(54) **METHOD AND SYSTEM FOR CONTROLLING A VEHICLE TIRE-TO-ROAD FRICTION ESTIMATION**

VERFAHREN UND SYSTEM ZUR STEUERUNG DER SCHÄTZUNG DES REIBWERTS ZWISCHEN FAHRZEUGREIFEN UND FAHRBAHN

PROCÉDÉ ET SYSTÈME POUR CONTRÔLER L'ESTIMATION DE FROTTEMENT SUR LA ROUTE D'UN VÉHICULE

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Description

Field of the Invention

[0001]   The present invention relates to a method and system for controlling a vehicle. In particular, the invention relates to a method and system for determining a tire-to-road friction ahead of an upcoming curve.

Background of the Invention

[0002]   Both autonomous vehicles and human drivers need to adapt the speed before entering curves to be able to stay on the road. The maximum speed with which a curve can be entered is primarily determined by the tire-to-road friction and the radius of the path that the car will take.

[0003]   For autonomous vehicles it is assumed that knowledge of friction is particularly important to guarantee to not departure the road. Large friction uncertainty means that vehicle speed must be lower and maybe too low for driver acceptance. The radius on the path can be estimated using e.g. on board cameras or map information, where curve cutting behaviour also can be accounted for. Getting reliable estimates of the tire-to-road friction is commonly known to be more difficult. The easiest way is brake fully and measure the deceleration, but this would be disturbing to the driver and to surrounding road users.

[0004]   To overcome this problem, several attempts have been made to make nonintrusive measurements of the tire-to-road friction using e.g. forward looking cameras, LIDAR's and accelerometers inside of the wheels.

[0005]   Recently, a promising new technology for reliably measuring tire-to-road friction without reducing the vehicle speed has been developed, see EP3106360A1. The technology measures the friction by simultaneously braking on the rear axle and accelerating on the front axle. Using this technology, measurements of the tire-to-road friction can be made without reducing the vehicle speed. However, the driver and passengers may possibly notice the measurements through the sound of the braking / propulsion system. The vehicle may also appear to "sit" on its rear axle when the measurement is performed, as braking on the rear axle and accelerating on the front axle temporarily will extend the vehicle slightly. Moreover, if the measurements are performed frequently, they will have a negative effect on the fuel consumption. Hence, there is a need to minimize the number of measurements while still providing a measure of the tire-to-road friction with sufficient confidence to assist the driver and autonomous vehicle to adapt the speed to be able to stay on the road.

[0006]   In EP2082936, a motion control device for vehicle has a position obtaining unit which obtains a relative position of a vehicle to curve, and a speed reduction controlling unit which performs a speed reduction control based on a vehicle speed determined by a determining unit. In EP2082936, vehicle speeds in different vehicle control modes are related to the friction coefficient. In particular, it is stated that the difference in speed between different control modes is smaller when the friction coefficient is smaller.

Summary

[0007]   In view of above-mentioned and other drawbacks of the prior art, it is an object of the present invention to provide a method for controlling a vehicle to perform a friction measurement only when required.

[0008]   According to a first aspect of the invention, the object is achieved by a method for controlling a vehicle traveling on a road. The method comprises: identifying an upcoming curve and determining properties of the curve; determining a current vehicle speed; estimating a friction between a tire of the vehicle and the road; estimating a maximum allowable vehicle speed when entering the curve based on the curve properties, vehicle speed and estimated friction; if the current vehicle speed is higher than the estimated maximum allowable vehicle speed, determining that a friction measurement is required, wherein the friction measurement requires braking the vehicle; if a distance between the vehicle and a curve entrance is higher than a predetermined threshold distance and if a braking action is detected, performing a friction measurement during the braking action to determine a current friction; if a distance between the vehicle and a curve entrance is lower than a predetermined threshold distance, performing a friction measurement to determine a current friction; and determining a maximum allowable vehicle speed based on the curve radius, vehicle speed and current friction.

