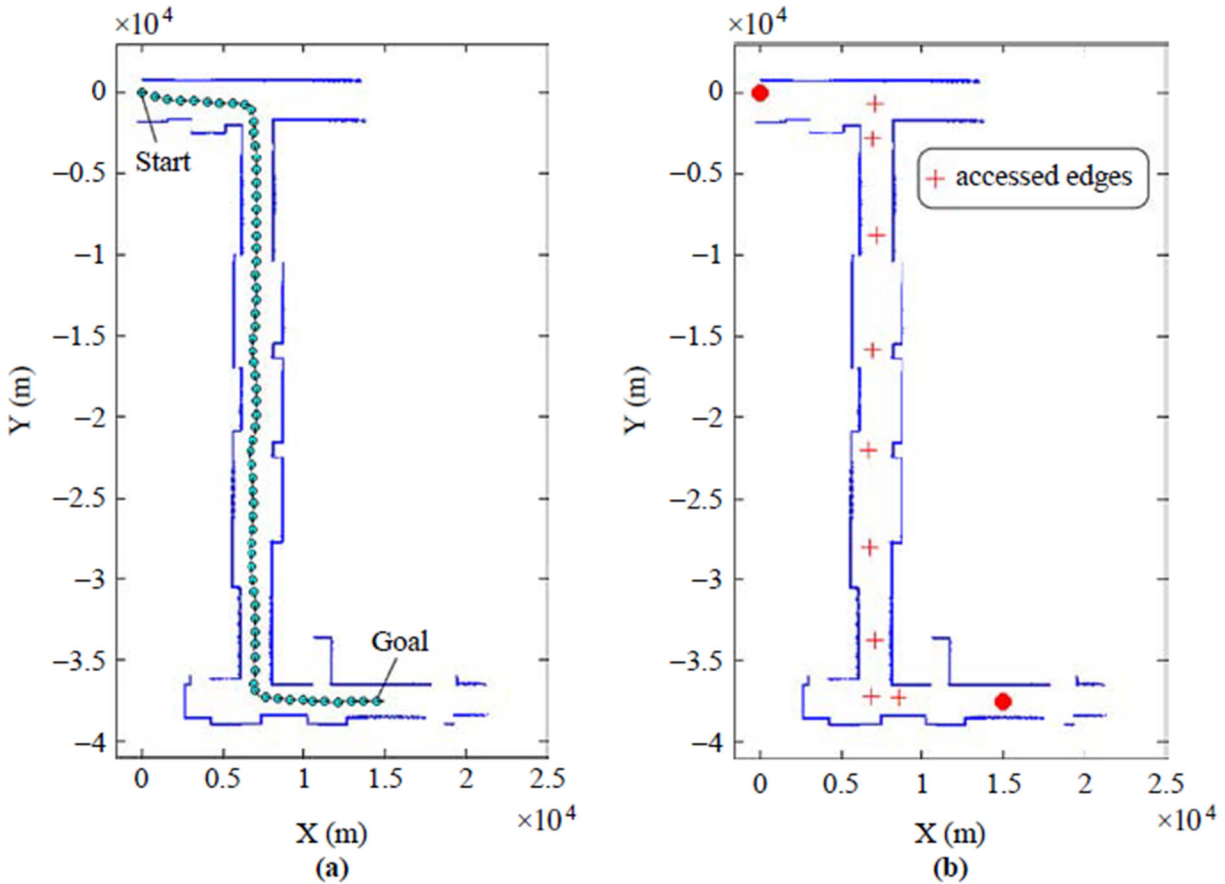
Yamamoto Figure 15 (shown below) depicts the determined route traveled by the robot. Ex1003, ¶205.

Figure 15 Approximate Voronoi diagram defined by constraints: (a) approximate Voronoi diagram; (b) motion of mobile robot



Ex1010, Fig. 15.

Yamamoto Figure 18 (shown below) similarly depicts the determined route in the map in which the robot will travel. Ex1003, ¶206.



Ex1010, Fig. 18.

Yamamoto discloses creating “sub-goals,” “target positions,” “Voronoi edges,” and “reference points” on the map which represent potential positions of the robot along the route and comprise the respective pose of the robot including a plurality of points, the pose corresponding to the position and orientation of the robot. Ex1010, 423 (“reference Point P_r ”); 429 (“After an exploration towards a target, the robot can perform autonomous maneuvers immediately by setting up

Diagram illustrating a 2D environment with a path and a legend:

- Unexplored edge
- Sub-goal
- Target position

Id., Fig. 19.

Yamamoto’s sub-goals, target positions, Voronoi edges, and reference points also qualify as the first and second discretized points as claimed. Ex1003, ¶208.

e. Element 1[b][2]

Yamamoto/Khatib discloses this limitation. Ex1003, ¶209.

Yamamoto discloses calculating repulsive forces. Ex1003, ¶209; Ex1010, 425 (“Also a repulsive potential well which prevents the mobile robot from collisions can be written as: [Equation (13)]”).

$$U_{\text{rep}}(K) = B \frac{e^{-\alpha K}}{K}$$

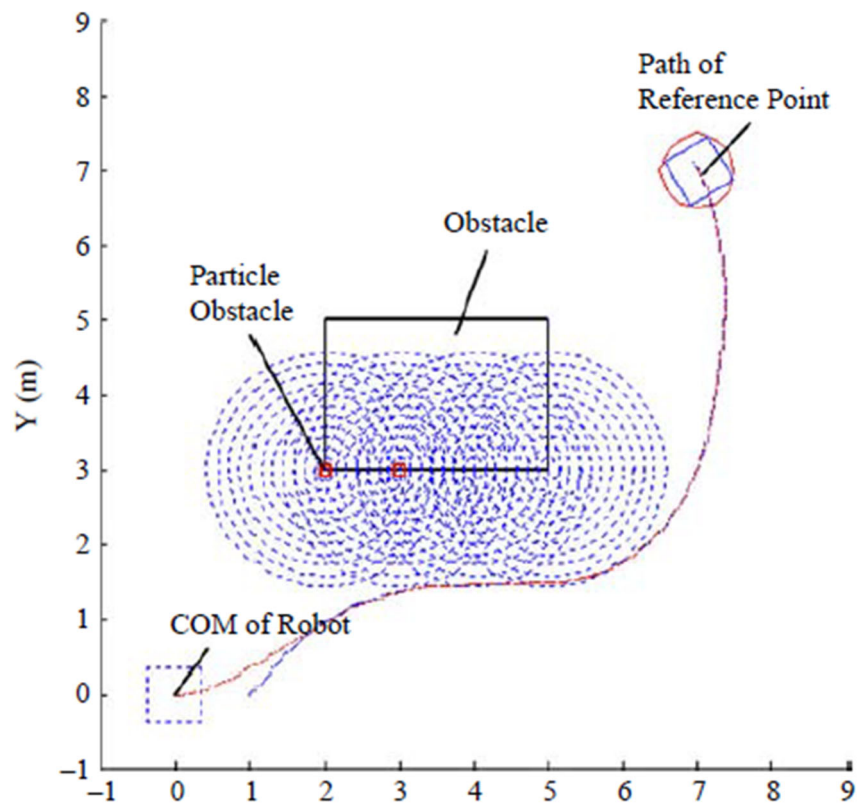
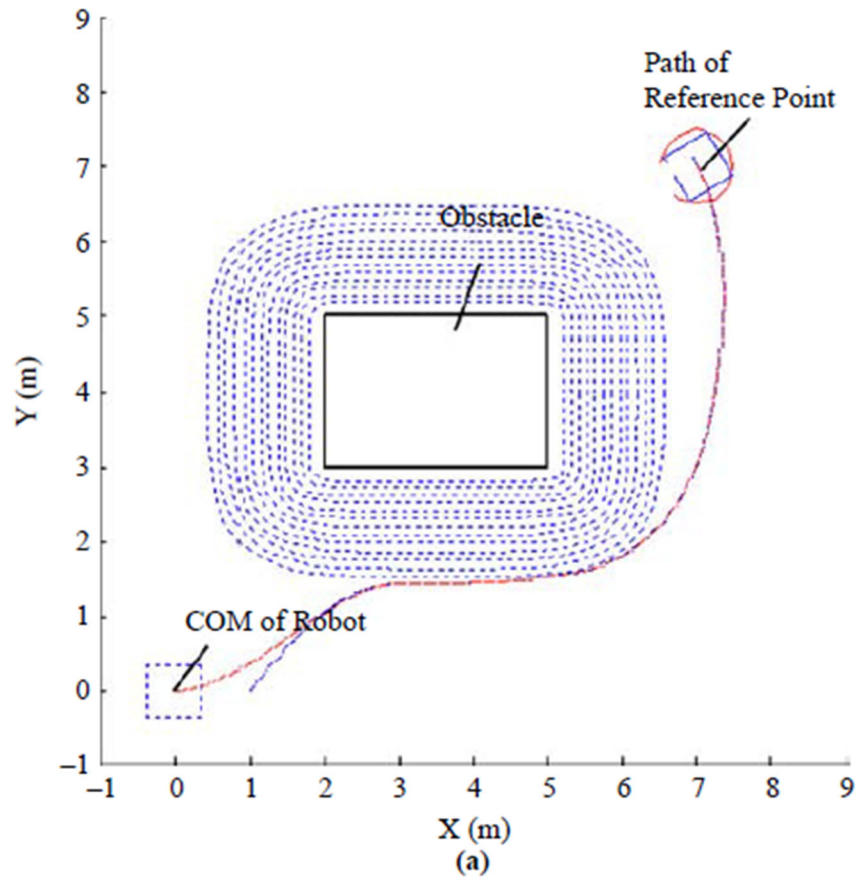
Ex1010, Equation (13).

