

Patent landscape

Search strategy

To find relevant patents we started by writing a list of relevant descriptive words related to subsystems we will be producing for our project. Once a list was written, we created a table of search results for each word individually and combinations of these words. The word lists can be found at the bottom of this document. As we are only interested in patents from Europe, USA and Great Britain, we limited our search to these patent offices. We used google patents to conduct our search. We found that often when we had narrowed our searches down to less than 50 results, many of the results were very unrelated to our project, this appears to be due to results being shown which did not necessarily contain every search term, even with double quotes to ensure exact words/phases were searched . To ensure we only analysed searches with some relevance to our system/subsystems, at every stage of searching we checked first few pages of results for patents that seemed relevant or shared some similarity to our system.

Search terms gripper	Results	Search terms base	Results
Hand	313,488	Base	273,673
Gripper	29,577	Platform	236,788
Manipulator	18,610	Chassis	98,166
End effector	5,440	Unmanned ground vehicle	1,489
Robot	83,419	UGV	6,703
Compliant	97,847	Robot	118,511
Festo	1,987	Lidar	3,779
Soft	278,645	Slam	2,449
Actuated	285,444	"Simultaneous localisation and mapping"	135
Universal	213,084	Localising	65,675
Adaptive	182,477	Autonomous	90,924
Fin ray	168	Mapping	152,665
Robot gripper	7,564	Self localising	2,652
Compliant gripper	2,883	Mobile	214,696
Soft gripper	55,801	Wheeled	249,175
Festo gripper	275	Slam base	3,536

Universal gripper	8,793		Localising base	13,063
Actuated gripper	71,372		Lidar base	979
Active gripper	12,606		Autonomous base	42,621
Fin ray gripper	1,271		Mapping base	106,259
Robot manipulator	8,144		Self localising base	1,355
Compliant manipulator	3,374		“Simultaneous localisation and mapping” base	116
Soft manipulator	2,073		Lidar platform	12,606
Festo manipulator	94		Slam platform	1,458
Universal manipulator	7,155		Localising platform	6,397
Active manipulator	1,703		Autonomous platform	8,144
Actuated manipulator	3,757		Self localising platform	1,883
Robot hand	28,044		Mapping platform	2,073
Compliant hand	46,301		“Simultaneous localisation and mapping” platform	32
Soft hand	108,061		Lidar robot	145
Festo hand	400		Slam robot	117
Active hand	104,918		Localising robot	200
Universal hand	65,065		Autonomous robot	927
Actuated hand	111,785		Self localising robot	92
Fin ray hand	1,983		Mapping robot	1,935
(Hand or gripper or manipulator) and (soft or compliant) and (active or actuated)	83510		“Simultaneous localisation and mapping” robot	70
(gripper or end effector) and (soft or compliant or variable stiffness) and actuated and (festo or fin ray)	278		Autonomous wheeled mobile lidar slam (platform or base or robot)	20
(gripper or end effector) and (soft or compliant) and (active or actuated) and robot and (festo or fin ray)	212			
(gripper or end effector) and (soft or compliant) and (active or actuated) and universal and robot and (festo or fin ray)	55			

Search terms for full system	Results
Lidar	3,779
Slam	2,449
Localising	65,675
Autonomous	90,924
Mapping	152,665
Mobile	214,696
Wheeled	249,175
Arm	308,913
Robot	155,342
Robot arm	16,585
Slam robot	2,221
Autonomous robot	3,271
Lidar slam robot	257
Mobile Lidar slam robot arm	59
Wheeled mobile lidar slam robot arm	15

Patent analysis

Patent info:

Patent title	Manipulator tool and holding and/or expanding tool with at least one manipulator tool
patent code	US20100263500A1
patent status	Granted

Priority date	2012-03-01
countries patent is active in	USA
threat to project	3.5/5
url	https://patents.google.com/patent/US20100263500A1/en?inventor=Leif+Kniese

Abstract

One or more embodiments of a flexible manipulator tools are provided. The flexible manipulator tool can include a distal end movable in at least one manipulation plane with respect to a proximal end. The flexible manipulator tool can also include at least two cheeks extending side by side to and spaced apart from each other.

Summary

A compliant gripper/manipulator whose tip can be actuated in at least one axis, with optional wings to increase the surface area of manipulation.

Claims

1. A flexible manipulator tool comprising:

a. a distal end movable in at least one manipulation plane with respect to a proximal end; and
b. at least two cheeks extending side by side to and spaced apart from each other, wherein the cheeks are flexible at least in the manipulation plane and extend from the proximal end to the distal end, wherein the cheeks are connected between the proximal end and the distal end by at least one at least tension-proof hinge element to permit a shearing movement relative to each other, wherein the cheeks are held at the proximal end at a distance from each other, wherein the one cheek is configured to be at least flexurally stiff and the other cheek to be at least tension-proof, and wherein the at least tension-proof cheek is connected at its distal end to the at least flexurally stiff cheek so as to transmit a pulling force, characterized in that one cheek is embodied to be driven at the proximal end in the longitudinal direction.

18. A holding tool comprising at least two jaws opposite one another with respect to a space, wherein at least one jaw is movable with respect to the other jaw, and wherein at least one jaw is formed by a manipulator tool, and wherein the manipulator tool comprises:

a. a distal end movable in at least one manipulation plane with respect to a proximal end; and
b. at least two cheeks extending side by side to and spaced apart from each other, wherein the cheeks are flexible at least in the manipulation plane and extend from the proximal end to the distal end, wherein the cheeks are connected between the proximal end and the distal end by at least one at least tension-proof hinge element to permit a shearing movement relative to each other, wherein the cheeks are held at the proximal end at a distance from each other, wherein the one cheek is configured to be at least flexurally stiff and the other cheek to be at least tension-proof, and wherein the at least tension-proof cheek is connected at its distal end to the at least flexurally stiff cheek so as

to transmit a pulling force, characterized in that one cheek is embodied to be driven at the proximal end in the longitudinal direction.