[0009]   In the present method, the friction measurement technology described in EP3106360A1 can be used to determine a tire-to-road friction. The technology measures the friction by simultaneously braking on the rear axle and accelerating on the front axle. Thereby, the friction measurement does not involve braking of the vehicle as such, i.e. it does not involve reducing the speed of the vehicle. However, during normal driving, the driver may still notice that a friction measurement is performed. Thereby, by performing a friction measurement during braking if possible, the friction measurement can be performed in a non-obtrusive manner without the driver noticing. However, it should be noted that other types of friction measurement technologies also can be used.

[0010]   Accordingly, present invention is based on the realization that it is not always required to perform a friction measurement when approaching a curve, and that it in many situations is possible to perform the friction measurement during normal driving of the vehicle if a friction measurement is required. For example, many drivers will slow down enough ahead of a curve such that a friction measurement can be performed during driver initiated braking. Unless the friction measurement is performed during driver initiated braking, a non-braking fric-

tion measurement is advantageously employed to minimize the influence on the vehicle experienced by the driver. Hence, unnecessary friction measurements can be avoided, the number of performed friction measurements is minimized, and the driver inconvenience of forced friction measurement is minimized.

[0011]   Hereby, it can be ensured that a friction value which is as correct as possible is used to determine the maximum allowable vehicle speed when reaching the curve entrance for preventing that the vehicle loses grip in the curve. It is here assumed that the tire-to-road friction in the curve does not differ significantly from the tire-to-road friction before the curve. In other words, the described method is not intended to account for unexpected and transient events influencing the friction properties of the curve, such as oil spills or ice patches. It is also assumed that the speed of the vehicle when entering the curve, i.e. the maximum allowable vehicle speed, can be safely maintained throughout the curve. Moreover, even if the vehicle was to lose the grip in the curve, other vehicle systems are assumed to take control, such as electronic stability control (ESC) systems.

[0012]   According to one embodiment of the invention, the method may further comprise, if the current vehicle speed is higher than the determined maximum allowable vehicle speed, braking the vehicle so that the vehicle speed when reaching the curve is lower than or equal to the determined maximum allowable vehicle speed. Thereby, automatic braking of the vehicle without the need for driver interaction can be performed to ensure that the vehicle speed is not too high when reaching the curve entrance. Thus, the described method may advantageously be implemented as a safety feature in autonomous or semi-autonomous vehicles.

[0013]   According to one embodiment of the invention, the method may further comprise, if the current vehicle speed is higher than the maximum allowable vehicle speed, braking the vehicle with a constant deceleration from the current location of the vehicle to the curve entrance so that the vehicle speed is equal to or lower than the determined maximum allowable vehicle speed when the vehicle reaches the curve entrance. By braking with a constant deceleration, a smooth and comfortable braking experience is achieved.

[0014]   According to one embodiment of the invention the method may further comprise, if the current vehicle speed is higher than the determined maximum allowable vehicle speed, alerting the driver, indicating that there is a risk of leaving the road unless the vehicle speed is reduced to the determined maximum allowable vehicle speed. Thereby, the method is advantageously used also in vehicles without self-driving functionality to alert the driver if the vehicle speed is above the determined maximum allowable sped. The alert may be in the form of a visible or audible indication, or a combination thereof. The alert is preferably provided in good time before braking is required so that a driver has time to safely reduce the vehicle speed as required. It can be assumed that a

driver need more time, i.e. a longer distance, to safely reduce the vehicle speed compared to an automated system. The predetermined threshold distance to the curve entrance may thus be set to be higher where the method is implemented in a vehicle where it is assumed that the driver is intended to control the vehicle speed compared to in an autonomous vehicle.

[0015]   According to one embodiment of the invention, the predetermined threshold distance is based on a distance required to reduce the vehicle speed from a current speed to the estimated maximum allowable vehicle speed when entering the curve. The threshold distance may thus be based on the vehicle speed, the estimated friction, and the vehicle braking capabilities. The threshold distance may also be set so that it is possible to brake the vehicle in a manner which is comfortable to the vehicle occupants since it may not be desirable to apply the highest possible braking force. The threshold distance may also be set differently in an autonomous vehicle compared to in a driver operated vehicle for reasons discussed above.