Yamamoto discloses calculating the potential field based on a detected point of an object. Ex1003, ¶210; Ex1010, 426 (“We use the closest sensory measurement from the obstacle surface, and define a smallish particle obstacle at the closest location which generates a small repulsive potential as well”).

Yamamoto discloses using the potential field method to calculate forces for a given reference point. *Id.*, 426 (“also the momentary force F which the reference point receives can be given by: [equation 15]”); Ex1003, ¶210.

Yamamoto also explains that its controller “use[s] the closest sensory measurement from the obstacle surface, and define[s] a smallish particle obstacle at the closest location which generates a small repulsive potential as well,” as illustrated in Figure 8(b). *Id.*, 426; Fig. 8(b). Ex1003, ¶211.

As Fig. 8 depicts, the obstacle from which repulsive forces are calculated is on the map. Ex1003, ¶212.



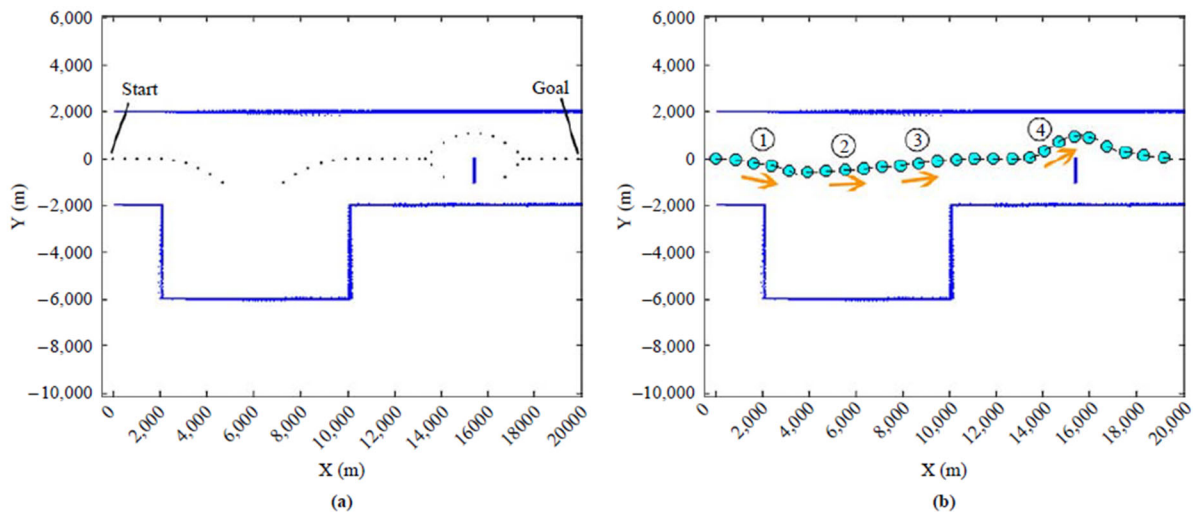
Ex1010, Fig. 8.

A POSITA would have found it obvious to compute repulsive forces for the plurality of points of the pose as Khatib discloses defining an adequate number of PSPs would better ensure protection of the robot from collision. Ex1006, 90; Ex1003, ¶213.

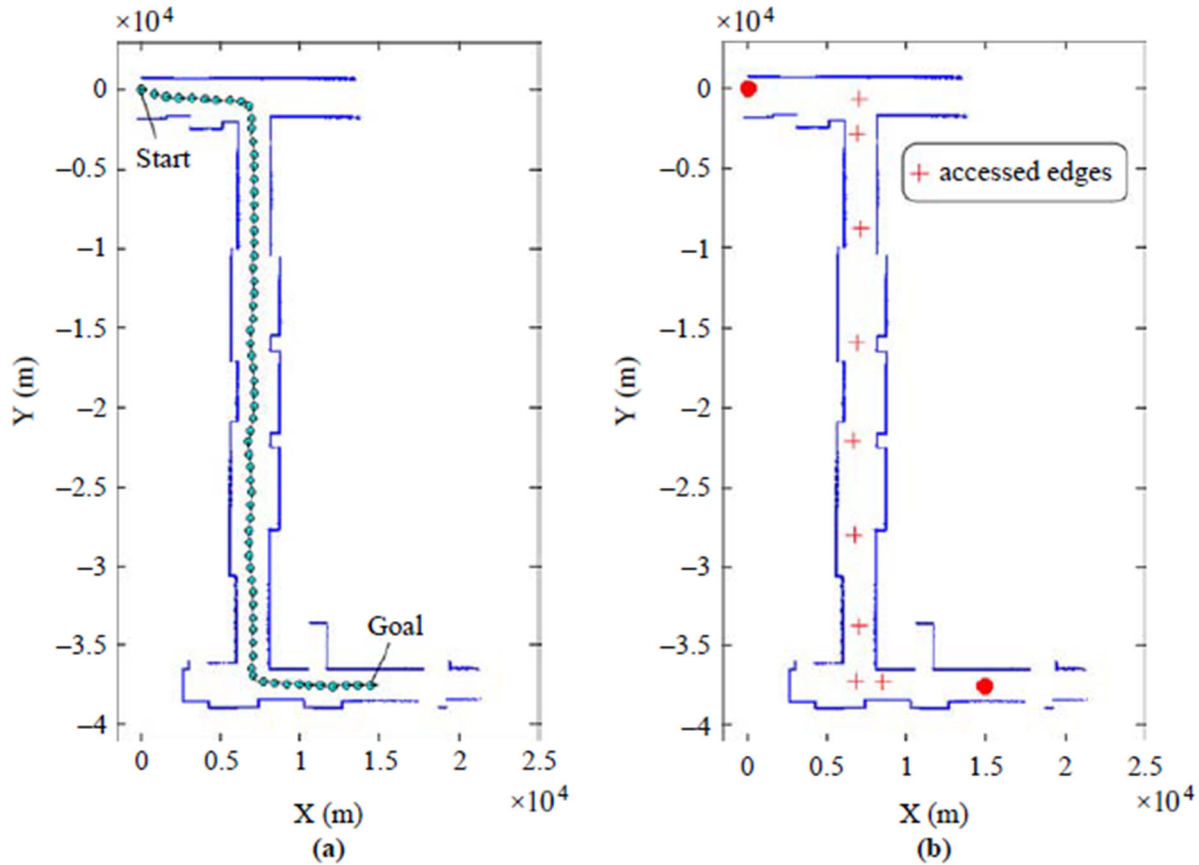
f. Claim 2

Yamamoto/Khatib discloses this limitation. Ex1003, ¶214. *See supra* element 1[b][1]. IV.C.2.e.

Yamamoto discloses poses spaced regularly or irregularly apart from each other such as to form a sequence along the route. Ex1010 Figs. 15, 18; Ex1003, ¶214.



Ex1010, Fig. 15.



Ex1010, Fig. 18.

g. Claim 3

Yamamoto/Khatib discloses this limitation. Ex1003, ¶215. *See supra* element 1[b][1]. IV.C.2.d.

Yamamoto's "sub-goals," "target positions," "Voronoi edges," and "reference points" represent potential positions of the robot along the route (respective pose) and correspond to the footprint of the robot . Ex1010, 423, 429. Ex1003, ¶215.

Yamamoto also discloses that the robot's position, and therefore Voronoi edges and sub-goals, are modeled by accounting for the "distance between two driving wheels" among other physical constraints such the radius of the wheels. *Id.*, 422; Ex1003, ¶216. A POSITA would have found it obvious to define the radius and other physical constraints depending on the desired footprint size and desired risk of collision. Ex1010 Fig. 2; Ex1003, ¶216.

h. Element 4[a]

Yamamoto/Khatib discloses this limitation. Ex1003, ¶¶217-218. *See supra* element 1[b][2]. IV.C.2.e.

Yamamoto teaches that repulsive forces from the point on the object prevent the robot from colliding with the object. Ex1010, 421 ("The potential field-based path strategy is straightforward and guarantees a safe navigation under dynamic environment."); *Id.*, 425 ("a repulsive potential [] which prevents the mobile robot from collisions can be written"). Ex1003, ¶218.

i. Element 4[b]

Yamamoto/Khatib discloses this limitation. Ex1003, ¶219. *See supra* element 1[b][2]. IV.C.2.e.

Yamamoto discloses positive constants are used to compute repulsive force (uniform repulsive force) Ex1010, 425. Ex1003, ¶219.

j. Element 4[c]

Yamamoto/Khatib discloses this limitation. Ex1003, ¶220. *See supra* element 1[b][2]. IV.C.2.e.