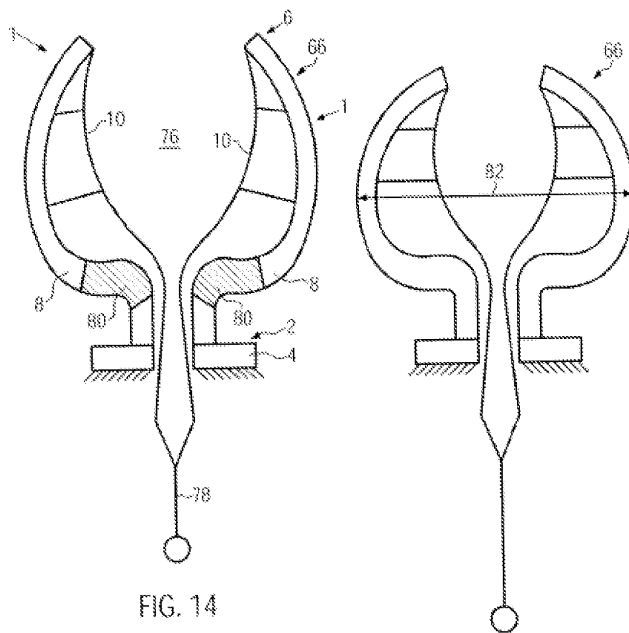


FIG. 14

FIG. 15

Interpretation:

A flexible manipulator tool. The tip has to move in one or more planes. Cheeks (inner and outer surfaces of the gripper) are flexible. Cheeks Extend from base to tip of each 'finger'. Tension-proof hinge elements are the struts inside the finger. Driven by the inside cheek being pulled down (relative to the image above). Then many potential adaptations of this design (such as tool-holders at the tip, **varying stiffness cheeks**, different sized cheeks, more than two cheeks, open ended finger-tips, etc...).

Threats

Very similar to our proposed fingers (based on the same finray effect (registered trademark)). From what we can tell, this device is actuated by pulling the inside cheek down into the palm, whereas our device has each cheek equally flexible cheeks and is symmetrical. Our fingers are actuated by pushing the finger into the object to be gripped. Our fingers cannot flex unless there is an object to be gripped. Also, this patent is only in the US.

Constraints on project

We will have to be careful to not have a mechanical means of flexing our fingers without having an object to grasp. If we can actuate our cheek(s) individually then we have infringed on the above patent.

Patent info:

Patent title	Mobile inspection robot
patent code	US20130231779A1
patent status	Granted
Priority date	2012-03-01
countries patent is active in	USA
threat to project	2.5/5
url	https://patents.google.com/patent/US20130231779A1/en?q=%22autonomous%22&q=%22slam%22&q=%22robot%22&q=%22navigation%22&q=%22lidar%22&q=%22mobile%22&q=%22arm%22

Abstract:

A mobile inspection robot that includes a robot body and a drive system supporting the robot body and configured to maneuver the robot over a work surface. A controller communicates with the drive system and a sensor system. The controller executes a control system that includes a control arbitration system and a behavior system in communication with each other. The behavior system executes an inspection behavior, the inspection behavior influencing execution of commands by the control arbitration system based on sensor signals received from the sensor system to identify and inspect electrical equipment.

Independent claims

1. A mobile inspection robot comprising:

- a robot body;
- a drive system supporting the robot body and configured to maneuver the robot over a work surface;
- a controller in communication with the drive system and executing a control system; and
- a sensor system in communication with the controller;

wherein the control system comprises a control arbitration system and a behavior system in communication with each other, the behavior system executing an inspection behavior, the

inspection behavior influencing execution of commands by the control arbitration system based on sensor signals received from the sensor system to identify and inspect electrical equipment.

2. A method of operating a mobile robot, the method comprising:

- driving the robot according to a drive command;
- maneuvering the robot adjacent electrical equipment; and
- obtaining a local sensory perception of the electrical equipment using a sensor system of the robot.

3. A mobile inspection robot comprising:

- a robot body;
- a drive system supporting the robot body and configured to maneuver the robot over a work surface;
- a controller in communication with the drive system;
- a mast disposed on the robot body and arranged substantially vertical with respect to the work surface;
- at least one scanner payload disposed on the mast and monitoring environmental parameters about the robot.

4. A method of monitoring environmental parameters, the method comprising:

- receiving sensor data from a mobile inspection robot;
- processing the received sensor data on a computing processor;
- electronically displaying a model of an environment about the robot; and
- electronically displaying the processed sensor data.

Interpretation

An autonomous inspection robot build to identify and inspect electrical equipment

Threat

Level of infringement

Claim 1: Not infringed, claim specifically states identifying and inspecting electrical equipment.

Claim 2: Not infringed, claim specifies navigating robot adjacent to electrical equipment and obtaining a sensory perception of the equipment

Claim 3: May be infringed, we will be using a camera on a mast, this may be considered a scanner although it cannot collect environmental parameters. We will be using a lidar to collect environmental parameters however it will not be on the mast

Claim 4: Infringed, we will be processing environmental sensor data, displaying a model of our surroundings and displaying the processed sensor data.

Enforceability

Claim 1: Not infringed

Claim 2: Not infringed

Claim 3: Low, scanner and environmental parameters are very vague descriptions.

Claim 4: Very low, the vast majority of autonomous robots receive environmental data from sensors, process the data and use this data to model the robots surroundings, this model and processed data is also usually displayed electronically

Constraints on project

Should claims 3 and 4 be enforceable, it is possible to circumvent them. Claim 4 can be circumvented by adapting the frame for the camera such that it is not considered a mast. For claim 3, in our system it is not absolutely necessary to display an environmental model or processed data.

Patent info:

Patent title	Autonomous personal service robot
patent code	US7228203B2
patent status	Granted
Priority date	2004-03-27
countries patent is active in	US,EP,WO
threat to project	0/5
url	https://patents.google.com/patent/US7228203B2/en?q=%22autonomous%22&q=%22slam%22&q=%22robot%22&q=%22navigation%22&q=%22lidar%22&q=%22mobile%22&q=%22arm%22

Abstract:

Autonomous personal service robot to monitor its owner for symptoms of distress and provide assistance. The system may include sensors to detect situations before they affect people such as smoke, heat, temperature and carbon monoxide sensors. The system can provide security for the home. The PRA may comprise features such as a medicine dispenser and blood pressure cuff. Features such as broadband internet, MP3 player, reading lights and eye glass tracker provide butler type capabilities that enable the system to appeal to markets beyond the elderly and infirmed. The system may also include an X10 transmitter/receiver to automatically control various household lights and appliances. Equipping the system with a robot arm enables the robot to fetch items, turn on and off wall switches and open the refrigerator.

