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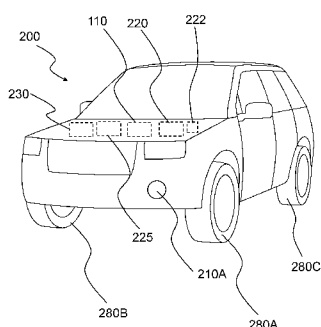


FIG. 2A

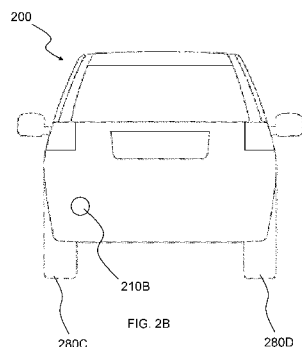


FIG. 2B

(57) Abstract: Aspects of the present invention relate to a control system (100) for controlling a recovery mode of a vehicle (200) for recovery of an object connected to a hitch point (210A-B) of the vehicle (200), the control system (100) comprising one or more processors collectively configured to receive lateral position data (160) indicative of a lateral movement and/or rotation of the vehicle (200), receive steering angle data (162) indicative of a steering angle of a first set of wheels (280A-D) of the vehicle (200), determine, in dependence on the lateral position data (160) and steering angle data (162), a further steering angle to be applied to a second set of wheels (280A-D) of the vehicle (200) to control the lateral movement and/or rotation of the vehicle (200) and counter the steering angle of the first set of wheels, and output a control signal (170) to cause a steering system (220) of the vehicle (200) to apply the further steering angle to the second set of wheels (280A-D). Aspects of the invention also relate to a system incorporating the control system (100) and a steering system (220) of a vehicle (200), a vehicle (200) incorporating the control system (100) or the system, and a method (300) of controlling a recovery mode of a vehicle (200).

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ASSISTED RECOVERY MODE

TECHNICAL FIELD

The present disclosure relates to a vehicle control system and control method for controlling an assisted recovery mode of a vehicle. Aspects of the invention relate to a control system, a system, a vehicle and a method.

BACKGROUND

It is known to use a vehicle to provide recovery assistance to an object such as another vehicle that has broken down or is stuck in a stationary position, for example, due to a slippery surface such as mud or sand, or due to an obstruction on the ground preventing the object from moving. To provide recovery assistance, the vehicle will usually be connected to the recovery vehicle via a hitch point and a tow rope. The vehicle will then put into drive to pull the object to another location, either to get further assistance or to a position where it is able to move. However, factors such as the characteristics of the terrain that the vehicle is on and the weight of the object can make it difficult for the vehicle to maintain traction throughout the recovery process, which can hamper the success of the recovery.

It is an aim of the present invention to address one or more of the disadvantages associated with the prior art.

SUMMARY OF THE INVENTION

Aspects and embodiments of the invention provide a control system, a system, a vehicle, and a method as claimed in the appended claims.

This disclosure provides a technique for improving the assisted recovery of a vehicle. The technique determines a steering angle to be applied to a set of wheels of the vehicle to counter act the steering angle being applied to another set of wheels, and control any other lateral movement and/or rotation experienced by the vehicle.

According to an aspect of the present invention there is provided a control system for controlling a recovery mode of a vehicle for recovery of an object connected to a hitch point of the vehicle, the control system comprising one or more processors collectively configured to receive lateral position data indicative of a lateral movement and/or rotation of the vehicle and receive steering angle data indicative of a steering angle of a first set of wheels of the vehicle. The one or more processors are collectively configured to determine, in dependence on the lateral position data and steering angle data, a further steering angle to be applied to a second set of wheels of the vehicle to control the lateral movement and/or rotation of the vehicle and counter the steering angle of the first set of wheels, and output a control signal to cause a steering system of the vehicle to apply the further steering angle to the second set of wheels.

In this way, the impact of any lateral movement or yaw rotation on the amount of effective longitudinal force achieved as torque is applied to the drivetrain is reduced, thereby minimising wheel slip. Additionally, by

providing a counter rotation to the steering applied to one set of wheels, this helps to maintain the steering and intended direction of travel.

The control system comprises one or more controllers collectively comprising at least one electronic processor having an electrical input for receiving an input signal; and at least one memory device electrically coupled to the at least one electronic processor and having instructions stored therein; and wherein the at least one electronic processor is configured to access the at least one memory device and execute the instructions thereon so as to receive lateral position data indicative of a lateral movement and/or rotation of the vehicle; receive steering angle data indicative of a steering angle of a first set of wheels of the vehicle; determine, in dependence on the lateral position data and steering angle data, a further steering angle to be applied to a second set of wheels of the vehicle to control the lateral movement and/or rotation of the vehicle and counter the steering angle of the first set of wheels; and output a control signal to cause a steering system of the vehicle to apply the further steering angle to the second set of wheels.

Optionally, the one or more processors may be configured to determine, in dependence on the steering angle data, an initial steering angle to counter the steering angle of the first set of wheels, and adjust, in dependence on the lateral position data, a magnitude and/or direction of the initial steering angle in dependence on a magnitude and/or direction of the lateral movement and/or rotation of the vehicle to thereby determine the further steering angle to be applied to the second set of wheels.

In this way, the steering angle applied to the second set of wheels to counter the steering of the first set of wheels can be adjusted to control any lateral movement and/or rotation experienced by the vehicle, whilst still maintaining the intended direction of travel. For example, if the vehicle is experiencing lateral movement and/or yaw rotation in substantially the same direction as the steering angle applied to the first set of wheels, the counter angle applied to the second set of wheels may be increased to counter the lateral movement and/or rotation. Similarly, if the vehicle is experiencing lateral movement and/or yaw rotation in the opposite direction to the steering angle applied to the first set of wheels, the counter angle applied to the second set of wheels may be decreased so as to control the lateral movement and/or rotation experienced by the vehicle.