Yamamoto Equation (13) is a formula for computing repulsive forces relative to where the obstacle is positioned relative to the respective pose. Ex1003, ¶220. Variable K in Equation (13), acts as the “distance from the obstacle, becoming zero at the surface, and increasing with successive contours away from the surface.” Ex1010, 425. Per Equation (13), as K, the distance from the obstacle to the route pose increases, the computed repulsive force would decrease and is thus dependent on characteristics of where the object is positioned relative to the respective pose as claimed. *Id.*; Ex1003, ¶220.

$$U_{\text{rep}}(K) = B \frac{e^{-aK}}{K}$$

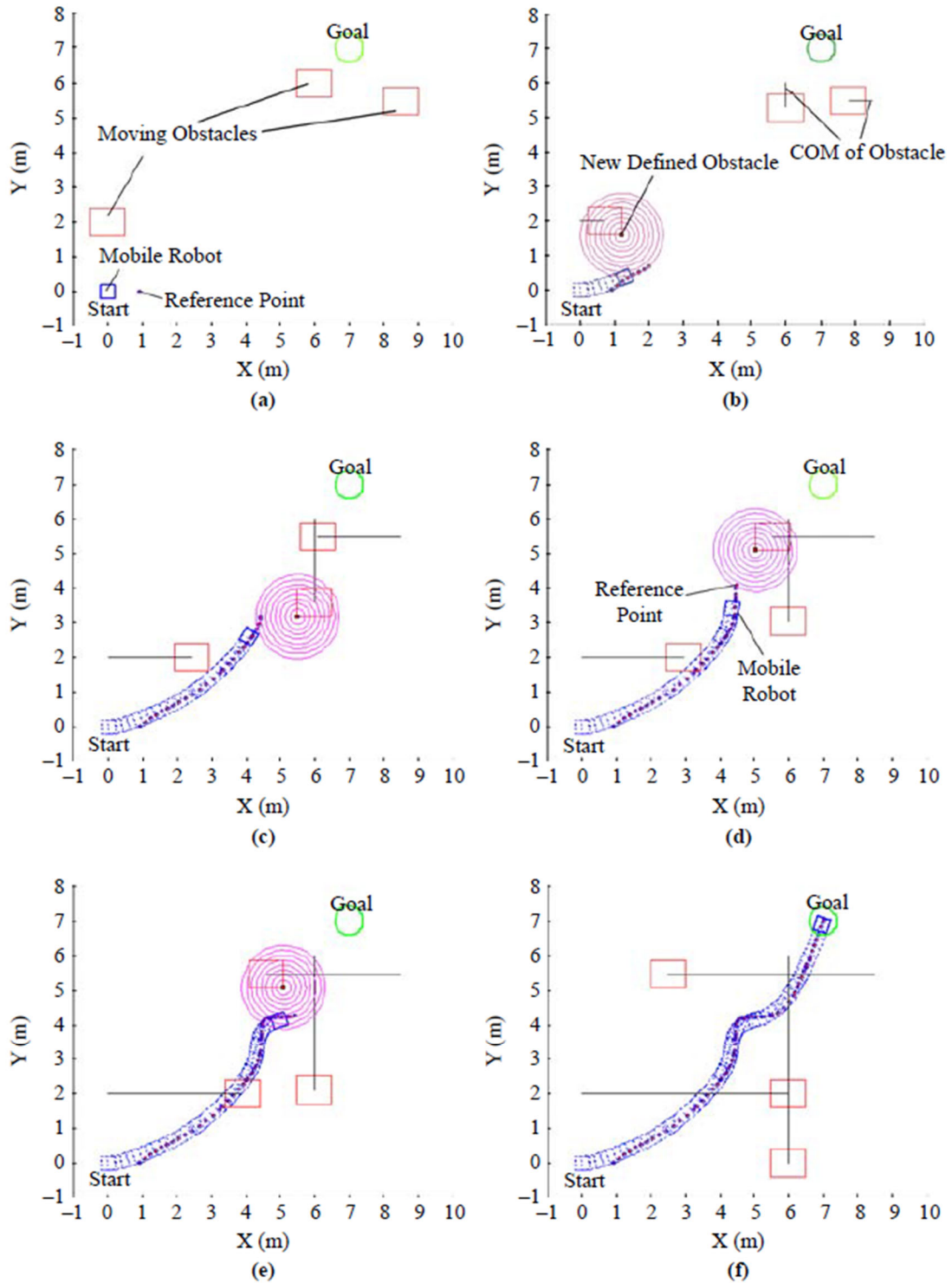
Ex1010, Equation (13).

k. Claim 5

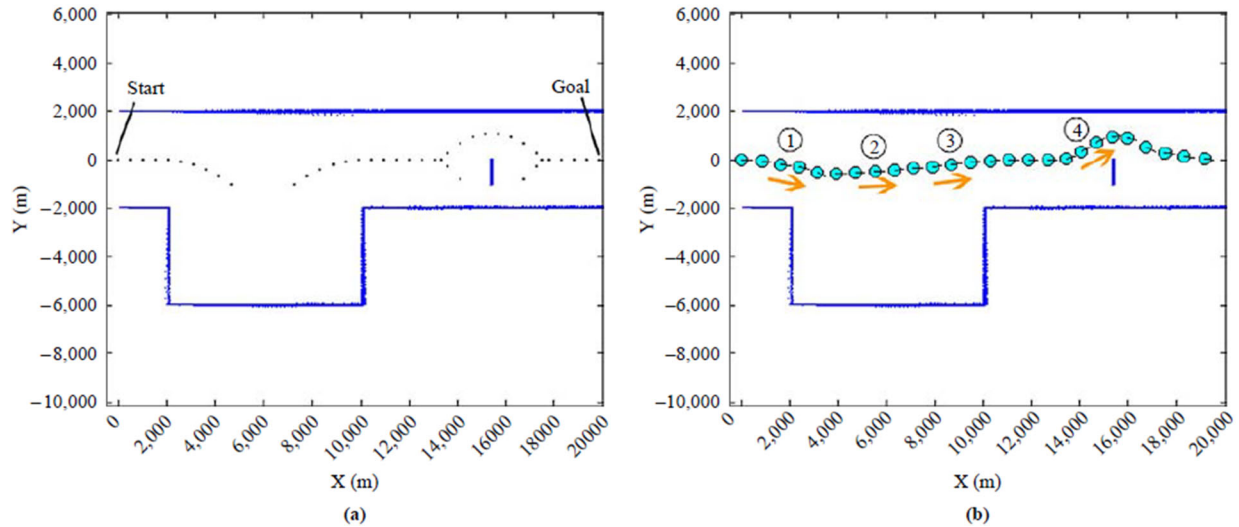
Yamamoto/Khatib discloses this limitation. Ex1003, ¶221. *See supra* elements 1[b][1], 1[b][2]. IV.C.2.d-e.

As explained above (Element 1[b][1]), Yamamoto discloses poses by constructing a Voronoi diagram. *Id.*, Fig. 15 (shown below); Ex1003, ¶221.

Yamamoto also discloses repositioning the robot based on potential forces. *Id.*, Fig. 12; Ex1003, ¶221. “Figure 12(a) to (e) thoroughly plot the obstacle avoidance path of the mobile robot in discrete time while it is maneuvered in a dynamic environment where three rectangular shapes of obstacles are moving in different directions.” Ex1010, 427.



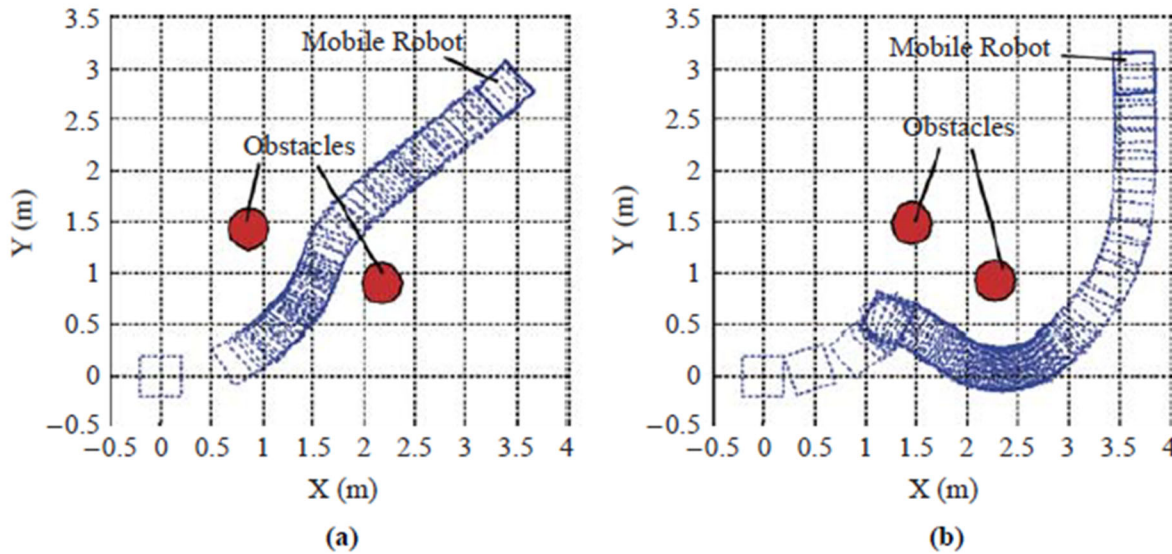
Ex1010, Fig. 12.



Id., Fig. 15.

Yamamoto discloses that “as to path planning, instead of scheming the path of the mobile robot directly we plan on calculating the path to reach the target position for the reference. As a result, the mobile robot will attain the target position as we expect by following the motion of the reference point.” *Id.*, 424.

Yamamoto discloses that repositioning of the route poses comprises translating and rotating the first route pose, as depicted in Figure 24(b), which shows the “shows the results of applying our technique in different deadlock conditions.” Ex1010, 433; Ex1003, ¶223.



Ex1010, Fig. 24 (illustrating “translating and rotating the first route pose” between $X=1$ and 1.5); Ex1003, ¶223.

I. Claim 6

Yamamoto/Khatib discloses this limitation. Ex1003, ¶224.

Yamamoto discloses “based on our collision avoidance algorithm by predefining start and goal positions the mobile robot can find a safe and smooth path for attaining the target position autonomously . . .” *Id.*; Ex1010, 427.

Yamamoto further explains “The system controller . . . is based on feedback linearization technique. . . to create a very smooth trajectory during obstacle avoidance.” Ex1010, 422, Equation (10) (“linearization between the control input and output.”)