Independent claims

1. An autonomous personal service robot comprising:

- a frame;
- a drive system coupled with said frame and configured to move said frame;
- at least one camera coupled with said frame;
- a processor coupled with said frame and configured to operate said drive system to move said at least one camera coupled with said frame to dynamically map an environment, said processor further configured to identify a person, track said person and change position of said frame in said environment to monitor said person using at least one image obtained from said at least one camera and wherein said processor is further configured to determine if an out-of-ordinary event has occurred;
- a video screen interface coupled with said processor;
- an audio interface coupled with said processor; and,
- said processor further configured to respond to emergency cries from said person obtained from said audio interface.

2. An autonomous personal service robot comprising:

- a frame;
- a drive system coupled with said frame and configured to move said frame;
- at least one camera coupled with said frame;
- a processor coupled with said frame and configured to operate said drive system to move said at least one camera coupled with said frame to dynamically map an environment, said processor further configured to identify a person, track said person and change position of said frame in said environment to monitor said person using at least one image obtained from said at least one camera and wherein said processor is further configured to determine if an out-of-ordinary event has occurred;
- a medical dispenser coupled with said autonomous personal service robot and configured to dispense medication at programmable intervals; and,

said processor further configured to alert a second person if said medication is not utilized by said person.

3. An autonomous personal service robot comprising:

a frame;

a drive system coupled with said frame and configured to move said frame;

at least one camera coupled with said frame;

a processor coupled with said frame and configured to operate said drive system to move said at least one camera coupled with said frame to dynamically map an environment, said processor further configured to identify a person, track said person and change position of said frame in said environment to monitor said person using at least one image obtained from said at least one camera and wherein said processor is further configured to determine if an out-of-ordinary event has occurred; and,

a light coupled with said autonomous personal service robot wherein said light is selected from a group consisting of emergency light, infrared light and reading light.

4. An autonomous personal service robot comprising:

a frame;

a drive system coupled with said frame and configured to move said frame;

at least one camera coupled with said frame;

a processor coupled with said frame and configured to operate said drive system to move said at least one camera coupled with said frame to dynamically map an environment, said processor further configured to identify a person, track said person and change position of said frame in said environment to monitor said person using at least one image obtained from said at least one camera and wherein said processor is further configured to determine if an out-of-ordinary event has occurred; and,

an X10 interface coupled with said autonomous personal service robot wherein said processor is configured to operate an X10 compliant device via said X10 interface.

5. A method for utilizing an autonomous personal service robot comprising:

identifying a person with at least one camera coupled with a processor that is further coupled with a frame and further coupled with a drive system configured to move said frame;

mapping an environment dynamically using said at least one camera;

tracking said person using said drive system to move said at least one camera coupled with said frame;

monitoring said person using said at least one camera;

determining if an out-of-ordinary event has occurred using said software component executing on said processor;

utilizing an audio interface coupled with said processor; and,

responding to emergency cries from said person.

6. A method for utilizing an autonomous personal service robot comprising:

identifying a person with at least one camera coupled with a processor that is further coupled with a frame and further coupled with a drive system configured to move said frame;

mapping an environment dynamically using said at least one camera;

tracking said person using said drive system to move said at least one camera coupled with said frame;

monitoring said person using said at least one camera;

determining if an out-of-ordinary event has occurred using said software component executing on said processor;

dispensing medication at programmed intervals utilizing a medical dispenser coupled with said autonomous personal service robot; and,

alerting a second person if said medication is not utilized by said person.

7. A method for utilizing an autonomous personal service robot comprising:

identifying a person with at least one camera coupled with a processor that is further coupled with a frame and further coupled with a drive system configured to move said frame;

mapping an environment dynamically using said at least one camera;

tracking said person using said drive system to move said at least one camera coupled with said frame;

monitoring said person using said at least one camera;

determining if an out-of-ordinary event has occurred using said software component executing on said processor; and,

displaying a light coupled with said autonomous personal service robot wherein said light is selected from a group consisting of emergency light, infrared light and reading light.

8. A method for utilizing an autonomous personal service robot comprising:

identifying a person with at least one camera coupled with a processor that is further coupled with a frame and further coupled with a drive system configured to move said frame;

mapping an environment dynamically using said at least one camera;

tracking said person using said drive system to move said at least one camera coupled with said frame;

monitoring said person using said at least one camera;

determining if an out-of-ordinary event has occurred using said software component executing on said processor; and,

utilizing an X10 interface coupled with said autonomous personal service robot wherein said processor is configured to operate an X10 compliant device via said X10 interface.

Interpretation

A service robot designed to monitor a person for out of the ordinary events, dispense medicine at programmable intervals, alert a third party if medicine is not taken, autonomous control of X10 interfaces and perform tasks such as fetching objects, turning on light switches and opening doors.

Threat

Level of infringement

Claims 1-8: Not infringed, all claims have an element pertaining to identifying a person and using a camera to dynamically map an environment.

Claim 1: Our system will not respond to emergency cries

Claim 2: Our system will not dispense medicine or alert someone if medicine is not taken by a person

Claim 3: Our system will not have an an infrared light, emergency light or a light used for reading

Claim 4: The system will not use a X10 interface

Claim 5: Repeat of claim 1

Claim 6: Repeat of claim 2

Claim 7: Repeat of claim 3

Claim 8: Repeat of claim 4

Enforceability

This patent cannot be enforced on our project as we do not infringe its claims

Constraints on project:

Our system does not currently plan to identify people or use the camera system to map the environment. In addition, should we opt to change from lidar based slam to visual slam and identify people, we still won't infringe on any of these claims.

Patent info:

Patent title	Hybrid mobile robot
patent code	US20110040427A1
patent status	Granted

Priority date	2007-10-31
countries patent is active in	US
threat to project	1/5
url	https://patents.google.com/patent/US20110040427A1/en?q=%22autonomous%22&q=%22robot%22&q=%22navigation%22&q=%22mobile%22&q=%22manipulator%22,%22arm%22

Abstract:

An autonomous hybrid mobile robot includes a base link and a second link. The base link has a drive system and is adapted to function as a traction device and a turret. The second link is attached to the base link at a first joint. The second link has a drive system and is adapted to function as a traction device and to be deployed for manipulation. One of the links houses a retractable navigational system. In another embodiment an invertible robot includes at least one base link and a second link. In another embodiment a mobile robot includes a chassis and a track drive pulley system including a tension and suspension mechanism. In another embodiment a mobile robot includes a wireless communication system.