Optionally, the one or more processors may be further configured to determine, in dependence on the lateral position data and steering wheel angle data, whether to operate one or more further systems of the vehicle to further control the lateral movement and/or rotation of the vehicle, and output, in dependence on the determining, a further control signal to operate the one or more further systems of the vehicle to further control the lateral movement and/or rotation of the vehicle.

In this way, further systems may be used to further offset any lateral movement or yaw rotation experienced by the vehicle, and thereby reduce the impact on the amount of effective longitudinal force achieved as torque is applied to the drivetrain.

The one or more processors may be configured to output the further control signal to operate the one or more further systems if the steering angle of the first set of wheels is within a predetermined angle range.

In this way, if only a small amount of steering angle is applied to the first set of wheels, such that the lateral movement and/or yaw rotation experienced by the vehicle is not the result of any steering and the counter rotation applied at the second set of wheels is therefore not sufficient to offset the lateral movement and/or yaw rotation of the vehicle, further systems can be used to offset the lateral movement or yaw rotation. For example, the predetermined angle range may comprise a steering wheel angle between -5° and $+5^{\circ}$ relative to the longitudinal centre line of the vehicle. As another example, the predetermined angle range may comprise a wheel angle of between -3° and $+3^{\circ}$ relative to the longitudinal centre line of the vehicle.

Optionally, the one or more processors may be configured to output the further control signal to operate the one or more further systems if the lateral movement and/or rotation of the vehicle is in a direction opposite to the steering angle of the first set of wheels.

In this way, if a relatively large steering angle is being applied but the lateral and movement and/or yaw rotation is in the opposite direction (i.e., it is not the result of the steering angle and the counter rotation applied to the second set of wheels may add to the lateral movement and/or rotation), further systems can be used to offset the lateral movement or yaw rotation.

Optionally, the one or more processors may be configured to output the further control signal to operate the one or more further systems if the lateral movement and/or rotation of the vehicle is at or above a threshold amount of lateral movement and/or rotation.

In this way, if the vehicle is experiencing a large amount of lateral movement or yaw rotation, such that the counter rotation applied at the second set of wheels is not sufficient to offset the lateral movement, further systems can be used to help provide the level of offset required. Conversely, if the lateral movement and/or rotation is below the threshold amount, the counter angle applied to the second set of wheels may be sufficient. For example, the threshold for lateral movement may be predetermined and correspond to an angle of $\pm 30^{\circ}$ about the roll axis of the vehicle 200. Similarly, the threshold for rotation may be predetermined and correspond to an angle of $\pm 30^{\circ}$ about the yaw axis of the vehicle 200. As another example, the one or more processors may be configured to determine the threshold amount of lateral movement and/or rotation based on one or more of the terrain mode of the vehicle, the rolling resistance between the wheels and the below surface, and the estimated coefficient of friction between the wheels and below surface.

Optionally, the one or more further systems may comprise one or more of a braking system of the vehicle, a suspension system of the vehicle, and one or more individual corner motors of the vehicle. It will however be appreciated that any other system that can control the orientation of the vehicle may be used.

Optionally, the one or more processors may be configured to receive the steering angle data from a steering angle sensor of the vehicle. The steering angle sensor may be located in any suitable position for measuring the steering angle applied to the wheels of the vehicle, for example, on the steering column connecting the steering wheel to the steering system.

Optionally, the one or more processors may be configured to receive the lateral position data from an inertial measurement unit of the vehicle.

- 5 Optionally, the first set of wheels may be remote from the hitch point, and the second set of wheels may be proximate to the hitch point.

In this way, the counter rotation applied to the loaded axle helps to maintain the steering at the unloaded axle and thereby minimise any lateral sliding of the wheels.

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Optionally, the first set of wheels may be coupled to a front axle of the vehicle, and the second set of wheels may be coupled to a rear axle of the vehicle. Conversely, however, it will be appreciated that the first set wheels may be coupled to the rear axle of the vehicle, and the second set of wheels may be coupled to the front axle of the vehicle.

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According to another aspect of the invention, there is provided a system comprising the control system as mentioned above and a steering system of the vehicle.

- 20 Optionally, the system may further comprise one or more of a braking system of the vehicle, a suspension system of the vehicle, and one or more individual corner motors of the vehicle.

According to yet another aspect of the invention, there is provided a vehicle comprising the system as mentioned above or the control system as mentioned above.

- 25 According to a further aspect of the invention, there is provided a method for controlling a recovery mode of a vehicle for recovery of an object connected to a hitch point of the vehicle. The method comprises receiving lateral position data indicative of a lateral movement and/or rotation of the vehicle, and receiving steering angle data indicative of a steering angle of a first set of wheels of the vehicle. The method also comprises determining, in dependence on the lateral position data and steering angle data, a further steering angle to be
30 applied to a second set of wheels of the vehicle to control the lateral movement and/or rotation of the vehicle and counter the steering angle of the first set of wheels, and outputting a control signal to cause a steering system of the vehicle to apply the further steering angle to the second set of wheels.

- 35 According to a still further aspect of the invention, there is provided a computer readable instructions which, when executed by a computer, are arranged to perform the method as mentioned above.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination.

- 40 That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or

file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

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One or more embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

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Figure 1 shows a block diagram illustrating a control system according to an embodiment of the present invention;

Figure 2A shows a schematic illustration of a vehicle according to an embodiment of the present invention;

Figure 2B shows a schematic illustration of a rear-view of the vehicle of Figure 2A;

Figure 3 shows a first flow chart showing operations performed by the control system of Figure 1 according to an embodiment of the present invention;

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Figure 4 shows a second flow chart showing operations performed by the control system of Figure 1 according to an embodiment of the present invention.

DETAILED DESCRIPTION

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With reference to Figure 1, there is illustrated a control system 100 for a vehicle. The control system 100 as illustrated in Figure 1 comprises one controller 110, although it will be appreciated that this is merely illustrative. The controller 110 comprises processing means 120 and memory means 130. The processing means 120 may be one or more electronic processing device 120 which operably executes computer-readable instructions. The memory means 130 may be one or more memory device 130. The memory means 130 is electrically coupled to the processing means 120. The memory means 130 is configured to store instructions, and the processing means 120 is configured to access the memory means 130 and execute the instructions stored thereon.