Yamamoto therefore discloses determining a “safe and smooth path” using linearization between the “predefine[ed] start and goal positions.” *Id.*, 427; Ex1003,

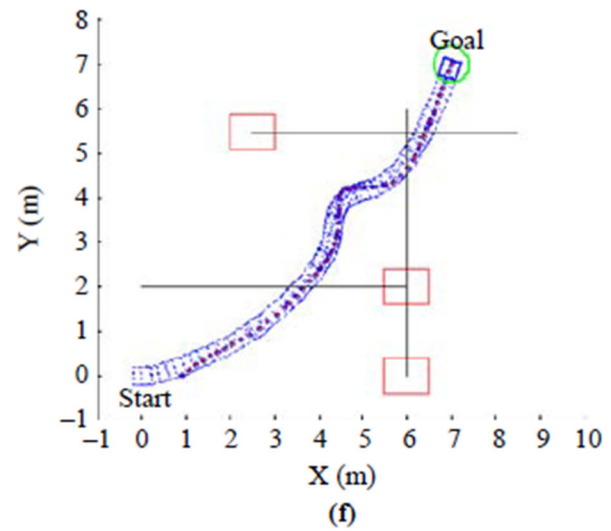
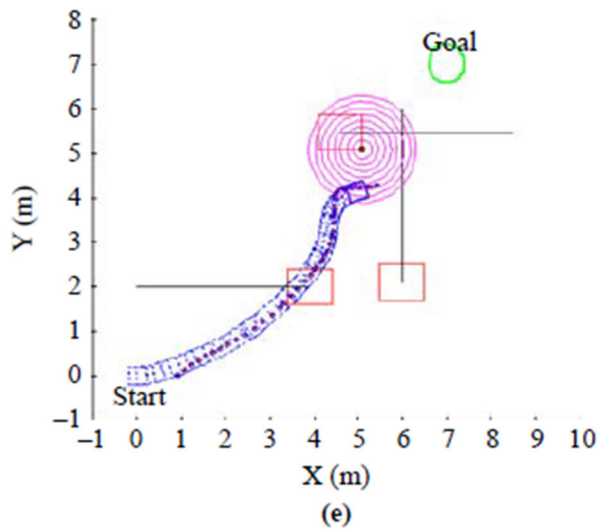
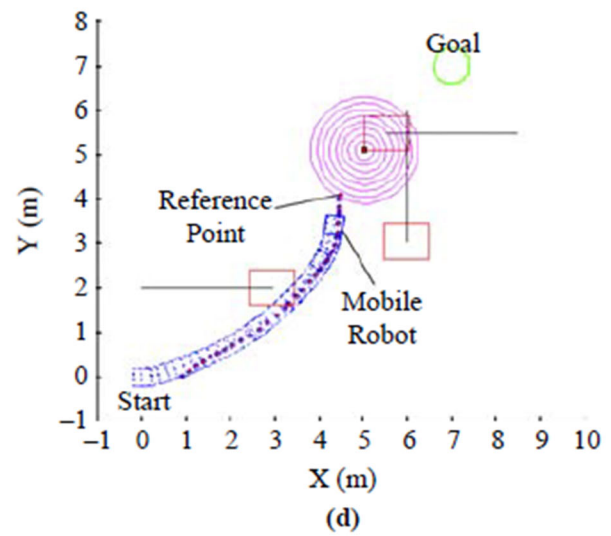
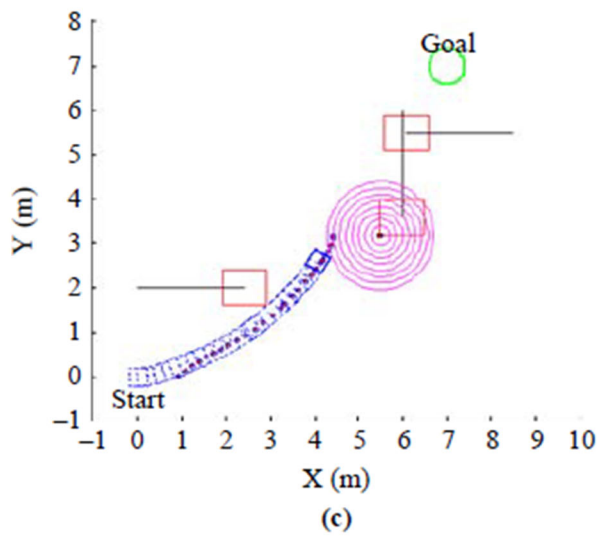
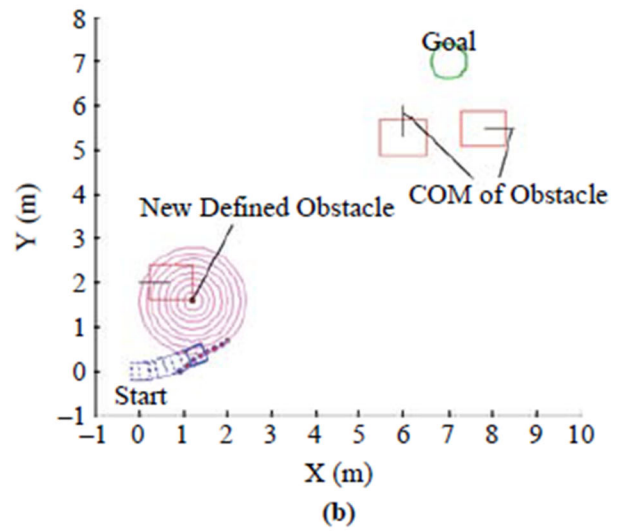
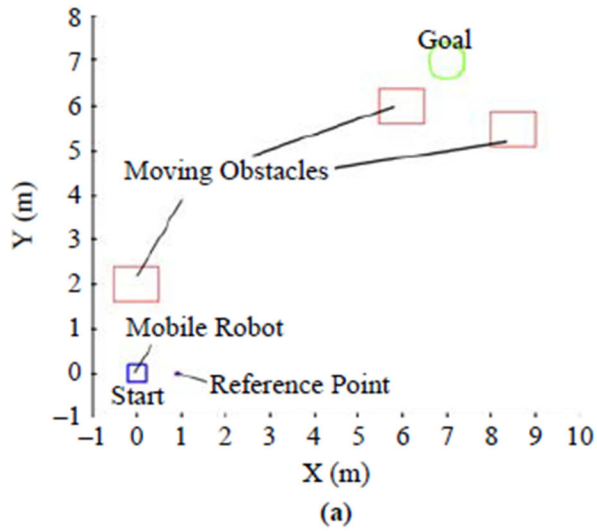
¶225. A POSITA would have understood that Yamamoto generates the path by interpolating a path between the start and goal positions. Ex1003, ¶225. Yamamoto's Figure 9 also illustrates an "obstacle avoidance path" between a reference point (i.e., a route pose) and an obstacle to generate a collision-free path during a look-ahead process. Ex1010, 428; Ex1003, ¶225. Yamamoto's Figure 5 also illustrates an "[i]mplementation of look-ahead control system," comparing the actual path travelled by the robot to a path that is determined by interpolating between multiple "reference points." Ex1010, 424. A POSITA would have understood that Figures 9 and 5 illustrate an interpolation between a sequence of route poses in which the robot travels along the route, to generate a collision free path. Ex1003, ¶225.

m. Claim 7

Yamamoto/Khatib discloses this limitation. Ex1003, ¶226.

Yamamoto discloses projected route poses by constructing a Voronoi diagram. *Id.*, Fig. 15; Ex1003, ¶226.

Yamamoto also discloses repositioning the robot based on potential forces. *Id.*, Fig. 12; Ex1003, ¶226. "Figure 12(a) to (e) thoroughly plot the obstacle avoidance path of the mobile robot in discrete time while it is maneuvered in a dynamic environment where three rectangular shapes of obstacles are moving in different directions." Ex1010, 427.



Id. Fig. 12.

Yamamoto discloses that “as to path planning, instead of scheming the path of the mobile robot directly we plan on calculating the path to reach the target position for the reference. Ex1003, ¶227. As a result, the mobile robot will attain the target position as we expect by following the motion of the reference point.” *Id.*, 424.

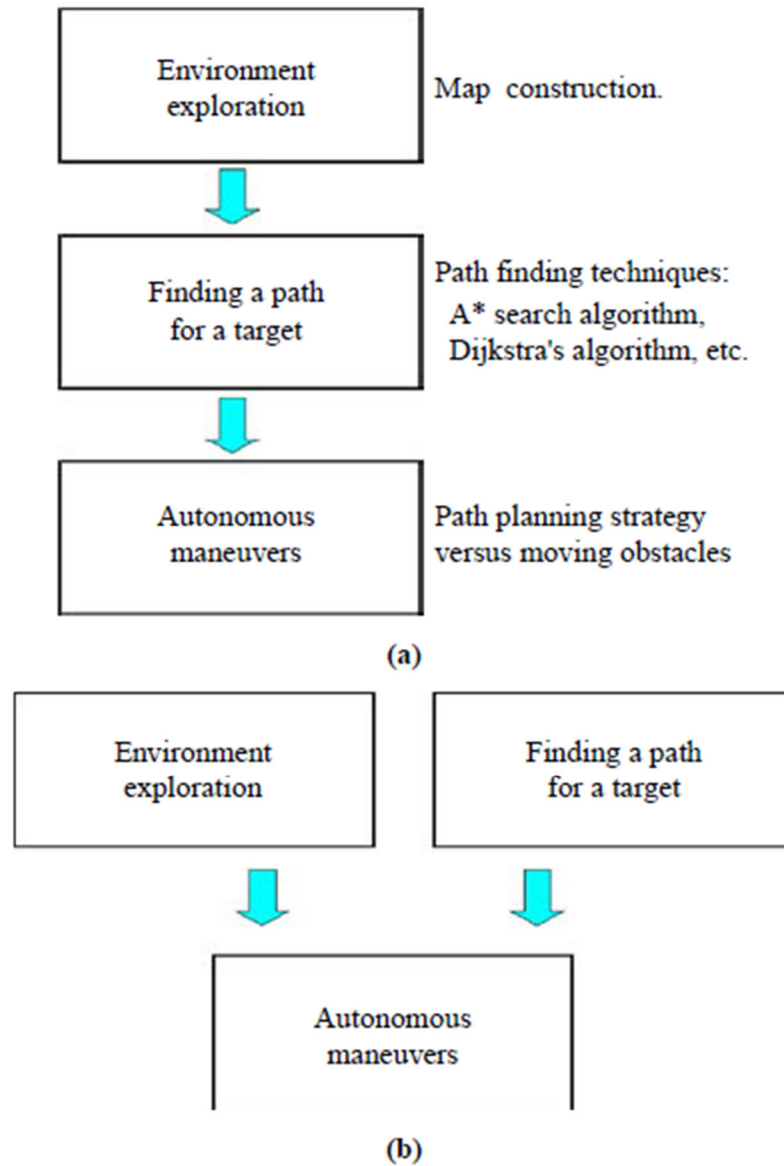
n. Element 8[pre]