Independent claims

1. An autonomous hybrid mobile robot comprising:

a base link having a drive system, wherein the base link includes a right base link and a left base link, wherein each of the right and left base links have a drive system, and the right base link and the left base link are spaced apart, the base link adapted to function as a traction device and a turret;

a second link attached to the base link at a first joint, the second link having a drive system and being adapted to function as a traction device and to be deployed for manipulation;

an end link attached to the second link at a second joint, the end link having a drive system and an end effector attached to the end link at a third joint and the end link being adapted to function as a traction device and to be deployed for manipulation; and

a navigational system housed inside one of the links to automate obstacle traversal, obstacle avoidance and object manipulation with minimal or no operator input.

2. An internal wireless communication system on-board mobile robots comprising:

a plurality of data transmission systems having a plurality of sensors connected to a plurality of transceivers, the data transmission systems are located in at least one of the mechanical subsystems which interface with other mechanical subsystems such as drive systems, links, end effector, fingers platform, and fingers; and

a plurality of data processing systems having a plurality of processing units connected to transceivers, the data processing systems are located in some or all of the mechanical subsystems such as drive systems, links, end effector, fingers, and fingers platform;

wherein the wireless exchange of data between the data transmission systems and data processing systems enables the mechanical subsystems which interface with other mechanical subsystems to have unrestricted freedom of motion and help exchange the relative and absolute spatial positions and other relevant data.

6. An end effector for mobile robots comprising:

a self contained module, the self contained module housing mechanical and electrical hardware;

a plurality of wireless communication modules housed in the self contained module for internal wireless communication with at least one of the robot's data processing systems, and operator's control unit;

wherein the self contained module is connected to the mobile robot end link via a plurality of rotational pivots.

16. A navigational system for mobilerobots comprising:

a LIDAR scanning sensor;

a stereo camera assembly;

a plurality of internal wireless communication units connected to the LIDAR scanning sensor and the stereo camera assembly; and

a housing mechanism which houses the LIDAR scanning sensor and the stereo camera assembly inside at least one of the robot links wherein the stereo camera assembly provides depth perception and the LIDAR scanning sensor augments the visual perception.

22. A method of operating a hybrid mobile robot which comprises:

a) Locomoting the position of the hybrid mobile robot using at least one of base link, second link, end link, end effector, and a combination of links for traction while the other links are positioned for maneuverability or for support;

b) Manipulating an external object using at least one of base link, second link, end link, end effector, and a combination of links while the other links are used to maintain stability;

c) Combining the locomotion and manipulation of steps a and b concurrently or in succession in various combinations to achieve at least one of locomotion of position, manipulation, and both locomotion and manipulation.

Interpretation

An autonomous mobile robot, comprising of a drive system, two link arm, end effector, lidar and stereo camera system where most systems and sensors communicate via wireless modules.

Threat

Level of infringement

Claim 1: Not infringed, our drive system would not be described as a set of links, our lidar will also not be housed inside a frame or link

Claim 2: Not infringed, our system will not use an internal wireless system

Claim 3: Not infringed, our end effector will not use a wireless communication module

Claim 4: Not infringed, our navigation system will not use a stereo camera assembly or a wireless communication unit for the lidar

Claim 5: Not infringed, our mobile platform would not be described as a set of links, the arm is a set of links but this will not be used for maneuverability or support

Enforceability

This patent is not enforceable on our project as we do not infringe its claims

Constraints on project

None unless we drastically redesign the project

Patent info:

Patent title	Robot controller
patent code	US7228203B2
patent status	Granted
Priority date	2002-12-12
countries patent is active in	US,JP,CN
threat to project	3.5/5
url	https://patents.google.com/patent/US7415321B2/en?q=%22autonomous%22&q=%22robot%22&q=%22mobile%22&q=%22manipulator%22,%22arm%22&country=US,EP,GB

Abstract:

Realized is a robot controller capable of handling a large amount of data of images and so on necessary for advanced intelligence of control while securing a real-time performance with a simple structure. For this purpose, there are provided a motion control device for performing a calculation process for achieving motion control of an object to be controlled, a recognition and planning device for performing task and motion planning of the object to be controlled and recognition of outside

world, an input/output interface for outputting a command to the object to be controlled and receiving as input, a state of the object to be controlled, and a route selecting device for controlling communications by switching connections among the motion control device the recognition and planning device, and the input/output interface. While controlling the communications by switching the connections among the motion control device, the recognition and planning device, and the input/output interface by the route selecting device, the motions of the robot of the object to be controlled are controlled on the basis of the results of the task and motion planning of the object to be controlled and the recognition of the outside world.

Independent claims

1. A robot controller comprising:

a motion control means for performing a calculation process for achieving motion control of an object to be controlled;

a recognition and planning means for performing task and motion planning of the object to be controlled and recognition of outside world;

an input/output interface for outputting a command to the object to be controlled and receiving as input, a state of the object to be controlled; and

a route selecting means for controlling communications by switching connections among the motion control means, the recognition and planning means, and the input/output interface by means of a switch that has a plurality of external input/output ports and switches among digital signal paths respectively connected to the motion control means, the recognition and planning means, and the input/output interface, wherein

motions of a robot of the object to be controlled are controlled on a basis of results of the task and motion planning of the object to be controlled and the recognition of the outside world while controlling the communications by switching the connections among the motion control means, the recognition and planning means, and the input/output interface by the route selecting means.

2. A robot controller comprising:

motion control means for performing a calculation process for achieving motion control of an object to be controlled;

recognition and planning means for performing task and motion planning of the object to be controlled and recognition of outside world;

an input/output interface for outputting a command to the object to be controlled and receiving as input, a state of the object to be controlled;

a first route selecting means connected to the recognition and planning means by means of a switch that has a plurality of external input/output ports and switches a digital signal path connected to the recognition and planning means to one of the ports; and

a second route selecting means connected to the motion control means, the first route selecting means, and the input/output interface by means of a switch that has a plurality of external input/output ports and switches among digital signal paths connected to the

motion control means, the recognition and planning means, and the input/output interface, wherein

motions of a robot of the object to be controlled is controlled on a basis of results of the task and motion planning of the object to be controlled and the recognition of the outside world while controlling communications by switching connections between the second route selecting means and the recognition and planning means by the first route selecting means and while controlling communications by switching connections between the recognition and planning means, the first route selecting means, and the input/output interface by the second route selecting means.