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The controller 110 comprises an input means 140 and an output means 150. The input means 140 may comprise an electrical input 140 of the controller 110. The output means 150 may comprise an electrical output of the controller 110. The input means 140 is arranged to receive a vehicle orientation signal 160 from one or more sensors of the vehicle, for example, an inertial measurement unit (IMU) of the vehicle. The vehicle orientation signal 160 is an electrical signal which is indicative of one or more characteristics of the orientation of the vehicle, including but not limited to, a gradient of the vehicle, a rotation of the vehicle (e.g., the rotation of the vehicle about its yaw axis) and a lateral movement of the vehicle (e.g., the lateral movement of the vehicle about its roll axis). The input means 140 is also arranged to receive a steering angle signal 162 from a steering angle sensor of the vehicle. The steering angle signal 162 is an electrical signal which is indicative of a steering angle of at least a first set of wheels of the vehicle. The input means 140 may also be optionally arranged to receive a recovery mode signal 164 from a user via a human-machine interface (HMI) of the vehicle 200 instructing the controller 110 to start operating the vehicle in a recovery mode which aids an assisted recovery of an object.

The output means 150 is arranged to output a steering control signal 170 to a steering system of the vehicle to cause the steering system to control a steering of a second set of wheels of the vehicle. The output means 150 may be optionally arranged to output a lateral control signal 172 to one or more further systems of the vehicle, to thereby operate the one or more further systems to control a lateral movement and/or rotation of the vehicle. The output means 150 may also be optionally arranged to output a driver control signal 174 to a human-machine interface (HMI) of the vehicle requesting the driver of the vehicle to move the vehicle. In cases where the vehicle is an autonomous or semi-autonomous vehicle, it will be appreciated that the driver control signal 174 may be output to an autonomous control system.

Figure 2A illustrates a vehicle 200 according to an embodiment of the present invention. The vehicle 200 comprises a controller 110 as illustrated in Figure 1. The controller 110 is shown as mounted within the vehicle 200 and is in communication with a steering system 220 located within the vehicle 200 such that the steering control signal 170 can be transmitted to the steering system 220. The controller 110 may also be in communication with a steering angle sensor 222 located within the vehicle 200 such that the steering angle signal 162 is transmitted from the steering angle sensor 222 to the controller 110. The steering angle sensor 222 may be provided on the steering column of the vehicle 200, and may also be integrated and/or in communication with the steering system 220. Similarly, the controller 110 may also be in communication with an inertial measurement unit 230 located within the vehicle 200 such that the orientation signal 160 is transmitted from the inertial measurement unit 230 to the controller 110. The controller 110 may also be in further communication with one of further control systems (shown generally at 225) located within the vehicle 200 such that the control signal 172 and 174 can be transmitted to the plurality of further control systems. The plurality of further control systems 225 may include, but not limited to, one or more of: a suspension system, one or more individual corner motors, a braking system of the vehicle, and a human-machine interface.

Vehicle 200 may be an EGO vehicle, i.e., a vehicle that is equipped with autonomous or semi-autonomous driving technology and is capable of sensing and navigating its environment without direct input from a human driver.

Vehicle 200 has at least one hitch point for connecting the vehicle 200 to an object in need of recovery. For example, vehicle 200 may have a first hitch point 210A located at the front of the vehicle 200, proximate to a front set of wheels 280A, 280B. It will of course be appreciated that this is purely illustrative and the first hitch point 210A may be located at any suitable position on the front of the vehicle 200. Similarly, there may be more than one hitch point located on the front of the vehicle 200.

Figure 2B illustrates a rear-view of the vehicle 200 of Figure 2A. The vehicle 200 may also have a second hitch point 210B located at the rear of the vehicle 200, proximate to a rear set of wheels 280C, 280D, for connecting the vehicle 200 to an object in need of recovery. It will again be appreciated that this is purely illustrative and the second hitch point 210B may be located at any suitable position on the rear of the vehicle 200. Similarly, there may be multiple hitch points on the rear of the vehicle 200. It will also be appreciated that the vehicle 200 may have one or both of the first and second hitch points 210A, 210B. The hitch points 210A, 210B provide

a connection point, to which a rope or some other connection means may be attached to the vehicle 200, to thereby connect the vehicle 200 to an object in need of recovery.

The steering system 220 may be configured to control the steering angle of the wheels 280A-D. In this respect, it will be appreciated that the wheels 280A-D may be controlled individually, with the steering angle being controlled directly by the steering system 220. Optionally, the front set of wheels 280A, 280B may be coupled to a first axle, and the rear set of wheels 280C, 280D may be coupled to a second axle. The steering system 220 may thus be configured to control the steering angle of the wheels 280A-D via the first and second axles.

It will of course be appreciated that the vehicle 200 may be operated to assist in the recovery of any suitable object, including but not limited to, a second vehicle, a trailer, a boat, a boulder, wood logs, or any object having weight that does not exceed the power capabilities of the vehicle 200.

Figure 3 is a flowchart 300 according to an embodiment of the present invention. The flowchart 300 illustrates steps performed by the control system 100 in controlling a recovery mode of a vehicle 200, such as the vehicle 200 illustrated in Figures 2A and 2B. In particular, the memory 130 may comprise computer-readable instructions which, when executed by the processor 120, perform the method 300 according to an embodiment of the invention.

At step 310, the control system 100 is configured to receive lateral position data of the vehicle 200. The lateral position data is received as an input signal 160 at the input means 140 of the controller 110 and comprises data indicative of the lateral movement and/or rotation of the vehicle 200 as measured by one or more sensors of the vehicle 200, such as an inertial measurement unit (IMU). It will be appreciated that the position of the vehicle about a roll axis and/or a yaw axis is indicative of any lateral movement and/or rotation being experienced by the vehicle 200, for example, induced by the load from an object being applied to a hitch point 210A, 210B that is laterally offset from the longitudinal centre line of the vehicle 200. Such lateral movement can reduce the amount of effective longitudinal force achieved as torque is applied by the drivetrain, which may in turn cause the wheels to slip as the vehicle 200 begins to move.