To the extent the preamble is limiting, the Yamamoto/Khatib combination discloses this limitation for the reasons explained for elements 1[pre], 1[a], 1[b][1]. IV.C.2.a-b, d. Ex1003, ¶¶228-229.

o. Element 8[a]

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶230. *See supra* elements 1[a], 1[b][1], 1[b][2], 3. IV.C.2.b, d-e, g.

Yamamoto Figure 1 (shown below) discloses determining a path (route) in the map for the robot to travel, “Finding a path for a target.” *Id.*

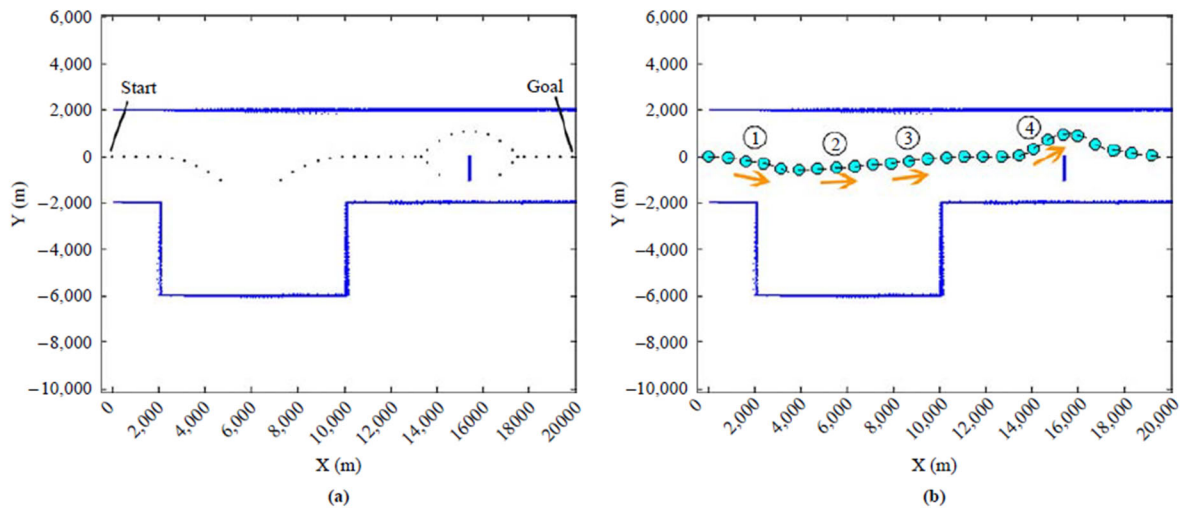


Ex1010, Fig. 1.

Figure 15 (shown below) depicts the determined route traveled by the robot.

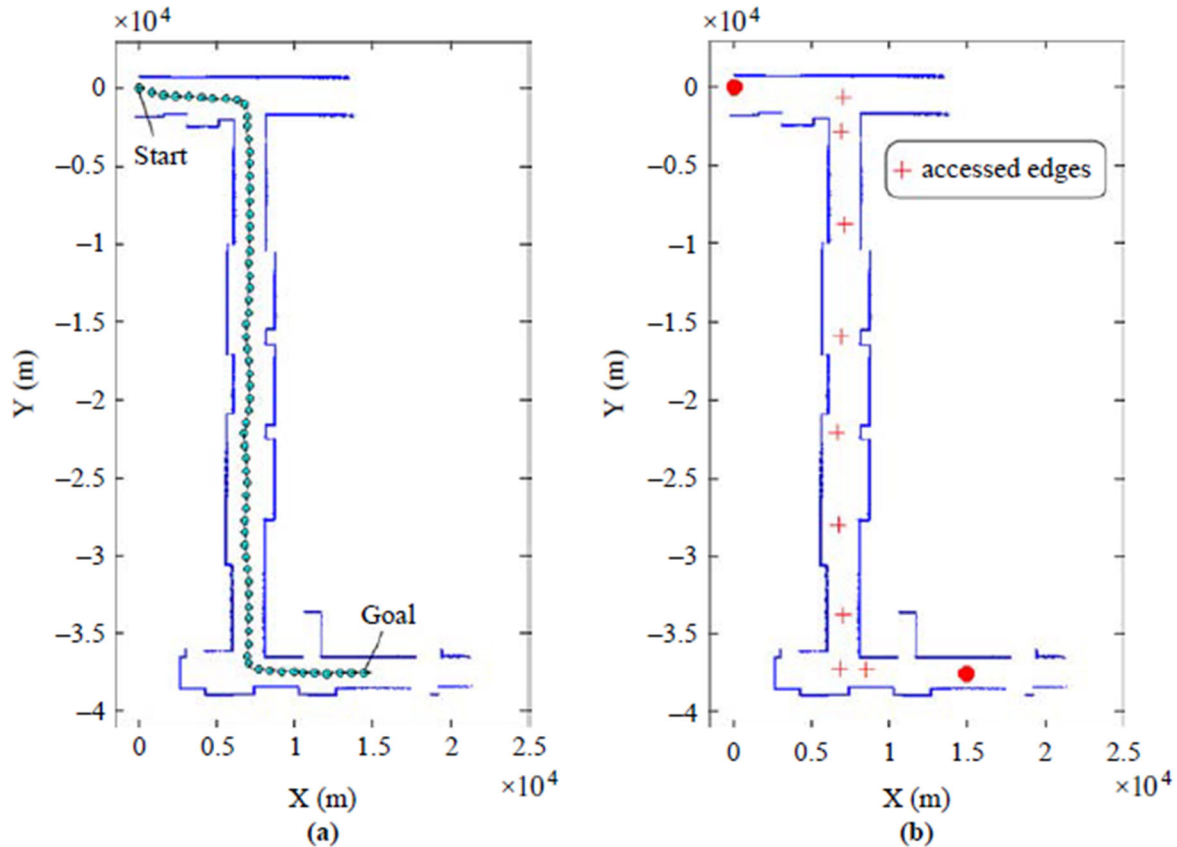
Ex1003, ¶231.

Figure 15 Approximate Voronoi diagram defined by constraints: (a) approximate Voronoi diagram; (b) motion of mobile robot



Ex1010, Fig. 15.

Yamamoto Figure 18 (shown below) similarly depicts the determined route in the map in which the robot will travel. Ex1003, ¶232.



Ex1010, Fig. 18.

p. Element 8[b]

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶233.

See element 1[b][2]. IV.C.2.e.

q. Claim 9

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶234.

See *supra* elements 1[b][2], claim 2. IV.C.2.e-f.

r. Claim 10

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶235.

See *supra* claim 3. IV.C.2.g.

s. Element 11[a]

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶¶236-237. *See supra* element 4[a]. IV.C.2.h.

t. Element 11[b]

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶238. *See supra* elements 1[b][2], 4[b]. IV.C.2.e, i.

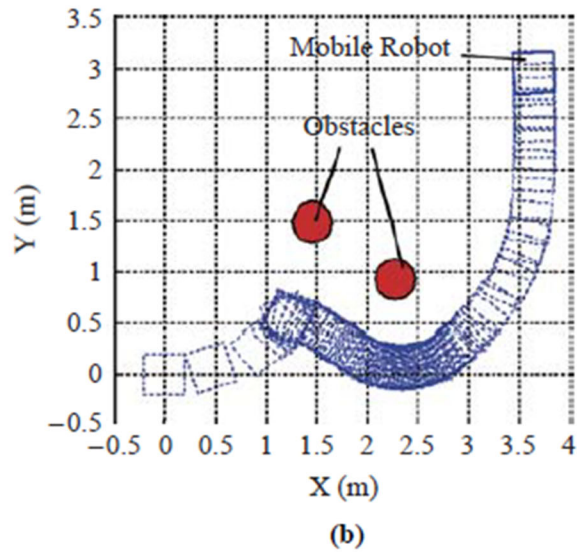
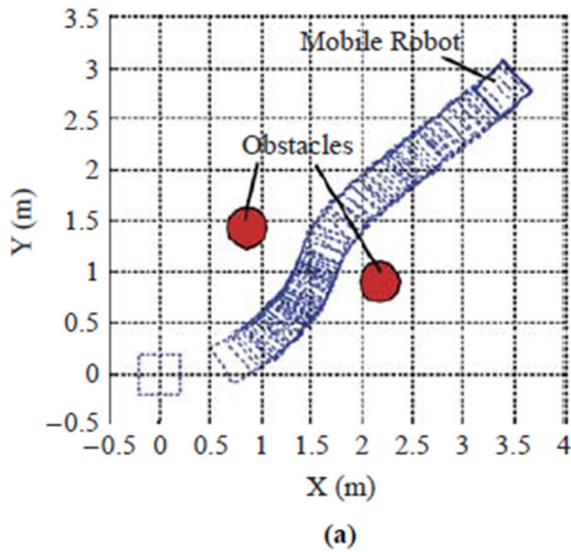
u. Element 11[c]

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶239. *See supra* elements 1[b][2], 4[c]. IV.C.2.e, j.

v. Claim 12

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶240. *See supra* elements 1[b][2], 8[b], claim 5. IV.C.2.e, p, k.