Interpretation

A generalised mobile robot control system, performing calculations to achieve motion, motion planning, sensing the outside world, a route planner, and robot motion generated to achieve some form of goal.

Threat

Level of infringement

This is a very broad patent, the vast majority of (if not all) intelligent, autonomous, mobile robot platforms will infringe this patent. All robotic systems running the navigation stack from ROS (including several commercial products, such as the PR2) will also violate this patent. All mobile robots using SLAM will violate this patent.

Enforceability

This patent is enforceable, however it is unlikely that any action will be taken against us unless we developed the system into a commercial product. If we were to take this system to market we would seek legal advice on this issue.

Constraints on project

Patent info:

Patent title	Agricultural robot system and method
patent code	US8381501B2
patent status	Granted
Priority date	2003-12-12
countries patent is active in	US
threat to project	0/5

url	https://patents.google.com/patent/US8381501B2/en?q=%22autonomous%22&q=%22robot%22&q=%22mobile%22&q=%22manipulator%22,%22arm%22&country=US,EP,GB&page=6
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Abstract:

An agricultural robot system and method of harvesting, pruning, culling, weeding, measuring and managing of agricultural crops. Uses autonomous and semi-autonomous robot(s) comprising machine-vision using cameras that identify and locate the fruit on each tree, points on a vine to prune, etc., or may be utilized in measuring agricultural parameters or aid in managing agricultural resources. The cameras may be coupled with an arm or other implement to allow views from inside the plant when performing the desired agricultural function. A robot moves through a field first to “map” the plant locations, number and size of fruit and approximate positions of fruit or map the cordons and canes of grape vines. Once the map is complete, a robot or server can create an action plan that a robot may implement. An action plan may comprise operations and data specifying the agricultural function to perform.

Independent claims

1. A method for using an agricultural robot system comprising:

entering a field having plants with a scout robot;

approaching a plant with said scout robot wherein said plant comprises agricultural elements including agricultural elements to be harvested with a worker robot;

logging coordinates of said scout robot by said scout robot;

mapping a location of at least one agricultural element comprising branches or leaves or fruits or vegetables within said plant by said scout robot to produce a map;

continuing said approaching, said logging and said mapping until at least a plurality of said plants in said field have been mapped;

wherein said mapping said location by said scout robot occurs without performing an agricultural operation that transforms or physically alters said agricultural elements and without harvesting said agricultural elements to be harvested of said plant within said field;

transmitting said map from said scout robot to said worker robot;

creating an action plan from said map to optimize agricultural operations by said worker robot at a later time wherein the action plan is created by said worker robot or by a server, wherein said action plan includes optimized robot arm motion paths of robot arms coupled with said worker robot;

moving said worker robot near said plant after said scout robot leaves said plant;

performing an agricultural operation that transforms or physically alters, or harvesting, said agricultural element or said agricultural element to be harvested associated with said plant by said worker robot using said action plan.

Interpretation

Patent describes a method for an agricultural robot system to find, log and map agricultural elements that are ready to be harvested using a scout robot, then transmit a map to a worker robot which can then harvest the plant

Threat

Level of infringement

Each element of this claim pertains to a system for use in agriculture, therefore the claim is not infringed

Enforceability

As this patent is specific to the field of agriculture, it cannot be enforced on our project.

Patent info:

Patent title	Universal gripper
patent code	US5853211A
patent status	Expired
Priority date	1997-01-10
countries patent is active in	US,JP,CA,DE,EP
threat to project	0/5
url	https://patents.google.com/patent/US5853211A/en?q=%22compliant%22,%22flexible%22,%22soft%22&q=%22gripper%22,%22end+effector%22,%22manipulator%22&q=%22universal%22,%22adaptable%22,multi&country=US,EP,GB

Abstract:

A universal gripper has a movable arm locked in a gripping position by abutting against a movable blocking member. A pair of pivoting arms are maintained in their gripping positions by a blocking member being linearly slid between ends of the arms. Varying movable arm configurations can be easily interchanged with each other and mounted to a body by way of a single fixed pivot pin. The opening angle of a gripper arm can be mechanically limited to various positions by selective positioning of an adjustment member.

Independent claims:

1. A gripper comprising:

- a body;
- an actuator mounted to said body;
- a first arm movably coupled to said body, said first arm operably moving in response to movement of said actuator;
- a camming surface located on one of said body and said first arm;
- a member operably riding along said camming surface;
- said member being moved to a blocking position abutting against a portion of said first arm when said first arm is in a gripping position so as to prevent movement of said first arm away from said gripping position until said actuator moves said member; and
- an indentation located in said camming surface, said member being located at said indentation for encouraging said first arm to remain in said gripping position even when moving pressure applied to said actuator is lost.

2. A gripper comprising:

- a body;
- an actuator mounted to said body;
- a first arm movably coupled to said body, said first arm operably moving in response to movement of said actuator;
- a camming surface disposed on said first arm;
- rollers operably riding along said camming surface; and
- an indentation disposed adjacent said camming surface, said rollers being located at said indentation for encouraging said first arm to remain in a gripping position even when moving pressure applied to said actuator is not present.

3. A gripper comprising:

- a body;
- an actuator mounted to said body;
- a camming surface;
- a roller operably riding along said camming surface;
- a first arm movably coupled to said body, said first arm operably moving in response to movement of said actuator; and
- a plurality of laterally oriented grooves located on said camming surface;

said roller engaging one of said grooves when said first arm grips a workpiece, said roller being located at one of said grooves for encouraging said first arm to remain in a gripping position even when moving pressure applied to said actuator is lost.

4. A gripper comprising:

a body;

an actuator mounted to said body;

a camming surface;

a member operably riding along said camming surface;

a first arm movably coupled to said body, said first arm operably moving in response to movement of said actuator;

an indentation disposed in said camming surface, said member being located at said indentation for encouraging said first arm to remain in a gripping position even when moving pressure applied to said actuator is lost; and

a second arm stationarily fixed to said body, said second arm sharing a common attachment point with said first arm.