At step 320, the control system 100 is configured to receive steering angle data of the vehicle 200. The steering angle data is received as an input signal 162 at the input means 140 of the controller 110 and comprises data indicative of the position of the steering wheel, for example, as measured by a steering wheel angle sensor of the vehicle 200, which in turn indicates whether the wheels 280A-D of the vehicle 200 are orientated away from the longitudinal centre line of the vehicle 200. For example, the assisted recovery may be taking place on a curved road, and so the user may have the steering wheel turned at an angle so that the vehicle 200 moves around the curve of the road, which may itself induce some lateral movement and/or rotation of the vehicle 200. In such cases, the steering wheel angle data 162 may be indicative of a steering angle of at least a first set of wheels 280A-B of the vehicle 200, which may be the set of wheels 280A-B at the front of the vehicle 200, optionally, coupled to a front axle of the vehicle 200. It will however be appreciated that the first set of wheels may instead be the wheels 280C-D at the rear of the vehicle 200, optionally, coupled to a rear axle of the vehicle 200.

From the lateral position data and steering angle data, at step 330, the processing means 120 is configured to determine a further steering angle to be applied to a second set of wheels 280C-D of the vehicle 200 to control the lateral movement and/or rotation of the vehicle and counter the steering angle of the first set of wheels 280A-B. In cases where the first set of wheels 280A-B are those coupled to the front axle, the second set of wheels 280C-D may be the set of wheels coupled to the rear axle of the vehicle 200. However, it will be appreciated that in cases where the first set of wheels are those coupled to the rear axle, the second set of wheels may be those coupled to the front axle. As such, if the steering angle data indicates that the first set of wheels 280A-B are rotated at a first angle relative to the longitudinal centre line of the vehicle 200, the further steering angle will be determined so as to counteract this first angle. If the lateral position data indicates additional lateral movement and/or rotation in a particular direction (e.g., due to the load on the hitch point 210A, 210B), the magnitude and/or direction of the further steering angle may be adjusted depending on the magnitude and/or direction of the lateral movement and/or rotation. As such, the processing means 120 may be configured to determine an initial steering angle to counter the steering angle of the first set of wheels 280A-B, and then adjust the magnitude and/or direction of the initial steering angle in dependence on the magnitude and/or direction of the lateral movement and/or rotation to thereby provide the steering angle to be applied to the second set of wheels 280C-D.

For example, if the first set of wheels are rotated at an angle of 45° in a clockwise direction relative to the longitudinal centre line of the vehicle 200 (i.e., so as to turn the vehicle 200 towards the right from the view point of a driver or passenger), the further steering angle may be determined to be 45° in an anti-clockwise direction relative to the longitudinal centre line of the vehicle 200 (i.e., so as to turn towards the left). If the lateral position data indicates additional lateral movement and/or rotation due to the load applied to the hitch point 210A, 210B that is in substantially the same direction as the steering angle of the first set of wheels 280A-B (e.g., the vehicle 200 is leaning to the right side from the view point of the driver), a larger further steering angle in the anti-clockwise direction may be determined so as to further counter this lateral movement and/or rotation. Conversely, if the lateral position data indicates additional lateral movement and/or rotation due to the load applied to the hitch point 210A, 210B that is in the opposite direction as the steering angle of the first set of wheels 280A-B (e.g., the vehicle 200 is leaning towards the left side from the view point of the driver), a smaller further steering angle in the anti-clockwise direction may be determined so as to control this lateral movement and/or rotation, whilst still maintaining the intended direction of travel.

Once the processing means 120 has determined the further steering angle to be applied to the second set of wheels 280C-D of the vehicle 200 so as to control the lateral movement and/or rotation of the vehicle 200 and counter the steering angle of the first set of wheels 280A-B, the controller 110 outputs, at step 340, a control signal 170 to cause the steering system 220 of the vehicle 200 to apply the further steering angle to the second set of wheels 280C-D. In this way, the impact of lateral movement or yaw rotation on the amount of effective longitudinal force achieved as torque is applied to the drivetrain is reduced, thereby minimising wheel slip. Additionally, by providing a counter rotation to the steering applied to one set of wheels, this helps to maintain the steering and intended direction of travel.

Optionally, prior to step 310, the control system 100 may be configured to receive user input data from a human-machine interface of the vehicle 200. The user input data is received as an input signal 164 at the input means 140 of the controller 100 and comprises data indicating a request to begin operating in the recovery mode of the vehicle 200.

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Alternatively, or additionally, once the control signal 170 has been output to the steering system 220 of the vehicle 200, the controller may also output a driver control signal 174 to a human-machine interface (HMI) of the vehicle 200 requesting the driver of the vehicle 200 to begin moving the vehicle 200. In cases where the vehicle 200 is an autonomous or semi-autonomous vehicle, it will be appreciated that the driver control signal 174 may be output to an autonomous control system.

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Figure 4 is a flowchart 400 according to an embodiment of the present invention. The flowchart 400 illustrates steps performed by the control system 100 in controlling a recovery mode of a vehicle 200, such as the vehicle 200 illustrated in Figures 2A and 2B.

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Steps 310, 320, 330, and 340 are the same as illustrated in Figure 3 and their discussion is not repeated in detail for brevity. However, compared to Figure 3, the flowchart 400 of Figure 4 contains a further step 335 at which the control system 100 determines whether to operate one or more further systems 225 of the vehicle 200 so as to further control the detected lateral movement and/or rotation. The processing means 120 receives the input signals 160 and 162 from the input means 140 and, upon executing the instructions stored in the memory means 130, determines whether to operate one or more further systems 225 of the vehicle 200 so as to further control the detected lateral movement and/or rotation.