Yamamoto discloses that the plurality of points of the respective pose configured to experience the repulsive force are capable of translating and rotating in response to repositioning of the respective pose as depicted in Figure 24(b), which shows the “shows the results of applying our technique in different deadlock conditions.” Ex1010, 433; Ex1003, ¶240.



Ex1010, Fig. 24 (illustrating “translating and rotating the first route pose” between $X=1$ and 1.5); Ex1003, ¶240.

w. Claim 13

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶241.

See supra claims 6-7. IV.C.2.1-m.

x. Element 14[pre]

The Yamamoto/Khatib combination discloses this limitation. Ex1003,

¶¶242-243. *See supra* element 1[b]. IV.C.2.c.

y. Element 14[a]

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶244.

See supra elements 8[pre], 8[a]. IV.C.2.n-o.

z. Element 14[b]

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶245.

See supra elements 1[b][2], 8[b]. IV.C.2.e, p.

aa. Claim 15

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶246.

See supra elements 1[b], 14[pre], claim 2. IV.C.2.c, x, f.

bb. Claim 16

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶247.

See supra elements 1[b], 14[pre], claims 3, 10. IV.C.2.c, g, r, x.

cc. Element 17[a]

The Yamamoto/Khatib combination discloses this limitation. Ex1003,

¶¶248-249. *See supra* elements 1[b], 4[a], 14[pre]. IV.C.2.c, h, x.

dd. Element 17[b]

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶250.

See supra elements 1[b][2], 4[b]. IV.C.2.e, i.

ee. Element 17[c]

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶251.

See supra elements 1[b][2], 4[c]. IV.C.2.e, j.

ff. Claim 18

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶252.

See supra elements 1[b], 1[b][2], 14[pre], claims 5, 7. IV.C.2.c, e, k-m. x.

gg. Claim 19

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶253.

See supra elements 1[b], 14[pre], claim 6. IV.C.2.c, l, x.

hh. Claim 20

The Yamamoto/Khatib combination discloses this limitation. Ex1003, ¶254.

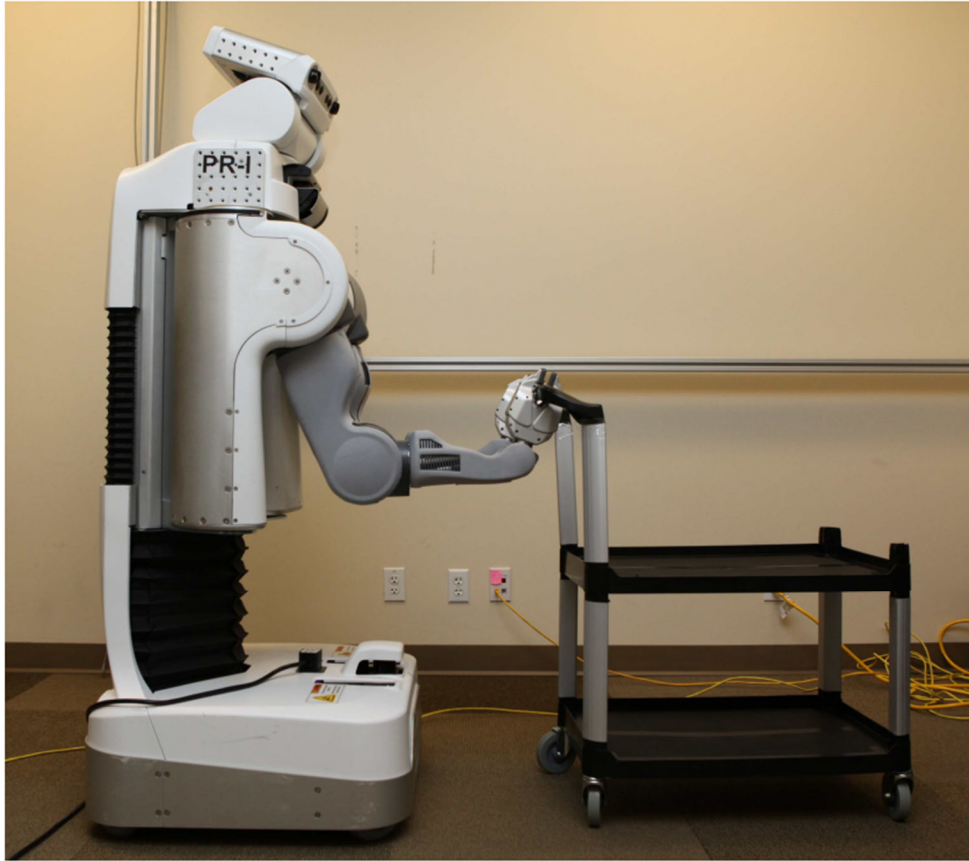
See supra elements 1[b], 1[b][2], 14[pre], claim 7. IV.C.2.c, e, m, x.

D. Ground 4: Beardsley in view of Castellanos, and Scholz Render Obvious Claims 3, 10, 16

1. Overview of Ground and Prior Art

a. Summary of Scholz

Scholz discloses a method for a “PR2 mobile manipulation robot” to achieve “safer navigation in the presence of dynamic obstacles” “especially in cluttered, crowded environments where the amount of space is limited” such as a “typical office environment.” Ex1015, 6115; *Id.* Fig. 1. Scholz discloses “planning, control, and sensing for navigation with moveable objects.” *Id.*, 6115. Scholz teaches an “anytime planner for generating near-optimal plans given a set of motion primitives that can drive [a] robot” and “a local controller which . . . is responsible for both following the plan and avoiding static and dynamic obstacles observed by sensors.”



Id., Fig. 1.

Scholz uses a “2D map of the environment . . . built [] from real sensor data using tools available in the ROS framework.” Scholz takes “sensor readings that may correspond to points on the cart or the robot, and those from points in the environment. Sensor readings corresponding to points on the cart are filtered out directly from a 2D costmap representation (Figure 3) of the collision environment if their 2D projection falls within the known polygonal footprint of the cart.” *Id.*, 6116. Scholz utilizes motion primitives to enable simultaneous navigation and articulation in motion planning. *Id.*, 6117. Ex1003, ¶56. Scholz further uses motion primitives

to check for collisions across projected footprints and to evaluate cost. *Id.*, 6117-6118. Ex1003, ¶56. Scholz teaches that primitives can also be used to reduce footprint size for tight turns. *Id.*, 6119. Ex1003, ¶56.

b. Motivation to Combine Beardsley, Castellanos, and Scholz

In addition to the reasons for combining Beardsley and Castellanos discussed above (*see supra* § IV.A.1.c), a POSITA would have been further motivated to combine those teachings with Scholz. Ex1003, ¶255. Scholz more accurately models the shape and projected motion of a robot than Beardsley, which is particularly advantageous in “cluttered” spaces such as those that might be traversed by a cleaning robot. Ex1015, 6115; Ex1003, ¶255. A more accurately modeled robot and greater articulation in projected motion for an autonomous mobile robot is also advantageous for larger robots, such as may be used in an industrial setting. Ex1015, 6115; Ex1003, ¶255. The additional detail in robot modeling and motion projection is also advantageous should a cleaning robot need to use an external implement, such as a floor cleaner, or ferry an external object, such as cleaning supplies. Ex1001, 2:37. Ex1015, 6115, Fig. 1, Fig. 4; Ex1003, ¶255.

2. Detailed Analysis of Ground 4

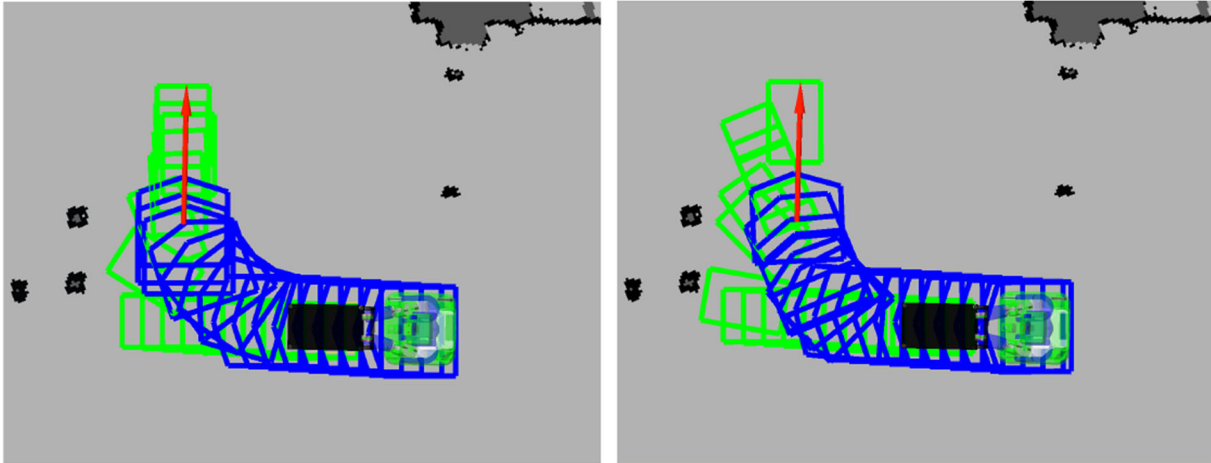
a. Claim 3

To the extent the Board finds that the Beardsley/Castellanos combination does not teach Claim 3, which depends from Claim 1, the Beardsley/Castellanos/Scholz combination teaches this limitation. *See supra* §§ IV.D.2.a-b, d; Ex1003, ¶256.

