

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
3 March 2011 (03.03.2011)

(10) International Publication Number
WO 2011/026119 A3

(51) International Patent Classification:
G05D 1/02 (2006.01)

[US/US]; 885 Glenhill Drive, Fremont, California 94539 (US).

(21) International Application Number:
PCT/US2010/047358

(74) Agents: **BERNSTEIN, Frank** et al.; Kenyon & Kenyon LLP, 333 West San Carlos Street #600, San Jose, California 95110 (US).

(22) International Filing Date:
31 August 2010 (31.08.2010)

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/238,597 31 August 2009 (31.08.2009) US

(71) Applicant (for all designated States except US): **NEATO ROBOTICS, INC.** [US/US]; 1916 Old Middlefield Way, Suite "A", Mountain View, California 94043 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **SOFMAN, Boris** [US/US]; 5403 Beacon Street, Pittsburgh, Pennsylvania 15217 (US). **ERMAKOV, Vladimir** [US/US]; 2951 Marietta Drive, Santa Clara, California 95051 (US). **EM-MERICH, Mark** [US/US]; 447 South 12th Street, San Jose, California 95112-2231 (US). **MONSON, Nathaniel David** [US/US]; 100 N. Whisman Road #411, Mountain View, California 94043 (US). **ALEXANDER, Steve**

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR SIMULTANEOUS LOCALIZATION AND MAPPING OF MOBILE ROBOT ENVIRONMENT

100

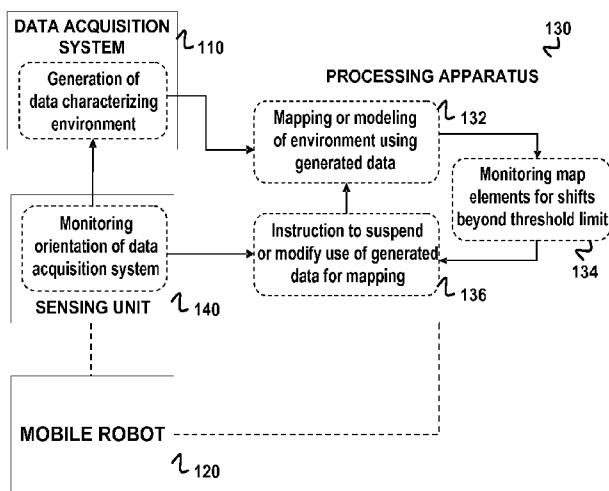


FIG. 1

(57) Abstract: Techniques that optimize performance of simultaneous localization and mapping (SLAM) processes for mobile devices, typically a mobile robot. In one embodiment, erroneous particles are introduced to the particle filtering process of localization. Monitoring the weights of the erroneous particles relative to the particles maintained for SLAM provides a verification that the robot is localized and detection that it is no longer localized. In another embodiment, cell-based grid mapping of a mobile robot's environment also monitors cells for changes in their probability of occupancy. Cells with a changing occupancy probability are marked as dynamic and updating of such cells to the map is suspended or modified until their individual occupancy probabilities have stabilized. In another embodiment, mapping is suspended when it is determined that the device is acquiring data regarding its physical environment in such a way that use of the data for mapping will incorporate distortions into the map, as for example when the robotic device is tilted.

WO 2011/026119 A3



Published:

(88) Date of publication of the international search report:

16 June 2011

- *with international search report (Art. 21(3))*
- *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2010/047358

A. CLASSIFICATION OF SUBJECT MATTER
 INV. G05D1/02
 ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 G05D

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/235585 A1 (TANAKA HIROTO [JP]) 19 October 2006 (2006-10-19)	1,2,6,20
Y	the whole document	3-5,21, 22
Y	----- WO 2009/012474 A1 (NEATO ROBOTICS INC [US]; SHAH PANKAJ [US]; KONOLIGE KURT [US]; AUGENBR) 22 January 2009 (2009-01-22) the whole document	3,4,21
Y	----- US 2005/171637 A1 (TANI TAKAO [JP] ET AL) 4 August 2005 (2005-08-04) the whole document	5,22
X	----- US 5 363 305 A (COX INGEMAR [US] ET AL) 8 November 1994 (1994-11-08) the whole document	7-11,23
	----- -/--	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

6 April 2011

Date of mailing of the international search report

19/04/2011

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
 NL - 2280 HV Rijswijk
 Tel. (+31-70) 340-2040,
 Fax: (+31-70) 340-3016

Authorized officer

Westholm, Mats

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2010/047358

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 957 984 A (RENCKEN WOLFGANG [DE]) 28 September 1999 (1999-09-28) the whole document	7-11,23
X	----- WO 03/040845 A1 (DYSON LTD [GB]; ALDRED MICHAEL DAVID [GB]; SHARDLOW ANDREW MICHAEL [GB] 15 May 2003 (2003-05-15) the whole document	7-11,23
A	----- US 2004/167669 A1 (KARLSSON L NIKLAS [US] ET AL) 26 August 2004 (2004-08-26) the whole document	12-15,24
A	----- US 2008/027591 A1 (LENSER SCOTT [US] ET AL) 31 January 2008 (2008-01-31) the whole document	12-15,24
A	----- US 5 202 661 A (EVERETT JR HOBART R [US] ET AL) 13 April 1993 (1993-04-13) the whole document	16-19,25
A	----- US 5 793 934 A (BAUER RUDOLF [DE]) 11 August 1998 (1998-08-11) the whole document	16-19,25

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2010/047358

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-6, 20-22

suspending use of the data identifying the environment of the robot
when the robot has lost its preferred orientation.

2. claims: 7-11, 23

suspending use of the data identifying the environment of the robot
when a shift in the map is detected.

3. claims: 12-15, 24

determination if the robot has become delocalized by comparison of the weights of introduced erroneous particles with the weights of generated particles representing a potential position of the robot.

4. claims: 16-19, 25

mapping in a cell-based grid, whereby cells are assigned probabilities indicating if the corresponding location is occupied or not.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/US2010/047358

Patent document cited in search report	Publication date	Publication date	Patent family member(s)	Publication date
US 2006235585	A1	19-10-2006	NONE	

WO 2009012474	A1	22-01-2009	AU 2008275883 A1	22-01-2009
			CA 2694013 A1	22-01-2009
			CN 101809461 A	18-08-2010
			EP 2171498 A1	07-04-2010
			JP 2010534825 T	11-11-2010
			KR 20100019576 A	18-02-2010
			US 2010030380 A1	04-02-2010

US 2005171637	A1	04-08-2005	JP 2005211463 A	11-08-2005

US 5363305	A	08-11-1994	JP 4227507 A	17-08-1992

US 5957984	A	28-09-1999	WO 9607959 A1	14-03-1996
			EP 0779998 A1	25-06-1997
			JP 10505177 T	19-05-1998
			JP 3770909 B2	26-04-2006

WO 03040845	A1	15-05-2003	AT 363679 T	15-06-2007
			AU 2002337343 B2	30-11-2006
			DE 60220435 T2	31-01-2008
			EP 1440354 A1	28-07-2004
			JP 4249624 B2	02-04-2009
			JP 2005508540 T	31-03-2005
			JP 2008077670 A	03-04-2008
			US 2005085947 A1	21-04-2005

US 2004167669	A1	26-08-2004	US 2007090973 A1	26-04-2007
			US 2010268697 A1	21-10-2010

US 2008027591	A1	31-01-2008	NONE	

US 5202661	A	13-04-1993	NONE	

US 5793934	A	11-08-1998	WO 9535531 A1	28-12-1995
			EP 0766846 A1	09-04-1997
			JP 10501908 T	17-02-1998
