METHOD OF STEERING A VEHICLE

Abstract: Vehicle and method of steering such a vehicle, wherein the vehicle has a steering wheel and steerable driving wheels and a transfer system for converting steering wheel actions to a steering angle of the steerable driving wheels, and wherein the transfer system is provided with a predefined stiffness value that determines said transfer system's transfer characteristic pertaining to a required amount of torque that is required in turning the steering wheel to effect a desired steering angle of the steerable driving wheels. In this vehicle and method of steering this vehicle, an area in front of the vehicle is monitored for detecting objects that the vehicle may hit when it continues its current path of movement. Depending on the detection of any such object the stiffness value of the transfer system is reduced so as to ease turning the steering wheel for effecting the desired steering angle of the steerable driving wheels.
METHOD OF STEERING A VEHICLE

The invention relates to a vehicle and a method of steering such a vehicle, wherein the vehicle has a steering wheel and steerable driving wheels and a transfer system for converting steering wheel actions to a steering angle of the steerable driving wheels, and wherein the transfer system is provided with a predefined stiffness value that determines said transfer system’s transfer characteristic pertaining to a required amount of torque that is required in turning the steering wheel to effect a desired steering angle of the steerable driving wheels.

Nowadays traffic involves vehicles that all have the features of the preamble. The transfer system of the known vehicle for converting the steering wheel actions to the steering angle of the steerable driving wheels are either implemented conventionally with a fixed connection, or are provided with a hydraulic or electrical system to convert rotational movement of the steering wheel to a corresponding angular position of the steerable driving wheels. When the transfer system is implemented with a fixed connection between the steering wheel and the driving wheels, it is also possible that the vehicle is provided with further means to assist the driver in the turning of the steering wheel.

During recent years automobile manufacturers and scientists are striving to assist the driver in his operations when driving the vehicle, particularly by providing the driver with feedback, for instance on the condition of the road. This may be done simply by advising the driver about the outside temperature, whereby a sufficiently low temperature may be indicative for freezing conditions and a slippery road. It may also be done more directly by manipulating the feel that the driver experiences while turning the steering wheel.

Another example that is known from the prior art is to provide the vehicle with one or more sensor’s to detect whether for instance a preceding vehicle comes to close which may result into a collision. For that situation it is proposed to provide the driver with feedback by making it harder to press the gas pedal.
EP-A-1 285 842 discloses a method for steering a vehicle according to the preamble of claim 1. According to the teaching of EP-A-1 285 842 an area in front of the vehicle is monitored for detecting objects that the vehicle may hit when it continues its current path of movement, and wherein depending on the detection of any such object the stiffness value of the transfer system is reduced so as to ease turning the steering wheel for effecting the desired steering angle of the steerable driving wheels. Consistent therewith the vehicle of EP-A-1 285 842 is embodied with at least one sensor for monitoring an area in front of the vehicle and to detect an object or objects in said area that the vehicle may hit when it continues its current path of movement. The vehicle known from EP-A-1 285 842 further comprises a control system which is arranged to reduce the stiffness value of the transfer system depending on the at least one sensor detecting any such object, so as to ease turning the steering wheel for effecting the desired steering angle of the steerable driving wheels.

The reduction of the stiffness value of the transfer system that conveys the steering wheel action to the steerable driving wheels, makes manoeuvring around objects and other road users that are to be avoided easier.

It is an object of the invention to improve the known method and vehicle, so as to improve the assistance rendered to the driver to avoid collisions with stationary or slowly moving objects and other road users.

For this purpose a method and system are proposed in accordance with one or more of the appended claims.

In the method and system of the invention the required response to the threatening collision requires that the stiffness value of the transfer system is reduced to a negative value. This is quite remarkable considering that the negative value of the stiffness between the steering wheel and the steerable driving wheels results as such in an unstable system. This instability however makes that the vehicle can respond as quickly as possible to a dangerous situation that the driver wishes to avoid by appropriately turning the steering wheel.

Generally speaking it is preferred that a remaining spatio-temporal critical factor between the vehicle and the ob-
ject, which may for instance be the remaining time to contact, is estimated and the stiffness value of the transfer system is then reduced in a manner that depends on said estimated remaining spatio-temporal critical factor between the vehicle and the object. In this way it is possible to accommodate the level of the reduction of the stiffness value of the said transfer system to the severity of the threatening collision. One thing and another can be appropriately carried out in a vehicle that to that end comprises calculating means to estimate a remaining spatio-temporal critical factor between the vehicle and the object, whereby the control system is connected to the calculating means and arranged to reduce the stiffness value of the transfer system in a manner that depends on said estimated remaining spatio-temporal critical factor between the vehicle and the object.