Scholz discloses dynamically reshaping the size of the robot footprint by reducing footprint size on turns. Ex1015, 6117 (“it reduces the dimensionality of the search space for planning while still retaining enough flexibility to allow the articulation needed to execute tight turns.”); *Id.*, 6119 (“The addition of the articulated primitives clearly helped the robot traverse tight corridors, made the plans look much more natural, and reduced the total footprint of the robot as it was making turns.”); Ex1003, ¶257.

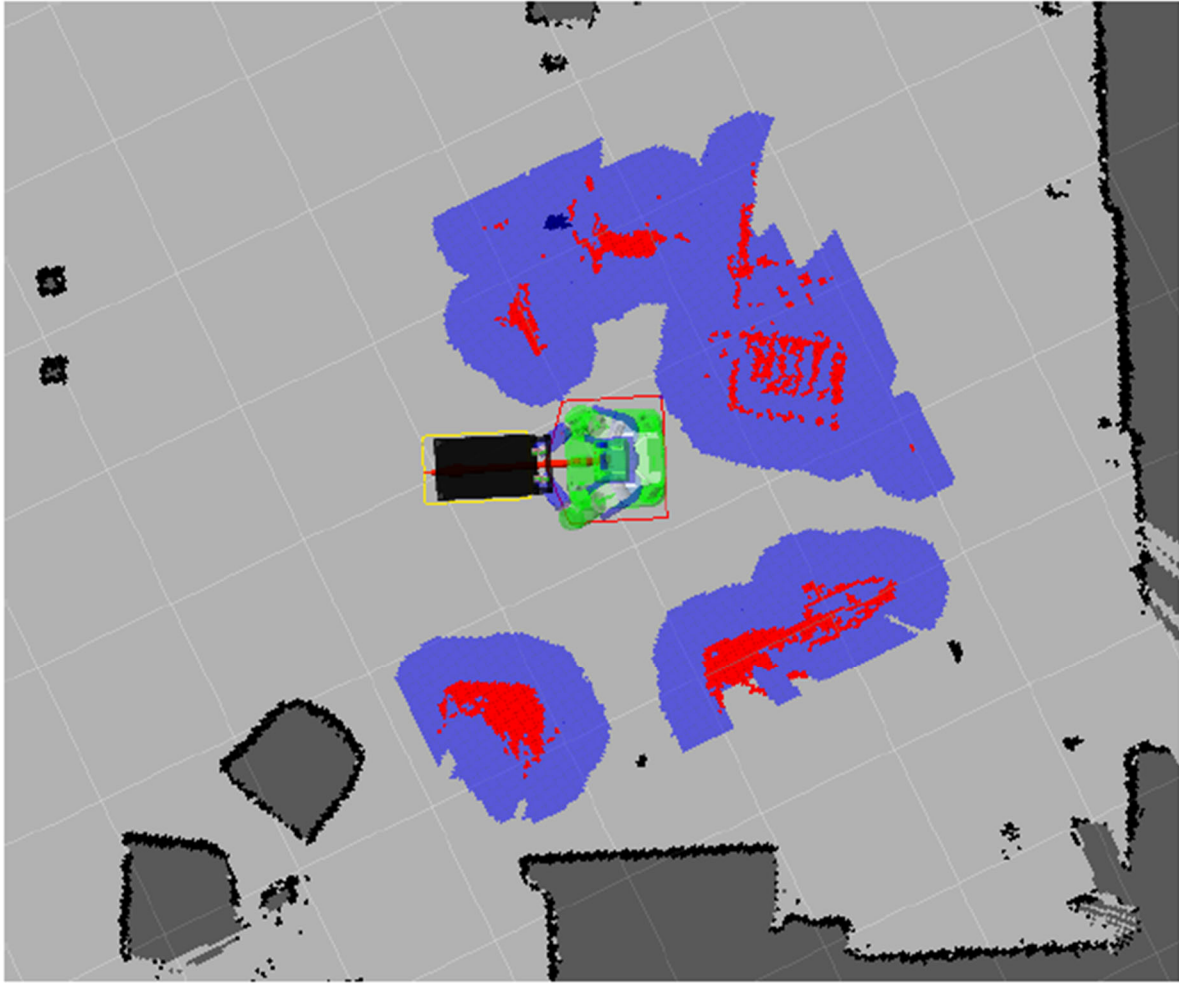
Scholz also discloses the robot’s motion may be modeled both with and without the use of primitives, where electing not to use primitives results in a larger footprint. See Ex1015, Fig. 8 (“The overall footprint of the robot when using articulated primitives is much smaller (left) than when it is not using them (right).”). A POSITA would have understood it would have been desirable to use primitives to model motion during turns where a constrained operational space may not afford the ability to use a larger footprint, which may otherwise provide a greater margin of

error to safeguard against collision but in a constrained space may hinder a mobile robot's movement. *Id.*, Ex1003, ¶257.

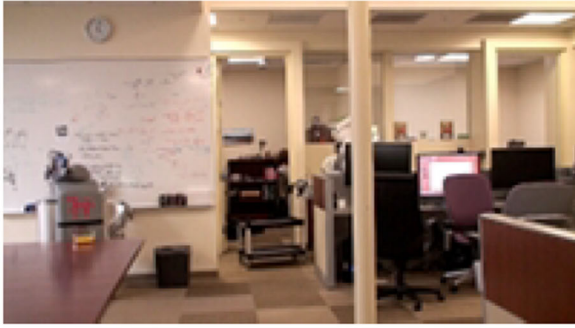


Ex1015, Fig. 8.

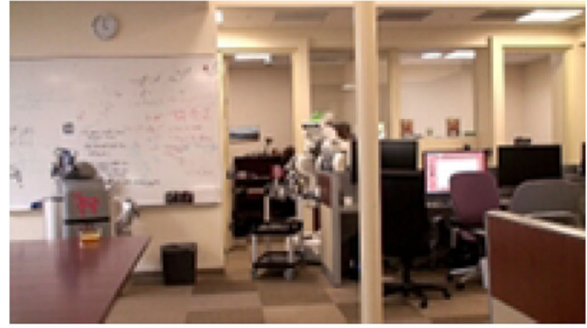
Scholz acknowledges collision risk depends on footprint size and depicts this reality in Fig. 3. Ex1015, Fig. 3, categorizing space surrounding obstacles as either “lethal” (smaller footprint) or within a threshold distance (larger footprint. A POSITA would have understood that large robot footprints have a low likelihood of collision and small robot footprints have a higher likelihood of collision. Ex1003, ¶258.



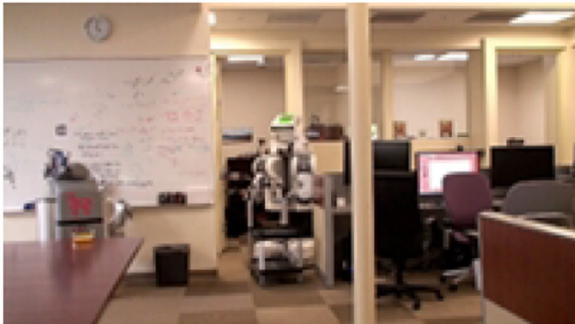
Ex1015, Fig. 3.



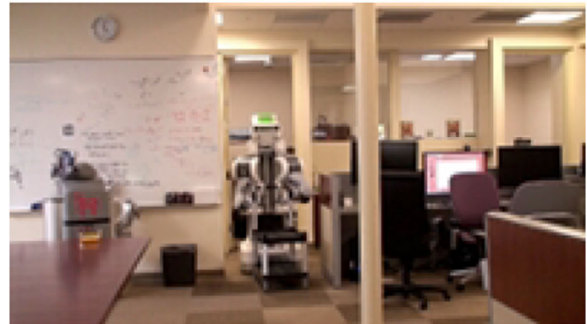
(a)



(b)



(c)



(d)

Ex1015, Fig. 6 (“Articulating the cart to execute a tight turn.”).

b. Claim 10

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Scholz combination teaches it for the same reasons as Claim 3. *See supra* § IV.D.2.a; Ex1003, ¶259.

c. Claim 16

To the extent the Board finds that the Beardsley/Castellanos combination does not teach this element, the Beardsley/Castellanos/Scholz combination teaches it for the same reasons as Claim 3. *See supra* § IV.D.2.a; Ex1003, ¶260.

V. ENABLEMENT AND SECONDARY CONSIDERATIONS

The prior art references relied upon in this Petition are enabled.

In parallel litigation, Patent Owner asserted that this patent (along with four other patents) generally solves a long-felt need, allowing it to become an industry leader in autonomous robots and artificial intelligence. It identified a number of awards and recognition in the industry and alleged that its products achieved commercial success and industry recognition. Further, it alleges that Petitioners willfully infringed the asserted patents and copied Patent Owner's technology. Ex1014, 11–14. Petitioners deny the allegations.