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For example, if there is no angle applied to the steering of the vehicle 200 or the steering angle is within a predetermined angle range (e.g., the angle of the steering wheel is within $\pm 5^\circ$ relative to the longitudinal centre line of the vehicle 200, or the angle of the wheels is within about $\pm 2^\circ$ to $\pm 3^\circ$ relative to the longitudinal centre line of the vehicle 200), and the lateral position data indicates that the vehicle 200 is leaning to one side, for example, towards the side of the hitch point 210A, 210B, it may be determined that one or more further systems 225 of the vehicle 200 should be operated so as to offset the lateral movement and/or rotation. As one example, a braking system of the vehicle 200 may be controlled so as to keep the wheels 280A-D of the vehicle 200 in substantially the same line as the longitudinal centre line of the vehicle 200, or at least maintain any steering angle applied. As another example, one or more individual corner motors of the vehicle 200 may be controlled so as to keep the wheels 280A-D of the vehicle 200 substantially aligned with the longitudinal centre line of the vehicle 200, or at least maintain any steering angle applied. As a further example, the suspension system 225 of the vehicle 200 may be controlled so as to lean the vehicle 200 away from the direction of the lateral movement and/or rotation. For example, if there is lateral movement and/or rotation towards the wheel 280A-D of the vehicle 200 proximate to the hitch point 210A, 210B, the height of the suspension may be adjusted so as to counteract the lateral movement and/or rotation, for example, by increasing the air pressure in the suspension proximate to the hitch point 210A, 210B.

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In this way, if no steering angle or only a small amount of steering angle is applied to the first set of wheels 280A-B, such that the lateral movement or yaw rotation is not primarily the result of any steering, and the counter rotation applied at the second set of wheels 280C-D is not sufficient to offset the lateral movement or yaw rotation of the vehicle 200, one or more further systems 225 can be used to offset the lateral movement or yaw rotation.

If an angle is being applied to the steering of the vehicle 200, as described above, and the lateral position data 160 indicates that the vehicle 200 is leaning or rotating in generally the same direction as the steering angle, the processing means 120 may determine that it is not necessary to offset that lateral movement and/or rotation with the one or more further systems 225. Conversely, if the lateral position data 160 indicates that the vehicle 200 is leaning or rotating in generally the opposite direction as the steering angle (e.g., relative to the longitudinal centre line of the vehicle 200), the processing means 120 may determine that one or more further systems 225 of the vehicle 200 should be operated so as to control this lateral movement and/or rotation, to thereby help maintain the steering and intended direction of travel. For example, the braking system of the vehicle 200 may be operated so as to apply braking to the wheels 280A-D of vehicle 200 to help maintain the steering and intended direction of travel. In this respect, applying braking to the wheels positioned on the side of the vehicle 200 corresponding to the intended direction of travel (i.e., the right wheels 280B, 280D if the steering angle corresponds to right turn, or the left wheels 280A, 280C if the steering angle corresponds to a left turn) will help to increase the rate of rotation in the intended direction. Conversely, if there excessive lateral movement and/or rotation in the direction of the steering angle, the braking system may apply braking to the wheels positioned on the side of the vehicle 200 corresponding to the opposite direction of the steering angle (i.e., the right wheels 280B, 280D if the steering angle corresponds to left turn, or the left wheels 280A, 280C if the steering angle corresponds to a right turn) to thereby decrease the rate of rotation.

Optionally, the processing means 120 may be configured to determine whether the amount of lateral movement and/or rotation in either direction is at or above a threshold, and determine that one or more further systems 225 should be operated so as to control this lateral movement and/or rotation if the amount of lateral movement and/or rotation is at or above the threshold. It will be appreciated that the threshold may be any suitable threshold corresponding to an amount of lateral movement and/or rotation whereby the application of counter steering alone becomes insufficient to control the lateral movement and/or rotation of the vehicle 200. For example, the threshold for lateral movement may be predetermined and correspond to an angle of $\pm 30^\circ$ about the roll axis of the vehicle 200. Similarly, the threshold for rotation may be predetermined and correspond to an angle of $\pm 30^\circ$ about the yaw axis of the vehicle 200. As another example, the processing means 120 may be configured to determine the threshold based on one or more of a terrain mode of the vehicle 200, the rolling resistance between the wheels 280A-D and the below surface and the coefficient of friction between the wheels 280A-D and the below surface. For example, on a surface having a low coefficient of resistance such as snow or ice, a larger threshold of lateral movement may be determined, whilst a smaller threshold of lateral movement may be determined for a more deformable surface such as wet grass or sand. In this respect, the threshold may be determined based on these inputs using a look-up table stored in the memory means 130. Similarly, if the vehicle 200 is mid-recovery such that torque is already being applied to the wheels 280A-D, a larger threshold of lateral movement and/or rotation may be determined.

In this way, if the vehicle 200 is experiencing a large amount of lateral movement or yaw rotation (e.g., due to the steering angle and the load on the hitch point 210A, 210B), such that the counter rotation applied at the second set of wheels 280C-D is not sufficient to offset the lateral movement and/or rotation, one or more further systems 225 can be used to help provide the level of offset required.

Once the processing means 120 has determined whether to operate one or more further systems 225 of the vehicle 200 so as to control the detected lateral movement, the controller 110 outputs, at step 340, a further control signal 172 to cause one or more further systems 225 of the vehicle 200 to further control the detected lateral movement and/or rotation. For example, the control signal 172 may be output as a brake control signal to the braking system of the vehicle 200, or a suspension control signal to the suspension system of the vehicle 200. A control signal may also be output to one or more individual corner motors of the vehicle 200.

It will be appreciated that various changes and modifications can be made to the present invention without departing from the scope of the present application.