[0016]   According to one embodiment of the invention, estimating a friction between a tire of the vehicle and the road may comprise acquiring a previously measured friction value for the curve, and estimating the friction to be lower than the previously measured friction. A previously measured friction value may for example be available in the vehicle if the vehicle has previously traveled through the curve under similar road conditions. It is also possible to acquire a previously measured friction value from a remote location such as a cloud server where measured friction values from different vehicles and under various road conditions may be stored. The friction estimation may also take current local weather information into account, for example temperature information and windscreen wiper activity.

[0017]   According to one embodiment of the invention, estimating a friction between a tire of the vehicle and the road may comprise acquiring a most recently measured friction value for the road on which the vehicle travels, and estimating the friction to be lower than the a most recently measured friction value. In a similar manner as above, the most recently measured friction value may be a friction measured by the vehicle or a value obtained from a remote location. The most recently measured friction value may also be received from another vehicle traveling on the road by utilizing a vehicle-to-vehicle (V2V) communication system. The term "estimating" should thus be interpreted broadly in the present context, where an estimated friction is represented by a friction value which is assumed to be representative of the tire-to-road friction in the curve.

[0018]   According to one embodiment of the invention, an estimated friction is preferably at least two standard deviations lower than an expected friction. It can thereby be determined that the estimated friction value is lower than an expected average value with 95% certainty. The expected value may be based on any of the previously

discussed measured friction values. It is of course also possible to use an estimated friction value which is even lower, and the difference between the estimated friction value and an expected value may be at least partially based on external factors such as road and weather conditions.

[0019] According to one embodiment of the invention, determining properties of the curve may comprise determining a curve radius. Furthermore, determining properties of the curve may comprise determining a curve shape, a road width, a lane width and a road camber. It is in general desirable to have as much information as possible describing the curve to be able to accurately estimate a maximum allowable vehicle speed through the curve, based on the current friction. The curve properties may be stored in the vehicle or be acquired from a remote server e.g. using a cloud communication infrastructure. It is also possible to determine curve properties using only in-vehicle sensors such as cameras, radar/LIDAR and the like. The curve radius can for example be estimated using only information acquired by an onboard camera. Accordingly, the properties of the curve may include any parameter describing the curve which can be used to estimate a maximum allowable vehicle speed when entering the curve.

[0020] According to one embodiment of the invention, the method may further comprise estimating a vehicle path through the curve based on the curve properties. Thereby, the vehicle speed can be adapted to an estimated and preferably optimized path through the curve, where the path can be refined depending on how much information describing the curve properties is available. A path through the curve may for example include cutting the curve so that the vehicle is not always in the middle of the lane. This may allow the vehicle to travel through the curve in a manner which is more similar to how a driver would drive through the curve, thereby providing a more familiar user experience.

[0021] According to one embodiment of the invention, determining properties of the curve may comprise acquiring information from a previously established map such as a map in a navigation system of the vehicle.

[0022] According to a second aspect of the invention, the object is achieved by a vehicle control system comprising a vehicle control unit configured to: identify an upcoming curve and determining properties of the curve; determine a current vehicle speed; estimate a friction between a tire of the vehicle and the road; estimate a maximum allowable vehicle speed when entering the curve based on the curve properties, vehicle speed and estimated friction; if the current vehicle speed is higher than the estimated maximum allowable vehicle speed, determining that a friction measurement is required; if a distance between the vehicle and a curve entrance is higher than a predetermined threshold distance and if a braking action is detected, performing a friction measurement during the braking action to determine a current friction; if a distance between the vehicle and a curve entrance

is lower than a predetermined threshold distance, performing a friction measurement to determine a current friction; and determine a maximum allowable vehicle speed based on the curve radius, vehicle speed and current friction.