5. A gripper comprising:

a body;

an actuator movable in relation to said body;

a first arm movably coupled to said body;

an adjustment member attached to said body, said adjustment member having a cylindrical portion and a flattened portion; and

a slide having an internal slot, said slot abutting against said cylindrical portion of said adjustment member when said adjustment member is in a first position and abutting against said flattened portion when said adjustment member is in a second position, said adjustment member being movable to said first position which limits movement of said first arm to a first predetermined angular position, said adjustment member also being movable to said second position which limits movement of said first arm to a second predetermined angular position greater than said first angular position.

6. A gripper comprising:

a body;

an actuator movable in relation to said body;

a first arm movably coupled to said body;

an adjustment member attached to said body, said adjustment member being movable to a first position which limits movement of said first arm to a first predetermined angular position, said adjustment member also being movable to a second position which limits

movement of said first arm to a second predetermined angular position greater than said first angular position;

a camming surface located on one of said body and said arm; and

a roller mechanism slidable along said camming surface to control movement of said arm, said adjustment member selectively limiting linear travel of said roller mechanism.

7. A powered gripper comprising:

a body having a distal end with a slot;

a pivot pin transversely extending through said body and intersecting said slot;

a first arm pivotably supported by said pivot pin internal to said slot;

a second arm supported by said pivot pin internal to said slot, said second arm having a different shape than said first arm, said second arm being stationarily affixed to said body once assembled, said second arm being removable from said body solely by removal of said pivot pin, whereby two of said arms are operably usable with said body at a time; and

a third arm having a hole suitable for receiving said pivot pin, said third arm having a different configuration than one of said first and second arms;

said pivot pin being linearly, stationarily fixed to said body during operable movement of at least one of said arms;

said pivot pin being removable to allow for interchangeability of said arms and reconfiguration of said powered gripper.

Threat

Level of infringement

This patent has expired

Enforceability

This patent has expired

Patent info:

Patent title	Gripping device for gripping object
patent code	EP2735409B1
patent status	Granted
Priority date	2012-11-27
countries patent is active in	EP

threat to project	4/5
url	https://patents.google.com/patent/EP2735409B1/en?q=%22compliant%22,%22flexible%22,%22soft%22&q=%22gripper%22,%22end+effector%22,%22manipulator%22&q=%22universal%22,%22adaptable%22,multi&q=robot&q=%22fin+ray%22&country=US,EP,GB

Abstract: N/A

Independent claims

1. Gripping device for gripping objects (12), comprising at least two gripping units (17a-b) movable by means of an operating movement between a release position and a gripping position gripping the object (12), wherein each of the gripping units (17a-b) has an individual gripping drive (27a-b), by way of which the operating movement between the gripping position and the open position can be generated, wherein each of the gripping units (17a-b) has a base unit (20) comprising a mounting interface (21) for the releasable mounting of an associated gripping element (22a-b), **characterised in that** each of the gripping elements (22a-b) has a gripping element base (26) with a mounting interface for the releasable mounting of an acting element (36), which bears against the object (12) in the gripping position.

Interpretation

Patent describes a gripping device with two or more fingers where each finger is actuated independently and releasable from the base of the gripper.

Threat

Level of infringement

Our gripper does infringe the independent claims of this patent.

Enforceability

This patent seems to cover most robotic grippers, including the majority of robot grippers currently on the market. If we were to take our system to market then we would seek legal advice on this issue.

Constraints on project

As this patent appears unenforceable we will not note any constraints on the project.

Patent info:

Patent title	Simultaneous Localization And Mapping For A Mobile Robot
patent code	US9037396B2

patent status	Granted
Priority date	2013-05-23
countries patent is active in	US
threat to project	1/5
url	https://patents.google.com/patent/US9037396B2/en?q=%22autonomous%22&q=%22slam%22&q=%22robot%22&q=%22lidar%22&q=%22mobile%22&country=US,EP,GB&page=1

Abstract:

A method of localizing a mobile robot includes receiving sensor data of a scene about the robot and executing a particle filter having a set of particles. Each particle has associated maps representing a robot location hypothesis. The method further includes updating the maps associated with each particle based on the received sensor data, assessing a weight for each particle based on the received sensor data, selecting a particle based on its weight, and determining a location of the robot based on the selected particle.

Independent claims

What is claimed is:

1. A method of localizing a mobile robot, the method comprising:

receiving sensor data of a scene about the robot, the sensor data comprising a three-dimensional point cloud;

executing a particle filter having a set of particles, each particle having an associated variance occupancy grid map and a robotlocation hypothesis;

accumulating cloud points in cells of the variance occupancy grid map based on first and second coordinates of the cloud points, each cell accumulating a height variance based on a third coordinate of the accumulated cloud points;

updating the variance occupancy grid map associated with each particle based on the received sensor data;

assessing a weight for each particle based on the received sensor data;

selecting at least one particle based on its weight; and

determining a location of the robot based on the at least one selected particle.

Interpretation

This patent covers a method of simultaneous localisation and mapping (SLAM) using a particle filter with a 3D point cloud as the primary data input, although the independent claim appears to only describe localisation.

Threat

Level of infringement

The SLAM package we will be using is hectorSLAM which has a BSD license. The independent claim above does describe some of the functionality of hectorSLAM (although hectorSLAM implements a host of improvements and innovations on the core concept of localisation). However, the claim above describes a 3D point cloud as a data input and hectorSLAM operates on a 2D scan.

Enforceability

The patent seems to describe monte-carlo localisation. A paper describing monte-carlo localisation was published in 1999 and can be found here: <https://rse-lab.cs.washington.edu/abstracts/sampling-aaai-99.abstract.html>

This particle-filter approach to SLAM is possibly the most popular approach to localising mobile robots and has been described in literature at least 14 years before this patent was approved. The independent claim above shows no obvious improvements or innovations to this method. For these reasons, this patent will be very difficult to enforce.

Constraints on project

We should potentially avoid moving to a 3D laser scanner.