Patent Owner's vague allegations on long-felt need, commercial success, industry recognition, and copying are untethered to the specific claims at issue in the Challenged Patent. Patent Owner establishes no nexus between the claims and any of the alleged secondary indicia of non-obviousness. Ex1003, ¶¶261-262. Petitioners disagree that these are evidence of secondary considerations of non-obviousness tied to the Challenged Claims. To the extent Patent Owner alleges that any secondary considerations of non-obviousness are tied to the Challenged Claims, Petitioners may address such allegations in its reply. Where, as here, there is a strong showing of obviousness, the Federal Circuit has held that even relevant secondary considerations supported by substantial evidence do not dislodge the primary conclusion of obviousness. *Ohio Willow*, 735 F.3d at 1344.

VI. CONCLUSION

There is a reasonable likelihood that the Challenged Claims are unpatentable. Petitioners respectfully request that IPR be instituted and that all Challenged Claims be found unpatentable.

DATED: December 1, 2025

Respectfully Submitted,

/Brian M. Buroker/

Brian M. Buroker (Reg. No. 39,125)
GIBSON, DUNN & CRUTCHER LLP
1700 M St., N.W
Washington, DC 20036
Phone: (202) 955-8500
Fax: (202) 467-0539
Email: bburoker@gibsondunn.com

*Attorney for Petitioners Avidbots Corp. and
Avidbots USA Corp.*

CERTIFICATION UNDER 37 C.F.R. § 42.24(d)

Under the provisions of 37 C.F.R. § 42.24(d), the undersigned attorney hereby certifies that the word count for Sections I–VII of the foregoing Petition for *Inter Partes* Review is 13,918 according to the word count tool in Microsoft Word.

DATED: December 1, 2025

By: /Brian M. Buroker/

Brian M. Buroker (Reg. No. 39,125)
GIBSON, DUNN & CRUTCHER LLP
1700 M St., N.W
Washington, DC 20036
Phone: (202) 955-8500
Fax: (202) 467-0539
Email: bburoker@gibsondunn.com

*Attorney for Petitioners Avidbots Corp. and
Avidbots USA Corp.*

CERTIFICATE OF SERVICE

The undersigned certifies service pursuant to 37 C.F.R. §§ 42.6(e) and 42.105(a), (b) on the Patent Owner via FedEx overnight mail of a copy of this Petition for *Inter Partes* Review and supporting materials at the Patent Owner at the correspondence address of record for the '539 Patent:

197519 - Pierson Ferdinand, LLP
1101 Pennsylvania Avenue N.W., Suite 300
Washington, DC 20005
United States

A courtesy copy was also sent via electronic mail to Patent Owner's litigation counsel at the following addresses:

Daniel P. Hughe
Daniel.Hughes@knobbe.com
Adam B. Powell
Adam.Powell@knobbe.com
Sheila N. Swaroop
Sheila.Swaroop@knobbe.com
Marko R. Zoretic
Marko.Zoretic@knobbe.com
Kendall M. Loebbaka
Kendall.Loebbaka@knobbe.com

Kevin Tottis
KTottis@tottislaw.com
Keith Stoltz
KStoltz@tottislaw.com

TOTTISLAW

KNOBBE, MARTENS, OLSON & BEAR, LLP

DATED: December 1, 2025

/Brian M. Buroker/

Brian M. Buroker (Reg. No. 39,125)
GIBSON, DUNN & CRUTCHER LLP
1700 M St., N.W
Washington, DC 20036
Phone: (202) 955-8500
Fax: (202) 467-0539
Email: bburoker@gibsondunn.com

*Attorney for Petitioners Avidbots Corp. and
Avidbots USA Corp.*

APPENDIX: CHALLENGED CLAIM LISTING

No.	Limitation
1[pre]	A robot for maneuvering along a route, comprising:
1[a]	one or more sensors coupled to the robot, the one or more sensors configured to collect data about an environment proximate to the robot including detected points on one or more objects in the environment; and
1[b]	a controller configured to execute computer readable instructions to,
1[b][1]	determine a route on a map for the robot to travel, the map corresponding to the environment and being generated by at least one or more sensors coupled to the robot, the route including a plurality of points such that a first point being discretized than a second point, each of the plurality of points corresponding to a respective pose of the robot, the respective pose of the robot including a plurality of points disposed therein, the respective pose corresponding to at least one of position and orientation of the robot, and
1[b][2]	compute repulsive forces from a point on an object onto the plurality of points of the respective pose, the object being on the map.
2	The robot of claim 1, wherein the respective pose of the robot and a subsequent respective pose of the robot being regularly or irregularly spaced apart from each other on the route such that the respective pose and the subsequent respective pose form a sequence along the route.
3	The robot of claim 1, wherein the respective pose corresponds to a footprint of the robot, the footprint configured to be adjustable between a small footprint and a large footprint, the small footprint having a high likelihood of collision with the object, and the large footprint having a low likelihood of collision with the object, the footprint of the robot configured to be dynamically reshaped.
4[a]	The robot of claim 1, wherein, the repulsive forces from the point on the object prevent the robot from colliding with the object,
4[b]	the repulsive forces from the object is uniform on the respective pose,
4[c]	and the repulsive forces is dependent on characteristics of where the object is positioned relative to the respective pose.

No.	Limitation
5	The robot of claim 1, wherein the plurality of points of the respective pose configured to experience the repulsive forces, the plurality of points capable of translating and rotating in response to repositioning of the respective pose.
6	The robot of claim 1, wherein the controller is further configured to execute the computer readable instructions to, perform interpolation between the respective pose and a subsequent respective route pose to generate a collision-free route between the respective pose and the subsequent respective route pose for the robot to travel.
7	The robot of claim 1, wherein the controller is further configured to execute the computer readable instructions to, reposition the respective pose and a subsequent respective pose in response to the repulsive forces on each point of the plurality of points.
8[pre]	A method for dynamic navigation and route planning of a robot in an environment, comprising:
8[a]	determining a route on a map for the robot, the route including one or more route poses, each route pose comprising a footprint indicative at least in part of a pose and a shape of the robot along the route and each route pose having a plurality of points disposed therein, the map corresponding to an environment and being generated by at least one sensor on the robot, the route including a plurality of points such that a first point being discretized than a second point, each of the plurality of points corresponding to a respective pose of the robot, the respective pose of the robot including a plurality of points disposed therein, the respective pose corresponding to at least one of position and orientation of the robot; and
8[b]	computing repulsive forces from a point on an object in the environment onto the plurality of points of a first route pose of the one or more route poses.
9	The method of claim 8, wherein the respective pose of the robot and a subsequent respective pose of the robot being regularly or irregularly spaced apart from each other on the route such that the respective pose and the subsequent respective pose form a sequence along the route.

No.	Limitation
10	The method of claim 8, wherein the respective pose corresponds to a footprint of the robot, the footprint configured to be adjustable between a small footprint and a large footprint, the small footprint having a high likelihood of collision with the object, and the large footprint having a low likelihood of collision with the object, the footprint of the robot configured to be dynamically reshaped.
11[a]	The method of claim 8, wherein, the repulsive forces from the point on the object prevent the robot from colliding with the object,
11[b]	the repulsive forces from the object is uniform on the respective pose, and
11[c]	the repulsive forces is dependent on characteristics of where the object is positioned relative to the respective pose.
12	The method of claim 8, wherein the plurality of points of the respective pose configured to experience the repulsive forces, the plurality of points capable of translating and rotating in response to repositioning of the respective pose.
13	The method of claim 8, further comprising: performing interpolation between the respective pose and a subsequent respective route pose to generate a collision-free route between the respective pose and the subsequent respective route pose for the robot to travel.
14[pre]	A non-transitory computer-readable storage apparatus having a plurality of instructions stored thereon, that when executed by at least one processor configure the at last one processor to:
14[a]	determine a route on a map for a robot, the route comprising one or more route poses, each route pose comprising a footprint indicative at least in part of a pose and a shape of the robot along the route and each route pose having a plurality of points disposed therein, the map corresponding to the environment and being generated by at least one sensor on the robot, the route including a plurality of points such that a first point being discretized than a second point, each of the plurality of points corresponding to a respective pose of the robot, the respective pose of the robot including a plurality of points disposed therein, the respective pose corresponding to at least one of position and orientation of the robot; and

No.	Limitation
14[b]	compute repulsive forces from a point on an object in the environment onto the plurality of points of a first route pose of the one or more route poses.
15	The non-transitory computer readable medium of claim 14, wherein the respective pose of the robot and a subsequent respective pose of the robot being regularly or irregularly spaced apart from each other on the route such that the respective pose and the subsequent respective pose form a sequence along the route.
16	The non-transitory computer readable medium of claim 14, wherein the respective pose corresponds to a footprint of the robot, the footprint configured to be adjustable between a small footprint and a large footprint, the small footprint having a high likelihood of collision with the object, and the large footprint having a low likelihood of collision with the object, the footprint of the robot configured to be dynamically reshaped.
17[a]	The non-transitory computer readable medium of claim 14, wherein, the repulsive forces from the point on the object prevent the robot from colliding with the object,
17[b]	the repulsive forces from the object is uniform on the respective pose, and
17[c]	the repulsive forces is dependent on characteristics of where the object is positioned relative to the respective pose.
18	The non-transitory computer readable medium of claim 14, wherein the plurality of points of the respective pose configured to experience the repulsive forces, the plurality of points capable of translating and rotating in response to repositioning of the respective pose.
19	The non-transitory computer readable medium of claim 14, wherein the at least one processor is further configured to execute the computer readable instructions to, perform interpolation between the respective pose and a subsequent respective route pose to generate a collision-free route between the respective pose and the subsequent respective route pose for the robot to travel.

No.	Limitation
20	The non-transitory computer readable medium of claim 14, wherein the at least one processor is further configured to execute the computer readable instructions to, reposition the respective pose and a subsequent respective pose in response to the repulsive forces on each point of the plurality of points.