



(51) International Patent Classification:  
G05D 1/02 (2020.01)

(21) International Application Number:  
PCT/US2018/047199

(22) International Filing Date:  
21 August 2018 (21.08.2018)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
62/558,937 15 September 2017 (15.09.2017) US  
62/693,078 02 July 2018 (02.07.2018) US

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(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, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, 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.

(54) Title: INTELLIGENT LADAR SYSTEM WITH LOW LATENCY MOTION PLANNING UPDATES

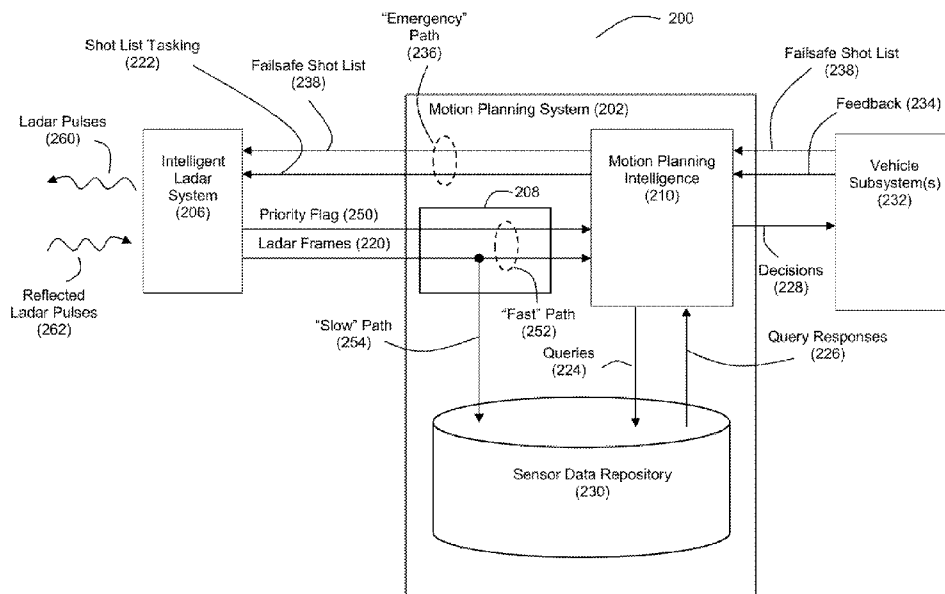


Figure 2

(57) Abstract: Systems and methods are disclosed for vehicle motion planning where a sensor, such as a ladar system, is used to detect threatening or anomalous conditions within the sensor's field of view so that priority warning data about such conditions can be inserted at low latency into the motion planning loop of a motion planning computer system for the vehicle. Also disclosed herein is a ladar system that includes ladar transmitter, ladar receiver, and camera, where the camera that is co-bore sited with the ladar receiver, the camera configured to generate image data corresponding to a field of view for the ladar receiver. Also disclosed are techniques where a ladar system can estimate intra-frame motion for an object within a field of view of the ladar system using a tight cluster of ladar pulses.



**(84) Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, 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, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

**Published:**

- *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))*

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

06 February 2020 (06.02.2020)

**(15) Information about Correction:**

see Notice of 02 January 2020 (02.01.2020)

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 18/47199

## A. CLASSIFICATION OF SUBJECT MATTER

IPC - G05D 1/02 (2019.01)

CPC - G05D 1/0212; G05D 1/0214; G05D 1/0223; G05D 1/0246; G05D 1/0238; G05D 1/0248

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)  
See Search History documentDocumentation searched other than minimum documentation to the extent that such documents are included in the fields searched  
See Search History documentElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)  
See Search History document

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2017/0242108 A1 (AEYE, Inc.) 24 August 2017 (24.08.2017), entire document, especially; para [0007], [0037]	1-4, 24-27
A	US 6,704,619 B1 (COLEMAN et al.) 09 March 2004 (09.03.2004), entire document, especially; col 3, ln 66 to col 4, ln 15, col 5, ln 10-25	1-4, 24-27
A	US 2016/0047899 A1 (US LADAR, Inc.) 18 February 2016 (18.02.2016), entire document	1-4, 24-27
A	US 2016/0054735 A1 (PELTON TECHNOLOGY, Inc.) 25 February 2016 (25.02.2016), entire document	1-4, 24-27

 Further documents are listed in the continuation of Box C. See patent family annex.