Patent info:

Patent title	Autonomous mobile robot
patent code	US7539557B2
patent status	Granted
Priority date	2004-03-27
countries patent is active in	US
threat to project	1/5
url	https://patents.google.com/patent/US7539557B2/en?q=%22autonomous%22&q=%22slam%22&q=%22robot%22&q=%22lidar%22&q=%22mobile%22&country=US,EP,GB

Abstract:

A mobile robot is equipped with a range finder and a stereo vision system. The mobile robot is capable of autonomously navigating through urban terrain, generating a map based on data from the range finder and transmitting the map to the operator, as part of several reconnaissance operations selectable by the operator. The mobile robot employs a Hough transform technique to identify linear features in its environment, and then aligns itself with the identified linear features in order to navigate through the urban terrain; while at the same time, a scaled vector field histogram technique is applied to the combination of range finder and stereo vision data to detect and avoid obstacles the mobile robot encounters when navigating autonomously. Also, the missions performed by the mobile robot may include limitation parameters based on distance or time elapsed, to ensure completion of the autonomous operations.

Independent claims:

1. A mobile robot for autonomously performing reconnaissance, comprising:

- a drive system configured to propel the mobile robot across terrain;
- a range sensor configured to detect a distance between the mobile robot and one or more objects in an environment of the mobile robot;
- a position reckoner including one or more of the group consisting of a global positioning satellite receiver, an odometer, or an inertial navigation system;
- a processor communicatively connected to the range sensor, to the position reckoner, and to the drive system, and configured to execute software instructions; and
- a memory store communicatively connected to the processor, the memory store having stored thereon a plurality of software instructions configured to be executed by the processor, the software instructions including:
 - a mapping routine configured to maintain an occupancy grid map of the environment of the mobile robot,
 - a linear feature routine configured to detect one or more linear patterns in the occupancy grid map and to determine a strongest line among the one or more linear patterns,
 - a navigational routine configured to control the drive system to move the mobile robot in a direction aligned with the strongest line among the one or more linear patterns, and
 - a localization routine configured to update the occupancy grid map using a scaled vector field histogram based on input from the range sensor and the position reckoner integrated using a Kalman filter with a motion model corresponding to the mobile robot.

2. A mobile robot for autonomously performing reconnaissance, comprising:

- a drive system configured to propel the mobile robot across terrain;
- a range sensor configured to detect a distance between the mobile robot and one or more objects in an environment of the mobile robot;

a processor communicatively connected to the range sensor and to the drive system, and configured to execute software instructions; and

a memory store communicatively connected to the processor, the memory store having stored thereon a plurality of software instructions configured to be executed by the processor, the software instructions including:

a mapping routine configured to maintain an occupancy grid map of the environment of the mobile robot,

a linear feature routine configured to detect one or more linear patterns in the occupancy grid map and to determine a strongest line among the one or more linear patterns, and

a navigational routine configured to control the drive system to move the mobile robot in a direction aligned with the strongest line among the one or more linear patterns,

wherein a location of the mobile robot when the mapping routine begins maintaining the occupancy grid map is designated as an initial location, and

wherein the navigational routine prevents the drive system from moving the mobile robot farther than 250 meters from the initial location.

3. A mobile robot reconnaissance system, comprising:

a mobile robot configured to perform autonomous reconnaissance, including:

a drive system configured to propel the mobile robot across terrain,

a range sensor configured to detect a distance between the mobile robot and one or more objects in an environment of the mobile robot,

a processor communicatively connected to the range sensor and to the drive system, and configured to execute software instructions,

a memory store communicatively connected to the processor, the memory store having stored thereon a plurality of software instructions configured to be executed by the processor, the software instructions including:

a mapping routine configured to maintain an occupancy grid map of the environment of the mobile robot,

a linear feature routine configured to detect one or more linear patterns in the occupancy grid map and to determine a strongest line among the one or more linear patterns, and

a navigational routine configured to control the drive system to move the mobile robot in a direction aligned with the strongest line among the one or more linear patterns, and

a transceiver configured to transmit the occupancy grid map and to receive a mission command; and

a teleoperation console configured to remotely communicate with the mobile robot, the teleoperation console including:

a display configured to present the occupancy grid map transmitted by the mobile robot to an operator and to present a mission command menu to the operator, the mission

command menu including a plurality of visual items each corresponding to at least one of a plurality of robot missions performable by the mobile robot,

an input unit configured to receive a mission command selection from the operator corresponding to at least one of the robots missions, and

a transmitter configured to transmit the mission command to the mobile robot corresponding to the mission command selection received by the input unit,

wherein the robot missions each include a teleoperation mode and an autonomous mode,

wherein the mobile robot is further configured to communicate with the teleoperation console in the teleoperation mode and to function autonomously in the autonomous mode even without communication with the teleoperation console.

Interpretation

This patent describes a mobile reconnaissance robot which employs computer vision to navigate and a combination of computer vision and a rangefinder to avoid obstacles.

Threat

Level of infringement

Claim 1 describes a 'position reckoner' subsystem comprised of one or more of the following: a GPS receiver, an odometer or an IMU. While our robot does have wheel encoders, they are not being used to generate odometric data, and the robot does not generate odometry directly from any sensors. Initial plans for our robot do not include a GPS or an IMU.

In addition, claims 1 5 and 9 describe a linear feature routine and a navigation system which follows linear patterns identified by the routine, which is an approach which the inner-workings of the SLAM system we are using does not employ.

Enforceability

As our system employs a different method of localisation to the one described above, the enforceability of this patent is irrelevant.

Constraints on project

None with our current SLAM system.

Patent info:

Patent title	Method and device of mapping and localization method using the same
patent code	US8588471B2
patent status	Granted
Priority date	2009-11-24

countries patent is active in	US
threat to project	1/5
url	https://patents.google.com/patent/US8588471B2/en?q=%22slam%22&q=%22lidar%22&q=robot&q=%22mobile%22&country=US,EP,GB&page=5

Abstract:

A mapping method is provided. The environment is scanned to obtain depth information of environmental obstacles. The image of the environment is captured to generate an image plane. The depth information of environmental obstacles is projected onto the image plane, so as to obtain projection positions. At least one feature vector is calculated from a predetermined range around each projection position. The environmental obstacle depth information and the environmental feature vector are merged to generate a sub-map at a certain time point. Sub-maps at all time points are combined to generate a map. In addition, a localization method using the map is also provided.