CLAIMS

1. A control system for controlling a recovery mode of a vehicle for recovery of an object connected to a hitch point of the vehicle, the control system comprising one or more processors collectively configured to:
- 5 receive lateral position data indicative of a lateral movement and/or rotation of the vehicle;
receive steering angle data indicative of a steering angle of a first set of wheels of the vehicle;
determine, in dependence on the lateral position data and steering angle data, a further steering angle to be applied to a second set of wheels of the vehicle to control the lateral movement and/or rotation of the vehicle and counter the steering angle of the first set of wheels; and
- 10 output a control signal to cause a steering system of the vehicle to apply the further steering angle to the second set of wheels.
2. A control system according to claim 1, wherein the one or more processors are configured to:
- 15 determine, in dependence on the steering angle data, an initial steering angle to counter the steering angle of the first set of wheels; and
adjust, in dependence on the lateral position data, a magnitude and/or direction of the initial steering angle in dependence on a magnitude and/or direction of the lateral movement and/or rotation of the vehicle to thereby determine the further steering angle to be applied to the second set of wheels.
- 20 3. A control system according to any preceding claim, wherein the one or more processors are further configured to:
- determine, in dependence on the lateral position data and/or steering wheel angle data, whether to operate one or more further systems of the vehicle to further control the lateral movement and/or rotation of the vehicle; and
- 25 output, in dependence on the determining, a further control signal to operate the one or more further systems of the vehicle to further control the lateral movement and/or rotation of the vehicle.
4. A control system according to claim 3, wherein the one or more processors are configured to output the further control signal to operate the one or more further systems if the steering angle of the first set of wheels is within a predetermined angle range.
- 30 5. A control system according to claim 3, wherein the one or more processors are configured to output the further control signal to operate the one or more further systems if the lateral movement and/or rotation of the vehicle is in a direction opposite to the steering angle of the first set of wheels.
- 35 6. A control system according to any of claims 3 to 5, wherein the one or more processors are configured to output the further control signal to operate the one or more further systems if the lateral movement and/or rotation of the vehicle is at or above a threshold amount of lateral movement and/or rotation.

7. A control system according to any of claims 3 to 6, wherein the one or more further systems comprises one or more of a braking system of the vehicle, a suspension system of the vehicle, and one or more individual corner motors of the vehicle.

8. A control system according to any preceding claim, wherein one or more processors are configured to receive the steering angle data from a steering angle sensor of the vehicle.

9. A control system according to any preceding claim, wherein one or more processors are configured to receive the lateral position data from an inertial measurement unit of the vehicle.

10. A control system according to any preceding claim, wherein the first set of wheels is remote from the hitch point, and the second set of wheels is proximate to the hitch point.

11. A control system according to any preceding claim, wherein the first set of wheels is coupled to a front axle of the vehicle, and the second set of wheels is coupled to a rear axle of the vehicle.

12. A system comprising the control system of any preceding claim and a steering system of the vehicle.

13. A system according to claim 12, wherein the system further comprises one or more of a braking system of the vehicle, a suspension system of the vehicle, and one or more individual corner motors of the vehicle.

14. A vehicle comprising the system of claims 12 or 13 or the control system of claims 1 to 11.

15. A method for controlling a recovery mode of a vehicle for recovery of an object connected to a hitch point of the vehicle, the method comprising:

receiving lateral position data indicative of a lateral movement and/or rotation of the vehicle;

receiving steering angle data indicative of a steering angle of a first set of wheels of the vehicle;

determining, in dependence on the lateral position data and steering angle data, a further steering angle to be applied to a second set of wheels of the vehicle to control the lateral movement and/or rotation of the vehicle and counter the steering angle of the first set of wheels; and

outputting a control signal to cause a steering system of the vehicle to apply the further steering angle to the second set of wheels.