* 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
"D" document cited by the applicant in the international application	"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
"E" earlier application or patent but published on or after the international filing date	"&" document member of the same patent family
"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	

Date of the actual completion of the international search

23 November 2019

Date of mailing of the international search report

**18 DEC 2019**Name and mailing address of the ISA/US  
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**INTERNATIONAL SEARCH REPORT**

International application No.

PCT/US 18/47199

**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.: 5-23, 28, 29, 34-41, 45-50, 55-62, 67-74, 78-85, 91-110, and 116-136  
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:  
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. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I: claims 1-4 and 24-27: drawn to a vehicle motion planning system and method.

Group II: claims 30-33, 42-44, 51-54, and 63: drawn to a lidar transceiver and method including a camera.

Group III: claims 64-66 and 75-77: drawn to an apparatus and method including computing intra-frame motion data for a target.

Group IV: claims 86-90 and 111-115: drawn to an apparatus and method including transmitting a plurality of lidar pulses in accordance with a selected shot list frame.

--See Extra 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.:  
1-4, 24-27

- 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**  
Information on patent family members

International application No.

PCT/US 18/47199

--Continuation of Box: III Observations where unity of invention is lacking--

The inventions listed as Groups I-IV 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:

**Special technical features:**

Group I requires the technical feature of a motion planning loop, not found in the other groups.

Group II requires the technical feature of a camera, not found in the other groups.

Group III requires the technical feature of computing intra-frame motion data, not found in the other groups.

Group IV requires the technical feature of a shot list frame, not found in the other groups.

**Shared Features:**

The only technical features shared by Groups I-IV that would otherwise unify the groups are a sensor.

The only additional technical features shared by Groups II-IV that would otherwise unify the groups are a ladar transceiver comprising a ladar transmitter, wherein the ladar transmitter is configured to transmit a plurality of ladar pulses toward a target within a field of view.

Further, the only additional technical features shared by Groups I and III that would otherwise unify the groups are a circuit or computer system computing motion based on processed data.

However, these shared technical features do not represent a contribution over prior art, because the shared technical features are disclosed by US 2009/0262760 A1 to Krupkin et al. (hereinafter Krupkin) 22 October 2009 (22.10.2009), which discloses a sensor including a ladar transceiver comprising a ladar transmitter (para [0173] - Reference is now made to FIG. 11, which is a schematic illustration of a system, generally referenced 600, constructed and operative in accordance with another embodiment of the disclosed technique. System 600 depicts a LADAR system, which can be mounted on a vehicle (not shown).), wherein the ladar transmitter is configured to transmit a plurality of ladar pulses toward a target within a field of view and a circuit or computer system computing motion based on processed data (para [0177], [0192] -As described above in FIG. 8D, since the flight path of the moving vehicle is less predictable when the vehicle is traveling in a straight direction, the FOV of the scan is increased. By increasing the FOV of the scan, the PRR needs to be increased in order to maintain the scan density of the pulsed beams of light. As mentioned above, maintaining the scan density is at the discretion of the operator of the vehicle.).

As the shared technical features were known in the art at the time of the invention, they cannot be considered special technical features that would otherwise unify the groups.

Groups I-IV therefore lack unity under PCT Rule 13.

Item 4 (contd.): Claims 5-23, 28, 29, 34-41, 45-50, 55-62, 67-74, 78-85, 91-110, and 116-136 have been found to be unsearchable as they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a) and are therefore not included in any of the above groups.