Independent claims

What is claimed is:

1. A mapping method, comprising:

scanning an environment to obtain depth information of environmental obstacles;

capturing an image of the environment to generate an image plane;

projecting the environmental obstacle depth information onto the image plane, so as to obtain a plurality of projection positions;

calculating at least one feature vector from a predetermined range around each of the projection positions in the image plane, wherein when the feature vector cannot be calculated from the predetermined range around each of the projection positions, at least an upper feature vector or at least a lower feature vector is calculated from upper or lower image data of each of the projection positions, wherein the upper feature vector or the lower feature vector is calculated according to upper or lower image data in the image plane relative to a vertical axis of each of the projection positions;

combining the depth information of environmental obstacles and each of the feature vectors to generate a sub-map for a certain time point; and

combining the sub-maps at all time points to generate a map.

2. A localization method, comprising:

obtaining a map comprising the depth information of environmental obstacles and at least one feature vector of an image corresponding to the depth information of environmental obstacles, wherein the step of obtaining the map comprises:

scanning an environment to obtain the environmental obstacle depth information;

capturing an image of the environment to generate an image plane;

projecting the depth information of environmental obstacles onto the image plane, so as to obtain a plurality of projection positions;

calculating at least one feature vector from a predetermined range around each of the projection positions in the image plane, wherein when the feature vector cannot be calculated from the predetermined range around each of the projection positions, at least an upper feature vector or at least a lower feature vector is calculated from upper or lower image data of each of the projection positions, wherein the upper feature vector or the lower feature vector is calculated according to upper or lower image data in the image plane relative to a vertical axis of each of the projection positions;

combining the depth information of environmental obstacles and each of the feature vectors to generate a sub-map for a certain time point; and

combining the sub-maps at all time points to generate the map;

using a visual sensing device to obtain an environmental image;

extracting at least one image feature point from the environmental image; and

performing a localization according to the image feature point and the map.

3. A mapping device, comprising:

at least one range sensing device, for scanning an environment to generate the depth information of environmental obstacles;

at least one visual sensing device, for capturing an image of the environment to generate an image plane, wherein the range sensing device and the visual sensing device are integrated as an embedded handheld device; and

an image processing device, coupled to the range sensing device and the visual sensing device, for projecting the depth information of environmental obstacles onto the image plane to obtain a plurality of projection positions, calculating at least one feature vector from a predetermined range around each of the projection positions in the image plane, and combining the depth information of environmental obstacles and the feature vectors to generate a map,

wherein when the feature vector cannot be calculated from the predetermined range around each of the projection positions, the image processing device further calculates at least an upper feature vector or at least a lower feature vector from upper or lower image data of each of the projection positions, wherein the upper feature vector or the lower feature vector is calculated

according to upper or lower image data in the image plane relative to a vertical axis of each of the projection positions.

Interpretation

This patent describes a SLAM system whose inputs are a camera and some form of rangefinder.

Threat

Level of infringement

It is implied that the patent above uses an RGBD camera, although the definitions used can be applied to 2D laser scanners. However, all independent claims refer to 'capturing an image of the environment', for which a camera (or other image sensor) is required. Our system does not use an image sensor for localisation or mapping.

Enforceability

This patent is not enforceable to our project as we don't infringe the claims made.

Constraints on project

None unless we switch to a SLAM approach utilising a combination of depth sensing and cameras to localise and/or map.

Patent info:

Patent title	Mobile human interface robot
patent code	US9400503B2
patent status	Granted
Priority date	2010-05-20
countries patent is active in	US
threat to project	1/5
url	https://patents.google.com/patent/US9400503B2/en?q=%22lidar%22&q=%22robot%22&country=US,EP,GB&page=1

Abstract:

A method of object detection for a mobile robot includes emitting a speckle pattern of light onto a scene about the robot while maneuvering the robot across a work surface, receiving reflections of

the emitted speckle pattern off surfaces of a target object in the scene, determining a distance of each reflecting surface of the target object, constructing a three-dimensional depth map of the target object, and classifying the target object.

Independent claims:

What is claimed is:

1. A method of object detection for a mobile robot, the method comprising:
 - emitting a speckle pattern of light onto a scene about the robot while maneuvering the robot across a work surface of a working area;
 - receiving odometry measurements from a drive system of the robot while maneuvering the robot across the work surface;
 - determining a first motion of the robot based on the odometry measurements;
 - determining a current location of the robot in the working area based on the first robot motion and a previously determined location of the robot;
 - receiving reflections of the emitted speckle pattern off surfaces of a target object in the scene;
 - determining a second motion of the robot using visual odometry of the robot based on an optical flow of the received reflections;
 - determining a robot motion error between the first robot motion based on the drive system odometry and the second robot motion based on the visual odometry;
 - adjusting the current location of the robot based on the robot motion error;
 - determining a distance of each reflecting surface of the target object;
 - constructing a three-dimensional depth map of the target object using the received reflections, the determined distance of each reflecting surface of the target object, and the adjusted current location of the robot; and
 - classifying the target object using the three-dimensional depth map, the classifying comprising:
 - determining a state, a pose, or a gesture of the target object;
 - classifying the target object as a living object based on the state, the pose, or the gesture of the target object;
 - determining whether the living object needs assistance by determining one or more of whether the living object is alive, sitting, lying down, waving, falling, or fallen based on the state, the pose, or the gesture; and
 - when the living object needs assistance, determining a type of assistance needed based on the state, the pose, or the gesture.

Interpretation

This patent describes a mobile robot using a combination of speckled structured light projection and odometry to avoid obstacles and localise.

Threat

Level of infringement

Our robot does not use a structured light depth-mapping system to localise and does not collect odometric data from its drive system. Furthermore, even though our robot may use an RGBD camera to classify objects, the classification routine will only be fed 2D RGB image streams. Our robot will not classify objects from 3D depth maps

Enforceability

Our system does not infringe upon this patent.

Constraints on project

As our project is currently planned we do not infringe on this patent, as such it causes no constraints on our project.

Summary

We have analysed patents relevant to subsystems we will be creating within this project and the system as a whole, with varying degrees of detail depending on patent relevancy. Some patents are not currently infringed but may limit possible adaptation of the system. There are also some potential key infringements, however these infringements appear to cover such a broad area that the infringement is unavoidable and seems to be infringed by many commercial systems on the market. Should we decide to take this product to market we will seek legal advice on these issues.