[0023] Additional effects and features of the second aspect of the invention are largely analogous to those described above in connection with the first aspect of the invention.

[0024] Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. The skilled person realize that different features of the present invention may be combined to create embodiments other than those described in the following, without departing from the scope of the invention, as defined by the appended claims.

Brief Description of the Drawings

[0025] These and other aspects of the present invention will now be described in more detail, with reference to the appended drawings showing an example embodiment of the invention, wherein:

> Fig. 1 is a flow chart outlining the general steps of a method according to an embodiment of the invention;
> Fig. 2 schematically illustrates the method according to an embodiment of the invention performed by a vehicle; and
> Fig. 3 schematically illustrates a control system according to an embodiment of the invention.

Detailed Description of Example Embodiments

[0026] The present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which currently preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness, and fully convey the scope of the invention to the skilled person. Like reference characters refer to like elements throughout.

[0027] Fig. 1 is a flow chart outlining the general steps of a method of controlling a vehicle 200 according to an embodiment of the invention; and the method will be described with further reference to Fig. 2 schematically illustrating the method performed by a vehicle 200.

[0028] The method is applied when a vehicle is travelling on a road 202 and approaching a curve 204 in the road 202. In particular, the method is aimed at determining if and where it is necessary to perform a friction measurement, to thereby determine a maximum allowable vehicle speed in order for the vehicle to be able to travel through the curve 204 without losing grip.

[0029] The following notation will be used in the description of the method:

- V_V = current vehicle speed
- μ_e = estimated tire-to-road friction
- V_{max_e} = estimated maximum allowable vehicle speed
- d_v = distance from vehicle to curve entrance
- d_T = threshold distance
- μ_c = current (measured) tire-to-road friction
- V_{max_d} = determined maximum allowable vehicle speed
- R = curve radius
- g = gravitational constant
- d_{min_e} = estimated minimum braking distance
- a_{max_e} = estimated maximum deceleration

[0030] The first step of the method involves identifying 100 an upcoming curve 204 and determining 102 properties of the curve. The curve information can for example be acquired from an in-vehicle navigation system or from a remote server as described earlier. A straightforward manner of determining the properties of a curve may be to approximate the curve as having a fixed radius R throughout the curve. However, the curve properties preferably comprise additional information describing a curve shape, a road width, a lane width and a road camber. Moreover, the method can for example be further refined to account for that most roads and vehicle trajectories are shaped as clothoids and not straights and circles. But for the sake of simplicity, the present description use a simple description of the road shape to describe the core ideas of the invention.

[0031] Once the curve is identified and curve properties are determined, the current vehicle speed V_V is determined 104 and a friction value μ_e for the curve is estimated 106. The friction value is deliberately underestimated in relation to an expected friction so that the probability that the actual friction is lower than the estimated friction is very low.

[0032] When the curve radius R, vehicle speed V_V and estimated friction μ_e is known, an estimated maximum allowable vehicle speed v_{max_e} can be estimated 108 as

$$v_{\max\_e} = \sqrt{\mu_e g R}.$$

[0033] Due to the estimated friction μ_e, assuming that the current vehicle speed V_V is higher than the estimated maximum allowable vehicle speed V_{max_e}, there is also a limitation on an estimated maximum allowed deceleration a_{max_e} of the vehicle before the curve. The estimated maximum allowed deceleration a_{max_e} can be determined as

$$a_{\max\_e} = -\mu_e g.$$

[0034] The maximum allowed deceleration a_{max_e} in turn determines a minimum distance from the curve d_{min_e} at which braking must be initiated to reach the maximum allowed vehicle speed v_{max_e} before reaching the curve entrance 206, where the minimum distance from the curve d_{min_e} is determined as

$$d_{\min\_e} = \frac{v_c^2 - v_{\min\_e}^2}{2\mu_e g}.$$

[0035] Accordingly, if the vehicle speed V_V is higher than the maximum allowable vehicle speed v_{max_e}, braking of the vehicle must begin at the latest at a distance from the curve entrance corresponding to the estimated minimum distance d_{min_e}.