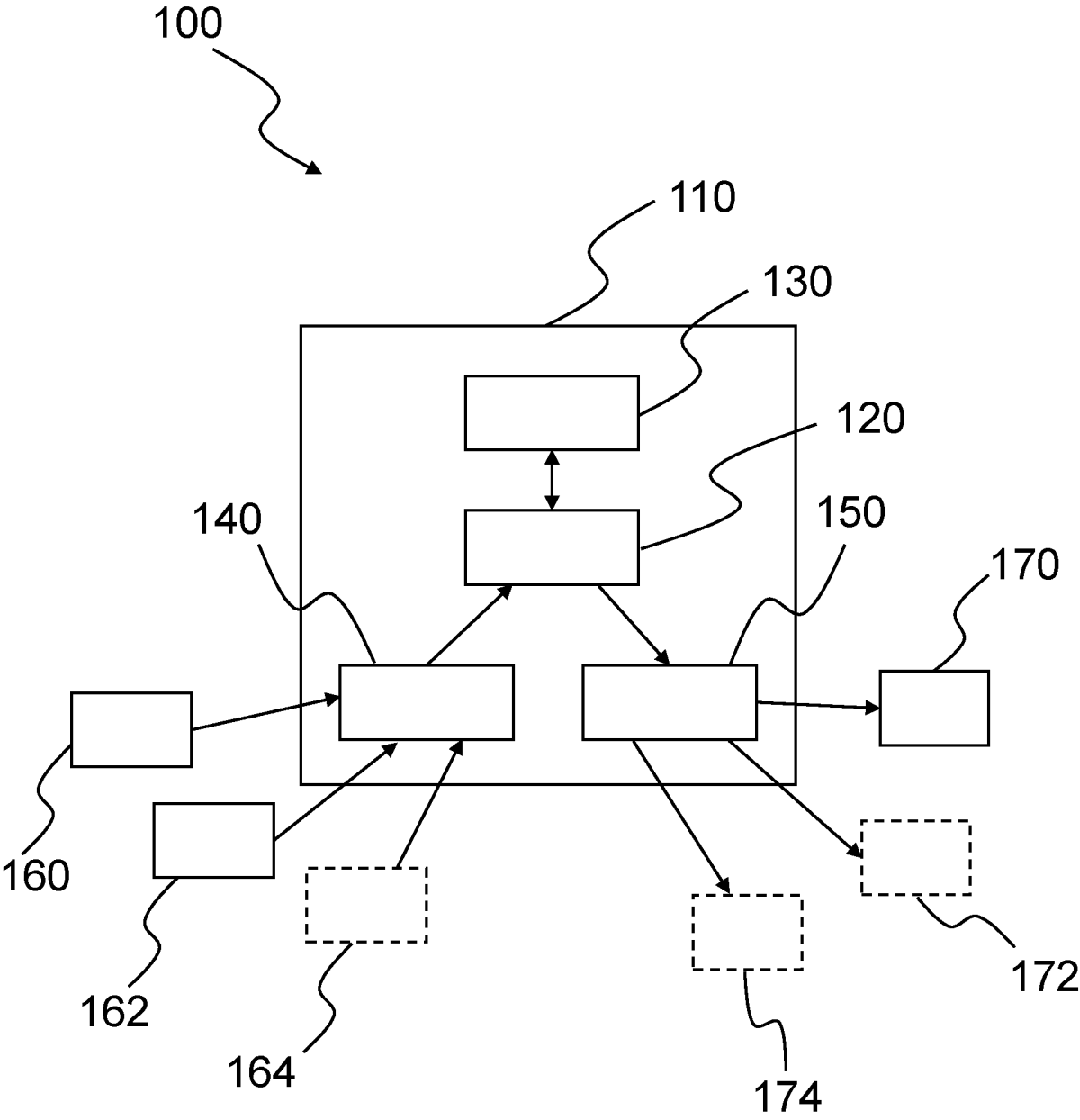


FIG. 1

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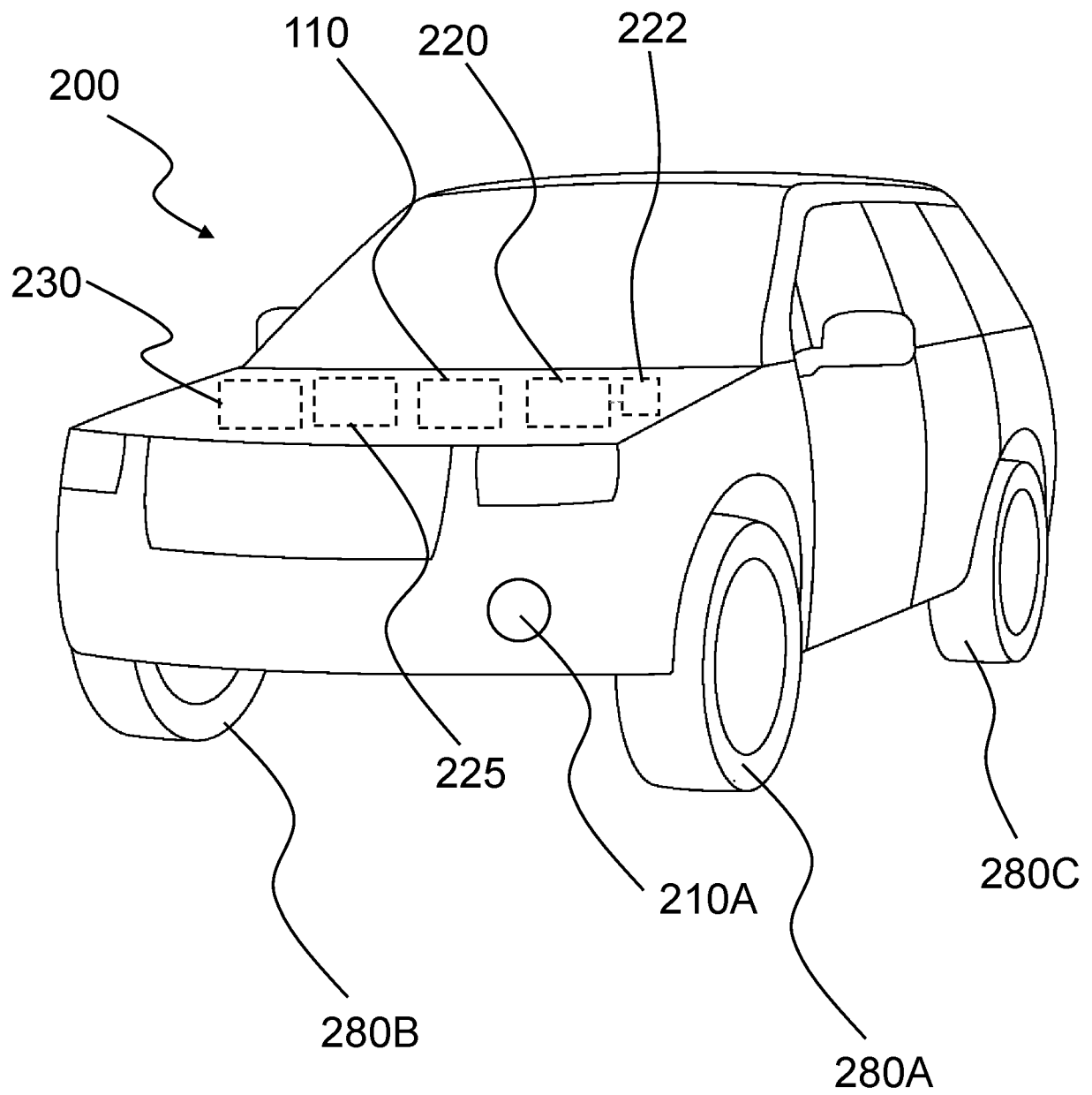
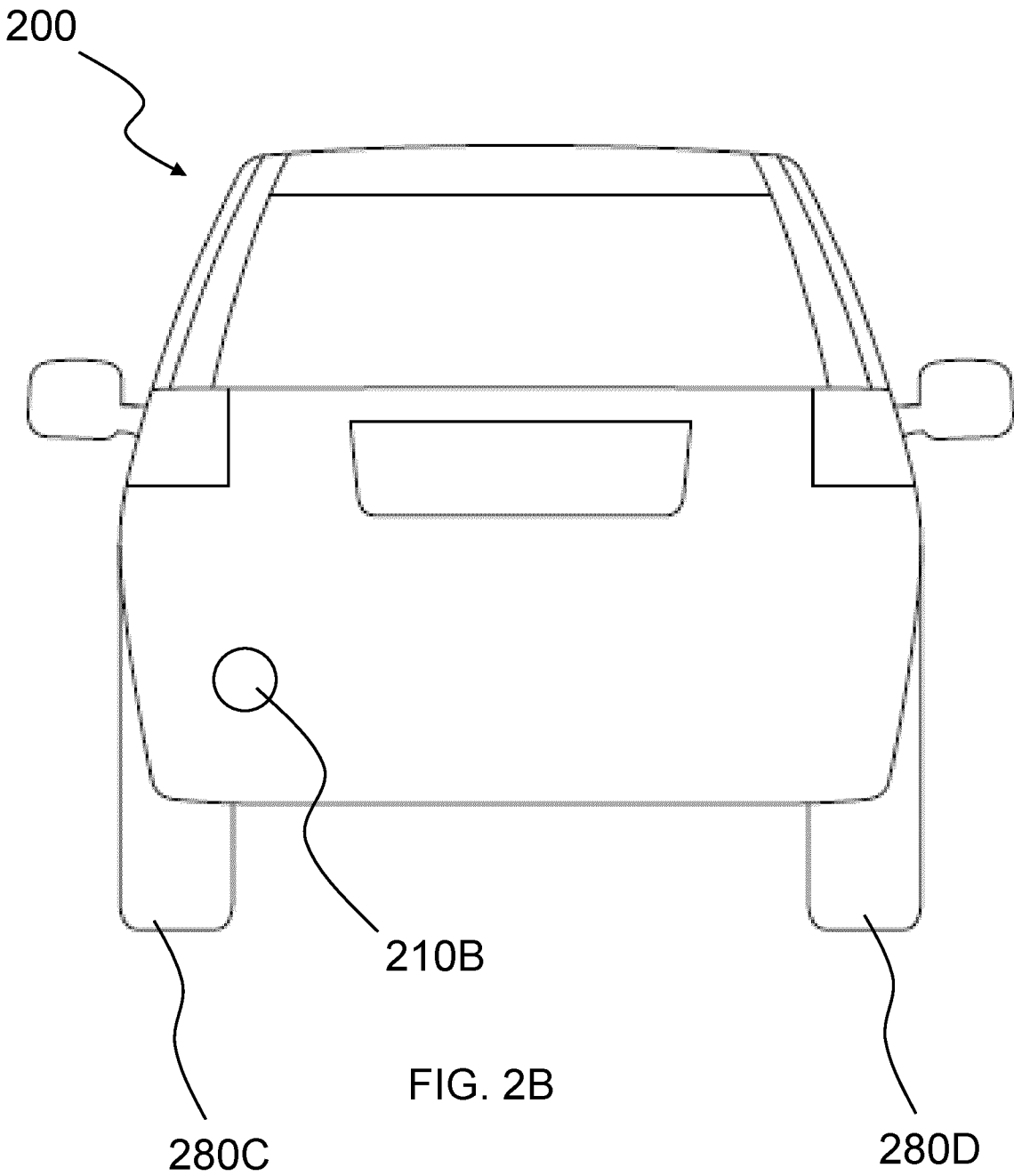


