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[Continued on next page]

(54) Title: TRAINED NAVIGATIONAL SYSTEM WITH IMPOSED CONSTRAINTS

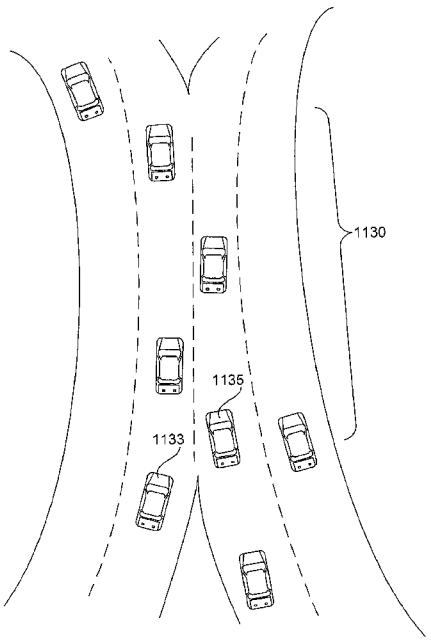

FIG. 11D

(57) Abstract: Systems and methods are provided for navigating an autonomous vehicle using reinforcement learning techniques. In one implementation, a navigation system for a host vehicle may include at least one processing device programmed to: receive, from a camera, a plurality of images representative of an environment of the host vehicle; analyze the plurality of images to identify a navigational state associated with the host vehicle; provide the navigational state to a trained navigational system; receive, from the trained navigational system, a desired navigational action for execution by the host vehicle in response to the identified navigational state; analyze the desired navigational action relative to one or more predefined navigational constraints; determine an actual navigational action for the host vehicle, wherein the actual navigational action includes at least one modification of the desired navigational action determined based on the one or more predefined navigational constraints; and cause at least one adjustment of a navigational actuator of the host vehicle in response to the determined actual navigational action for the host vehicle.

WO 2017/120336 A3

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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, 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.

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— *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**:
24 August 2017

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/012334

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.:

1, 2, 33-35

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/US2017/012334

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01C21/34 B60W30/09 G05D1/00 G06N3/00 G06K9/00
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)
G01C B60W G05D G06N G06K G06T

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 practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 170 352 A (MCTAMANEY LOUIS S [US] ET AL) 8 December 1992 (1992-12-08) column 3, line 60 - column 4, line 4 column 7, line 60 - column 9, line 6 column 9, lines 34-49 -----	1,2, 33-35
A	US 2015/151725 A1 (CLARKE ANNA [IL] ET AL) 4 June 2015 (2015-06-04) paragraphs [0006] - [0030] ----- -/--	1,2, 33-35

[X] Further documents are listed in the continuation of Box C.

[X] 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 application or patent 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	Date of mailing of the international search report
28 April 2017	10/07/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Gagin, Thibaut

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2017/012334

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	RANKA KULIC ET AL: "Autonomous Vehicle Obstacle Avoiding and Goal Position Reaching by Behavioral Cloning", IEEE INDUSTRIAL ELECTRONICS, IECON 2006 - 32ND ANNUAL CONFERENCE ON, IEEE, PISCATAWAY, NJ, USA, 1 November 2006 (2006-11-01), pages 3939-3944, XP031077105, ISBN: 978-1-4244-0135-2 Sections II, III -----	1,2, 33-35
A	MICHAEL KRÖDEL: "Autonome Optimierung des Verhaltens von Fahrzeugsteuerungen auf der Basis von Verstärkungslernen", 20060530, 30 May 2006 (2006-05-30), pages 1-30, XP002571029, the whole document -----	1,2, 33-35

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2017/012334

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5170352 A	08-12-1992	NONE	
US 2015151725 A1	04-06-2015	CN 106030609 A	12-10-2016
		EP 3092599 A1	16-11-2016
		US 2015151725 A1	04-06-2015
		US 2015151742 A1	04-06-2015
		US 2015151751 A1	04-06-2015
		US 2015151753 A1	04-06-2015
		US 2015153735 A1	04-06-2015
		US 2015367850 A1	24-12-2015
		US 2016052514 A1	25-02-2016
		US 2016167650 A1	16-06-2016
		US 2016229410 A1	11-08-2016
		US 2016347322 A1	01-12-2016
		WO 2015083009 A1	11-06-2015

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, 2, 33-35

Navigation system/method analysing images to:
find a navigational state, then navigational action, further modified by constraints. Decision making by a trained navigational system.

1.1. claim: 2

Further characterisation of the trained system

1.2. claim: 33

type of actuators

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2. claims: 3-16

Navigation system/method analysing images to :
find a navigational state, then navigational action, further modified by constraints. Decision making by a trained navigational system.
Further characterisations of constraints: prohibition zone around obstacles.

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3. claim: 17

Navigation system/method analysing images to:
find a navigational state, then navigational action, further modified by constraints. Decision making by a trained navigational system.
Further characterisations of constraints: movement of identified objects.

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4. claims: 18-23

Navigation system/method analysing images to:
find a navigational state, then navigational action, further modified by constraints. Decision making by a trained navigational system.
Further characterisations of constraints: Speed behaviour of vehicle with regards to a detected pedestrian.

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5. claims: 24, 25

Navigation system/method analysing images to:
find a navigational state, then navigational action, further modified by constraints. Decision making by a trained navigational system.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Further characterisations of constraints: maximum deceleration rate of host vehicle.

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6. claim: 26

Navigation system/method analysing images to:
find a navigational state, then navigational action, further modified by constraints. Decision making by a trained navigational system.
Further characterisations of constraints: mandatory stop.

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7. claims: 27-32

Navigation system/method analysing images to:
find a navigational state, then navigational action, further modified by constraints. Decision making by a trained navigational system.
Further characterisations of constraints: Navigation timing linked to other vehicle behaviour.

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8. claims: 36-50

Navigation system/method analysing images to:
find a navigational state, then navigational action, further modified by constraints. Dealing with several conflicting constraints

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9. claims: 51-98

Navigation system/method analysing images to:
find a navigational state, then navigational action, further modified by constraints. Dealing with identifying factors that modify the constraints.

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10. claims: 99-108, 114-124

Navigation system/method analysing images to:
find target vehicle, its behaviour with regards to detected obstacle and defined host vehicle navigation with relationship to analysis.

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11. claims: 109-113

Navigation system/method analysing images to:
find target vehicle, its behaviour with regards to the host vehicle and defined host vehicle navigation with relationship to analysis.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

12. claims: 125-135

Navigation system/method analysing images to:
find a navigational state and compare several potential navigation actions.