The method of the invention is preferably executed in a way that the level of reduction of the stiffness value of the transfer system is increased in a manner that is inversely proportional to the estimated remaining spatio-temporal critical factor between the vehicle and the object. In this manner an automatic accommodation is realized that takes account of the necessity to respond quicker as the time to collision reduces. Accordingly the control system of the vehicle of the invention is for that purpose arranged to increase the level of reduction of the stiffness value of the transfer system in a manner that is inversely proportional to the remaining spatio-temporal critical factor between the vehicle and the object as estimated by the calculating means by the calculating means.

Advantageously further at least one lane is calculated pertaining to a trajectory that the vehicle may follow so as to avoid hitting the object, wherein the stiffness value of the transfer system is controlled to approach its original predefined value in as much as the path that the vehicle follows actually approaches said trajectory. To that end the vehicle of the invention is preferably provided with a trajectory planner to calculate at least one lane pertaining to a trajectory that the vehicle may follow so as to avoid hitting the object, whereby the control system is arranged to control the stiffness value of the transfer system so as to have it approach to its original predefined value in as much as the path that the vehicle follows actually approaches said calculated trajectory.
The invention will hereinafter be further elucidated with reference to the drawing.

In the drawing:

- Figure 1 shows a vehicle of the invention which in the usual way is provided with a steering wheel and in steerable driving wheels, and is maneuvered in accordance with the method of the invention to avoid colliding a stationary object;

- Figure 2 shows a graph representing various stiffness values of transfer characteristics pertaining to a required amount of torque that is required in turning the steering wheel of the vehicle shown in figure 1 to effect a desired steering angle of the steerable driving wheels of this vehicle;

- Figure 3 shows the main components of the control logic that is implemented in the vehicle of the invention in order to enable that it is operated in accordance with the method of the invention.

Referring first to figure 2 several graphs are shown wherein the X-axis represents a desired steering angle of the steerable driving wheels 11, 12 (see figure 3), and wherein the Y-axis represents the required amount of torque that has to be applied to the steering wheel 10 (see figure 3). Figure 2 shows three graphs, notably \( f_a \), \( f_b \), and \( f_c \).

Graph \( f_a \) shows a relaxed case in which the stiffness is only slightly decreased compared to a nominal stiffness.

Graph \( f_b \) shows a case in which the stiffness has a negative value when the desired steering angle does not deviate much from the vehicle going straightforward.

Graph \( f_c \) represents the case that these stiffness as a negative value in a large range of desired steering angles.

The mentioned graphs \( f_a \), \( f_b \), and \( f_c \) correspond to the trajectories a, b, and c that are indicated in figure 1, and which relate to the shown vehicle 1 following the path to the left L or the path to the right R to avoid collision with the object 2.

The path indicated with a is an example of a relaxed avoidance of the object 2. The paths indicated with b and c are examples of more critical situations, whereby the time to contact (or another spatio-temporal critical factor) that the vehicle 1 collides with the object 2 is for example c less than the time to contact for example b.
To enable that the vehicle 1 of the invention is operated in accordance with the method of the invention for steering such a vehicle 1, the vehicle 1 comprises at least one sensor 3, 4 for monitoring an area 5 in front of the vehicle 1 and to detect an object 2 or objects in said area 5 that the vehicle 1 may hit when it continues its current path of movement 6.

The vehicle 1 further comprises a control system 7 as shown in figure 3 which is arranged to reduce the stiffness value \( f_a \), \( f_b \), and \( f_c \) of the transfer system 13 for converting a rotational position of the steering wheel 10 to a corresponding angular position of the driving wheels 11, 12 of the vehicle 1. The reduction of the stiffness value \( f_a \), \( f_b \), and \( f_c \) of the transfer system 13 depends on the at least one sensor 3, 4 detecting any such object 2 so as to ease turning the steering wheel for effecting the desired steering angle of the steerable driving wheels 11, 12. Although the steering wheel 10, the steerable driving wheels 11, 12 and the transfer system 13 that links these wheels 10, 11, 12 together are depicted in the figures, these features per se are also known from the vehicle of the prior art. A further elucidation thereof can therefore be dispensed with.

Figure 3 further shows that part of the control logic (generally depicted with reference 14) are calculating means 8 to estimate a remaining time to contact TTC between the vehicle 1 and the object 2, whereby the control system 7 is connected to the calculating means 8 and arranged to reduce the stiffness value of the transfer system 13 in a manner that depends on said estimated remaining time to contact between the vehicle 1 and the object 2 as calculated by the calculating means 8.

The control system 7 as shown in figure 3 is arranged to increase the level of reduction of the stiffness value \( f_a \), \( f_b \), and \( f_c \) of the transfer system 13 in a manner that is inversely proportional to the remaining time to contact TTC between the vehicle 1 and the object 2 as estimated by the calculating means 8.