FIG. 2A

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300

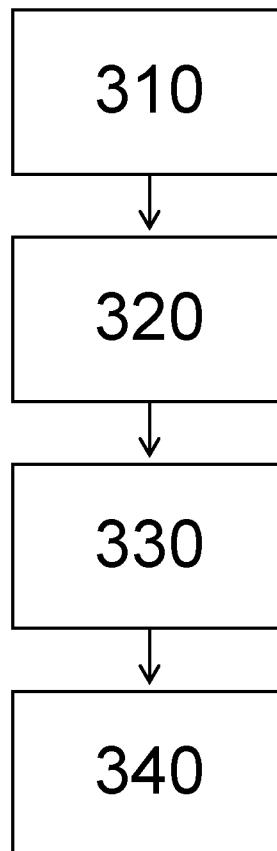


FIG. 3

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400

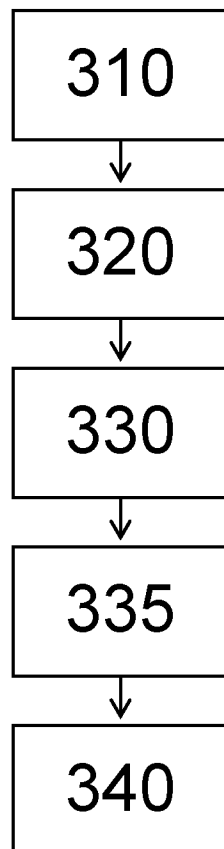


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2024/065423

A. CLASSIFICATION OF SUBJECT MATTER

INV. B62D9/00

ADD. B62D6/00 B62D7/15

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)

B62D B60W

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 2021/214004 A1 (SETO SHINJI [JP] ET AL) 15 July 2021 (2021-07-15)	1,2,8,9, 11-15
Y	paragraph [0018] - paragraph [0059];	3-7
A	figures 1-5	10

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Y	US 2008/281489 A1 (LE VOURCH YVES [FR]) 13 November 2008 (2008-11-13) paragraph [0021] - paragraph [0080]; figures 1-3	1-15

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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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"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

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"&" document member of the same patent family

Date of the actual completion of the international search

14 September 2024

Date of mailing of the international search report

26/09/2024

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2024/065423

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Y	US 2014/005892 A1 (BAER MICHAEL [DE] ET AL) 2 January 2014 (2014-01-02) paragraph [0007] - paragraph [0015] paragraph [0023] - paragraph [0030]; claims 1,7; figure 1 -----	3-7
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Information on patent family members

International application No

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