



(51) International Patent Classification:

E01C 23/01 (2006.01) B60W 30/14 (2006.01)
G01C 7/04 (2006.01) B60W 30/18 (2012.01)
G01B 21/30 (2006.01) B60W 40/064 (2012.01)
B60W 40/06 (2012.01) B60W 40/068 (2012.01)
B60W 30/12 (2020.01) G01B 5/28 (2006.01)

(21) International Application Number:

PCT/US2020/015372

(22) International Filing Date:

28 January 2020 (28.01.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

62/797,895 28 January 2019 (28.01.2019) US
PA201970135 27 February 2019 (27.02.2019) DK

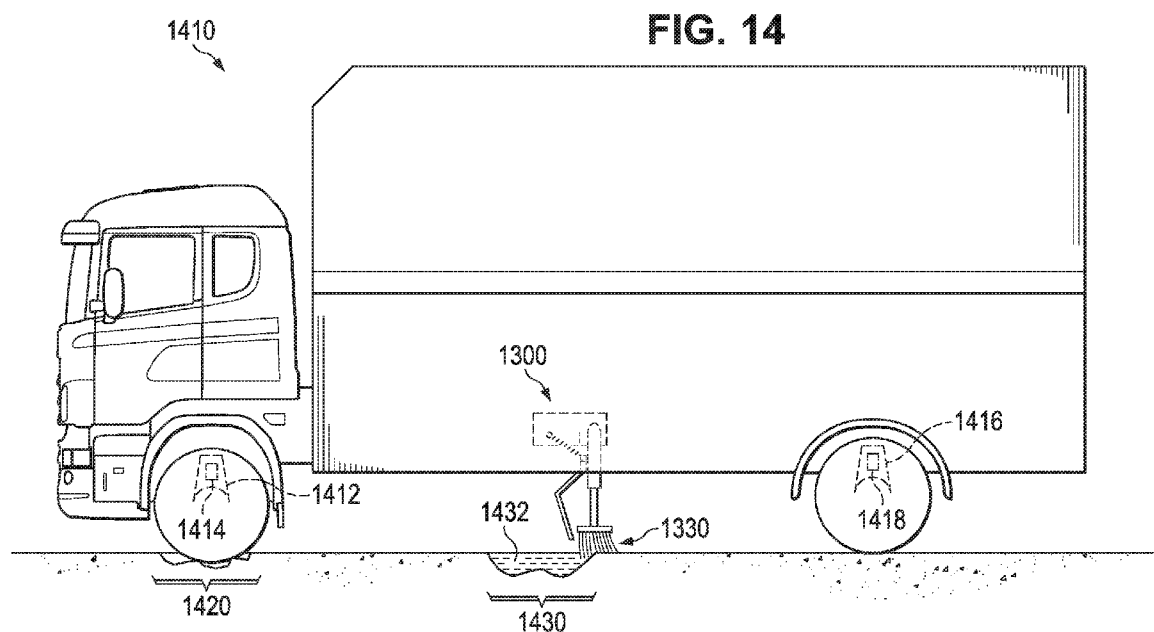
(71) Applicant: MOTIONAL AD LLC [US/US]; 100 Northern Avenue, Boston, Massachusetts 02210 (US).

(72) Inventors: BATTIS, Zachary Thomas; 104 Maple Heights Road, Pittsburgh, Pennsylvania 15232 (US). SUN, Ludong; 2715 Murray Avenue, Apt. 306, Pittsburgh, Pennsylvania 15217 (US). WOODARD, Ky; 717 Liberty Avenue #1411, Pittsburgh, Pennsylvania 15222 (US). WANG, Qian; 2800 Saint Andrews Square, Apt. 2227, Allison Park, Pennsylvania 15101 (US). ZHAO, Yiming; 2700 Thoroughbred Ct. #753, Allison Park, Pennsylvania 15101 (US). LEE, Stephanie; 6105 Spirit Street, Apt. 232, Pittsburgh, Pennsylvania 15206 (US). ZHAO, Lin; 4742 Centre Avenue, Apt. 104, Pittsburgh, Pennsylvania 15213 (US).

(74) Agent: REILLY, Christopher L. et al.; Fish & Richardson P.C., PO Box 1022, Minneapolis, Minnesota 55440-1022 (US).

(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,

(54) Title: DETECTING ROAD ANOMALIES



(57) Abstract: An apparatus is provided which includes a processing circuit and a plurality of sensors connected to a vehicle, where at least one of the plurality of sensors is positioned on an undercarriage of the vehicle. The plurality of sensors can detect variations in a road on which the vehicle is traveling. The plurality of sensors can also generate information corresponding to the variations of the road. The plurality of sensors can also transmit the information corresponding to the variations in the road to the processing circuit. The information collected by the plurality of sensors may then be used to augment a driving capability of the vehicle.