Figure 3 further shows that the control logic 14 is provided with a trajectory planner 9 to calculate at least one lane pertaining to a trajectory a, b, c that the vehicle 1 may follow so as to avoid hitting the object 2. The control system 7 is further arranged to control the stiffness value of the trans-
fer system 13 so as to have it approach to its original prede-
fined value in as much as the path that the vehicle 1 follows
actually approaches said calculated trajectory a, b, c.
CLAIMS

1. Method of steering a vehicle (1), wherein the vehicle (1) has a steering wheel (10) and steerable driving wheels (11, 12) and a transfer system (13) for converting steering wheel (10) actions to a steering angle of the steerable driving wheels (11, 12), wherein said transfer system (13) is provided with a predefined stiffness value \((f_a, f_b, f_c)\) that determines said transfer system’s transfer characteristic pertaining to a required amount of torque that is required in turning the steering wheel (10) to effect a desired steering angle of the steerable driving wheels (11, 12), and wherein an area (5) in front of the vehicle (1) is monitored for detecting objects (2) that the vehicle (1) may hit when it continues its current path of movement (6), whereby depending on the detection of any such object (2) the stiffness value \((f_a, f_b, f_c)\) of the transfer system (13) is reduced so as to ease turning the steering wheel (10) for effecting the desired steering angle of the steerable driving wheels (11, 12) characterized in that the stiffness value \((f_a, f_b, f_c)\) of the transfer system (13) is reduced to a negative value.

2. Method of steering a vehicle (1) according to claim 1, characterized in that a remaining spatio-temporal critical factor between the vehicle (1) and the object (2) is estimated and the stiffness value \((f_a, f_b, f_c)\) of the transfer system (13) is reduced in a manner that depends on said estimated remaining spatio-temporal critical factor between the vehicle (1) and the object (2).

3. Method of steering a vehicle according to claim 2, characterized in that the level of reduction of the stiffness value \((f_a, f_b, f_c)\) of the transfer system (13) is increased in a manner that is inversely proportional to the estimated remaining spatio-temporal critical factor between the vehicle (1) and the object (2).

4. Method of steering a vehicle according to any one of claims 1-3, characterized in that at least one lane is calculated pertaining to a trajectory \((a, b, c)\) that the vehicle (1) may follow so as to avoid hitting the object (2), and that the stiffness value \((f_a, f_b, f_c)\) of the transfer system (13) is con-
trolled to approach its original predefined value in as much as the path that the vehicle (1) follows actually approaches said trajectory (a, b, c).

5. Vehicle (1) comprising a steering wheel (10) and steerable driving wheels (11, 12) and a transfer system (13) for converting steering wheel actions to a steering angle of the steerable driving wheels (11, 12), wherein the transfer system (13) is provided with a predefined stiffness value \((f_a, f_b, f_c)\) that determines said transfer system’s transfer characteristic pertaining to a required amount of torque that is required in turning the steering wheel (10) to effect a desired steering angle of the steerable driving wheels (11, 12), and which further comprises at least one sensor (3, 4) for monitoring an area (5) in front of the vehicle (1) so as to detect an object (2) or objects in said area (5) that the vehicle (1) may hit when it continues its current path of movement (6), and that it comprises a control system (7) which is arranged to reduce the stiffness value \((f_a, f_b, f_c)\) of the transfer system (13) depending on the at least one sensor (3, 4) detecting any such object (2), so as to ease turning the steering wheel (10) for effecting the desired steering angle of the steerable driving wheels (11, 12) characterized in that the control system (7) is arranged to reduce the stiffness value \((f_a, f_b, f_c)\) of the transfer system (13) to a negative value.

6. Vehicle (1) according to claim 5, characterized in that it comprises calculating means (8) to estimate a remaining spatio-temporal critical factor between the vehicle (1) and the object (2), whereby the control system (7) is connected to the calculating means (8) and arranged to reduce the stiffness value \((f_a, f_b, f_c)\) of the transfer system (13) in a manner that depends on said estimated remaining spatio-temporal critical factor between the vehicle (1) and the object (2).

7. Vehicle (1) according to claim 6, characterized in that the control system (7) is arranged to increase the level of reduction of the stiffness value \((f_a, f_b, f_c)\) of the transfer system (13) in a manner that is inversely proportional to the remaining spatio-temporal critical factor between the vehicle (1) and the object (2) as estimated by the calculating means (8).

8. Vehicle (1) according to any one of claims 6-7,
characterized in that it is provided with a trajectory planner (9) to calculate at least one lane pertaining to a trajectory (a, b, c) that the vehicle (1) may follow so as to avoid hitting the object (2), and that the control system (7) is arranged to control the stiffness value \(f_a, f_b, f_c\) of the transfer system (13) so as to have it approach to its original predefined value in as much as the path that the vehicle (1) follows actually approaches said calculated trajectory (a, b, c).
A. CLASSIFICATION OF SUBJECT MATTER
INV. B60W50/08 B62D6/00 B62D15/02
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)
B60W B60K B62D

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
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<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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Further documents are listed in the continuation of Box C.

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 document but published on or after the international filing date
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<table>
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