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[Continued on next page]

(54) Title: TARGET RECOGNITION AND LOCALIZATION METHODS USING A LASER SENSOR FOR WHEELED MOBILE ROBOTS

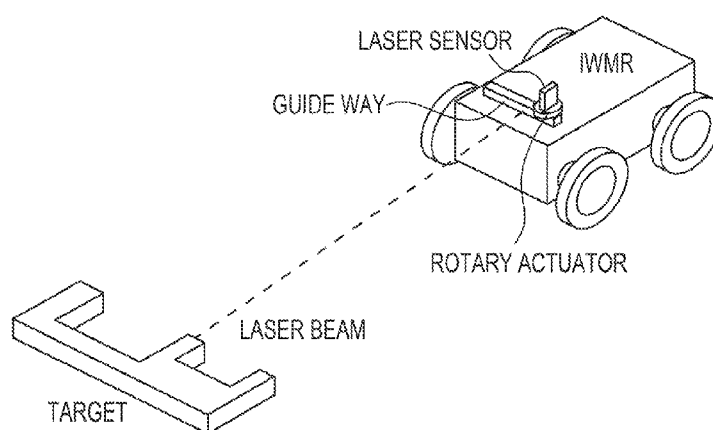


FIG. 1

(57) Abstract: A localization scheme and method using a laser sensor for indoor wheeled mobile robots (IWMMR), which need to localize themselves for working autonomously, is provided. In this method, a laser sensor moves inside an onboard guide way and its distance measurements are used to robustly detect and recognize a unique target based on edge detection and pattern recognition techniques. From the distance measurements with respect to the recognized target, a kinematic model is developed to determine the IWMMR orientation and location in the global co-ordinates (in 2-D). Such target recognition and localization methods are validated with experimental results.



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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/40499

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G05B 19/00 (2012.01)

USPC - 700/259

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)

IPC8 : G05B 19/00 (2012.01)

USPC : 700/259

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

IPC8 : G05B 19/00 (2012.01); G05D 1/00 (2012.01)

USPC : 700/245, 258, 259; 701/23, 27, 28

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

PubWEST(PGPB,USPT,EPAB,JPAB), PatBase(All), Google (Patents, Scholar). Terms: depth, variation, laser, scan, texture, recess, crenellated, tag, fiducial, marker, mark, target, barcode, 3d, three dimension, surface, step, unique, recognize, localize, etc.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	NICKERSON et al. "The ARK project: Autonomous mobile robots for known industrial environments." In: Robotics and Autonomous Systems, Volume 25, Issues 1-2, 31 October 1998, Pages 83-104 [online]. Retrieved on 25 October 2012 (25.10.2012). Retrieved from the Internet at URL:<http://www.sciencedirect.com/science/article/pii/S0921889098000323>, entire document, especially Figure 2, 8, 9; page 85, left column, para 1; page 87, right column, para 2, 3; page 90, left column, para 1, 2; page 90, right column, para 2; page 93, left column, para 1; page 96, right column; page 97, left column, para 1; page 98, right column, para 2, 3; sections 5.1.1, 5.1.2	1-5, 7 ----- 6, 8, 9
Y	BENGTTSSON et al. "Robot localization based on scan-matching - estimating the covariance matrix for the IDC algorithm." In: Robotics and Autonomous Systems, vol. 44, 2003, pages 29-40 [online]. Retrieved on 25 October 2012 (25.10.2012). Retrieved from the Internet at URL:<http://www.sciencedirect.com/science/article/pii/S0921889003000083>, entire document, especially page 32, left column, para 2, 3; section 5.1; Figure 11	6
Y	Van Gestel et al. "A performance evaluation test for laser line scanners on CMMs." In: Optics and Lasers in Engineering, Volume 47, Issues 3-4, March-April 2009, Pages 336-342 [online]. Retrieved on 25 October 2012 (25.10.2012). Retrieved from the Internet at URL:<http://www.sciencedirect.com/science/article/pii/S0143816608001292>, entire document, especially section 1, para 3; section 6, para 1	8, 9
Y	US 2008/0154504 A1 (HEIN et al.) 26 June 2008 (26.06.2008), entire document, especially Fig. 2; para [0014], [0015], [0019], [0049]	1-9



Further documents are listed in the continuation of Box C.



* Special categories of cited documents:	"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
"A" document defining the general state of the art which is not considered to be of particular relevance	"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
"E" earlier application or patent but published on or after the international filing date	"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
"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)	"&" document member of the same patent family
"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	

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/40499

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.: 14-18
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 continuation 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 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.:
1-9

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.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 12/40499

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Jensfelt, Patric. "Localization Using Laser Scanning and Minimalistic Environmental Models." Licentiate Thesis, Automatic Control Department of Signals, Sensors and Systems; Royal Institute of Technology, Stockholm, Sweden. 1999. [online]. Retrieved on 25 October 2012 (25.10.2012). Retrieved from the Internet at URL: < http://www8.cs.umu.se/research/for/dl/LOCALIZATION-NAVIGATION/Localization%20Using%20Laser%20scanning%20and%20Minimalistic%20Environmental%20Models.pdf >, entire document	1-2
A	US 2006/0196945 A1 (MENDELS) 07 September 2006 (07.09.2007), entire document, especially para [0032], [0036]	1-9
A	US 7,845,560 B2 (EMANUEL et al) 07 December 2010 (07.12.2010), entire document	1-9
A	US 6,697,761 B2 (AKATSUKA et al.) 24 February 2004 (24.02.2004), entire document	1-9
A	US 4,796,198 A (BOULTINGHOUSE et al.) 03 January 1989 (03.01.1989), entire document	1-9
A	US 4,566,032 A (HIROOKA et al.) 21 January 1986 (21.01.1986), entire document	1-9
A	US 2010/0092079 A1 (ALLER) 15 April 2010 (15.04.2010), entire document	1-9
A	US 2009/0055024 A1 (KAY) 26 February 2009 (26.02.2009), entire document	1-9
A	Boulanger et al. "Integration of synthetic surface relief in range images." In: Computer Vision, Graphics, and Image Processing, Volume 47, Issue 3, September 1989, Pages 361-372 [online]. Retrieved on 25 October 2012 (25.10.2012). Retrieved from the Internet at URL: < http://www.sciencedirect.com/science/article/pii/0734189X89901187 >, entire document	1-9

Box III - Observations where unity of invention is lacking:

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1.

Group I: claims 1-9 directed to a target system

Group II: claims 10-13 directed to a method of localizing a wheeled robot

The groups of inventions above do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

The special technical feature of the Group I claims is a target having a surface with depth variations, which is not present in the claims of Group II.

The special technical feature of the Group II claims is detecting edges on a target based on laser sensor measurements and transforming collected measurements into vehicular coordinates, which is not present in the claims of Group I.

Groups I-II share the technical feature of a mobile robot with a laser scanner for localizing the robot. This generic feature does not avoid the prior art, as evinced by US 2008/0154504 A1 to Hein et al which notably teaches an example of a robot localization system which uses a laser scanner (para [0014], [0015], [0019]). See also US 4,796,198 A to Boultinghouse et al (col 3, ln 64 to col 4, ln 51).

Therefore, the listed inventions lack unity of invention under PCT Rule 13 because they do not share a same or corresponding special technical feature.

Note - claims 14-18 are improper multiple dependent claims not in compliance with PCT Rule 6.4 (a) and have not been included in any of the groups above.