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, ST, SV, SY, TH, TJ, TM, TN, TR,
TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(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))
- with amended claims (Art. 19(1))

Date of publication of the amended claims:

05 November 2020 (05.11.2020)

AMENDED CLAIMS

received by the International Bureau on 21 September 2020 (21.09.2020)

What is claimed is:

1. A fully autonomous vehicle (AV), comprising:
a processing circuit; characterized in that the fully autonomous vehicle comprises:
a plurality of sensors coupled to the AV, wherein at least one sensor of the plurality of sensors is positioned on an undercarriage of the AV, and wherein the plurality of sensors are configured to:
detect variations of a navigable surface on which the AV is traveling;
generate information corresponding to the variations of the navigable surface; and
transmit the information corresponding to the variations of the navigable surface to the processing circuit, the information collected by the plurality of sensors being configured to augment a driving capability of the AV by adjusting the control of the AV, wherein at least one sensor of the plurality of sensors is in contact with the navigable surface.
2. The fully autonomous vehicle of claim 1, wherein the processing circuit processes, using one or more machine learning algorithms, the information corresponding to the variations that is received from the plurality of sensors.
3. The fully autonomous vehicle of claim 2, wherein the one or more machine learning algorithms comprises at least one support vector machine algorithm.
4. The fully autonomous vehicle of any of claims 2-3, wherein the one or more machine learning algorithms comprises at least one neural network algorithm.
5. The fully autonomous vehicle of any of claims 1-4, wherein the processing circuit transmits the information collected by the plurality of sensors to a remote server, wherein the remote server exchanges information with other vehicles connected to the remote server.

6. The fully autonomous vehicle of any of claims 1-5, wherein the processing circuit transmits the information collected by the plurality of sensors to one or more other vehicles that are in a vicinity of the AV corresponding to the plurality of sensors.

7. The fully autonomous vehicle of any of claims 1-6, wherein augmenting the driving capability of the AV further comprises:

determining, using the processing circuit, that the navigable surface has a level of traction that is below a threshold; and

in response to the determination, reducing, using a control circuit, a speed of the AV.

8. The fully autonomous vehicle of any of claims 1-7, wherein augmenting the driving capability of the vehicle comprises:

detecting, using the processing circuit, an obstacle on the road according to the information collected by the plurality of sensors; and

in response to the detecting, adjusting, using a control circuit, a steering of the AV to avoid the obstacle.

9. The fully autonomous vehicle of any of claims 1-8, wherein the processing circuit is configured to:

detect lane demarcations on a surface of the road according to the information collected by the plurality of sensors, wherein the lane demarcations are distinguishable from the navigable surface according to the information collected by the plurality of sensors; and

generate a map of lane lines on the surface of the road using the lane demarcations.

10. The fully autonomous vehicle of any of claims 1-9, wherein augmenting the driving capability of the vehicle comprises:

determining, using the processing circuit, that the variations of the navigable surface occur at periodic intervals; and

in response to the determination, steering, using a control circuit, the AV in a direction towards a section of the road away from the variations on the surface of the road.

11. The fully autonomous vehicle of any of claims 1-10, wherein augmenting the driving capability of the AV comprises:

determining, using the processing circuit, that the variations of the navigable surface occur at periodic intervals; and

in response to the determination, reducing a speed of the AV.

12. The fully autonomous vehicle of any of claims 1-11, wherein augmenting the driving capability of the vehicle comprises:

determining, using the information collected by the plurality of sensors, a slip ratio of a surface of the road;

in response to the determination, estimating a friction value of the surface of the road;

and

adjusting the driving capability of the AV in accordance with the estimated friction value.

13. The fully autonomous vehicle of claim 12, wherein augmenting the driving capability of the vehicle further comprises:

determining, using the estimated friction value, a type of material used for a surface of the road; and

adjusting a speed of the AV in accordance with type of material used for the surface of the road.

14. The fully autonomous vehicle of any of claims 1-13, wherein augmenting the driving capability of the vehicle comprises:

performing a look up of a friction table using the information collected by the plurality of sensors;

in response to the look up, estimating a friction value of a surface of the road; and

adjusting the driving capability of the AV in accordance with the estimated friction value.

15. The fully autonomous vehicle of any of claims 1-14, wherein the plurality of sensors comprises:

a first sensor;

a second sensor; and

wherein the first sensor processes information of a first type and the second sensor processes information of a second type that is different than the first type.

16. The fully autonomous vehicle of any of claims 1-15, wherein the processing circuit generates, using the information collected by the plurality of sensors, a height map of a surface of the road.

17. The fully autonomous vehicle of any of claims 1-16, wherein the processing circuit is configured to:

determine, using the information collected by the plurality of sensors, a condition of a surface of the road; and

classify the determined condition of the surface of the road as having one or more of snow, ice, rain or obstacles.

18. The fully autonomous vehicle of any of claims 1-17, wherein augmenting the driving capability of the AV comprises:

receiving, from one or more neighboring vehicles, additional information about variations of the navigable surface;

comparing the information collected by the plurality of sensors to the additional information received from the one or more neighboring vehicles; and

computing a confidence measure in the information collected by the plurality of sensors in accordance with the comparison.

19. The fully autonomous vehicle of any of claims 1-18, wherein the plurality of sensors comprises a sensor array, and wherein the sensor array includes sensors positioned in one or more rows.

20. The fully autonomous vehicle of any of claims 1-19, wherein the plurality of sensors comprises one or more sensors embedded in at least one of a tire of the AV or a suspension of the AV.
21. A method of operating a fully autonomous vehicle using the fully autonomous vehicle of any of claims 1-20.
22. A system comprising:
a fully autonomous vehicle (AV); characterized in that the system comprises:
a plurality of sensors coupled to the AV; and
a first device with one or more processors and memory, the first device performing operations to detect road anomalies and adjust the driving capability of the AV using the actions of any of claims 1-20.
23. A non-transitory computer-readable medium encoding instructions operable to cause a data processing apparatus to detect road anomalies and adjust the driving capability of a fully autonomous vehicle using the actions of any of claims 1-20.