[0036] Thereby, if the current vehicle speed V_V is higher than the estimated maximum allowable vehicle speed v_{max_e}, it is determined 112 that a friction measurement is required. The details describing how a friction measurement can be preformed by simultaneously braking on the rear axle and accelerating on the front axle is described in detail in EP3106360A1 and will not be discussed in detail in the present disclosure. However, it should be noted that the described method involves measuring the friction without changing the vehicle speed. Accordingly, the braking of the rear axle, which is counteracted by an acceleration of the front axle, does not result in changing the vehicle speed. The cited method may be referred to as a non-braking friction measurement method. This is in contrast to previously known methods involving braking of the vehicle. In addition to the above referenced method, it is also possible to use other non-braking friction measurement methods, such as an optical measurement of the road properties.

[0037] Next, if the distance d_v between the vehicle 200 and the curve entrance is higher than a predetermined threshold distance d_T and if a braking action is detected, a friction measurement is performed 116 during the braking action to determine a current friction μ_c. The predetermined threshold distance d_T is set to be higher than the estimated minimum distance d_{min_e} so that there is sufficient time to perform a friction measurement. The amount by which the threshold distance exceeds the minimum distance d_{min_e} may for example be based on the current vehicle speed v_v, the estimated friction μ_e and the estimated time/distance required for performing the friction measurement. A braking action of the vehicle sufficiently long for performing a braking friction measurement may for example be in the range of 1-2 seconds.

[0038] Accordingly, if the vehicle 200 is at a safe distance form the curve entrance 206 and if the driver brakes the vehicle, a friction measurement is performed during the diver initiated braking. Thereby, the current friction is known and there is no need for an additional friction measurement. If no braking action is detected, the distance from the vehicle 200 to the curve 204 will eventually be less than the threshold distance d_T.

[0039] Next, if the current distance d_v between the vehicle 200 and the curve entrance 206 is lower than the predetermined threshold distance d_T, and no friction measurement has been performed since the curve 204 was identified, a friction measurement is performed 118 to determine a current tire-to-road friction μ_c. At minimum, the threshold distance d_T is the estimated minimum braking distance d_{min_e} plus the distance required for performing the friction measurement.

[0040] Based on the determined, i.e. measured, current tire-to-road friction μ_c a maximum allowable vehicle speed v_{max_d} can be determined 120 based on the curve radius, vehicle speed and current friction as.

$$v_{\max\_d} = \sqrt{\mu_c g R}.$$

[0041] Thereby a more informed determination of the maximum allowable vehicle speed v_{max_d} is performed and if the current vehicle speed is higher than the determined maximum allowable vehicle speed v_{max_d}, the vehicle is braked so that the vehicle speed when reaching the curve is lower than or equal to the determined maximum allowable vehicle speed v_{max_d}. The vehicle 200 may be braked automatically or by driver initiated braking. In a non-automated system, the safety margins are advantageously increased such that the driver both has time to react and to perform the required braking in a safe manner. In other words, the threshold distance d_T is preferably higher in a non-automated system.

[0042] The vehicle control system 300 comprises a control unit 208 configured control the vehicle to perform the described steps of the method. The control unit 208 may include a microprocessor, microcontroller, programmable digital signal processor or another programmable device. The control unit 208 may also, or instead, include an application specific integrated circuit, a programmable gate array or programmable array logic, a programmable logic device, or a digital signal processor. Where the control unit 208 includes a programmable device such as the microprocessor, microcontroller or programmable digital signal processor mentioned above, the processor may further include computer executable code that controls operation of the programmable device.

[0043] Moreover, the control unit 208 may be embodied by one or more control units, where each control unit may be either a general purpose control unit or a dedicated control unit for performing a specific function.

[0044] Fig. 3 schematically illustrates a control system 300 where the control unit is connected to the various sub-systems responsible for performing the various functions of the method.

[0045] As illustrated in Fig. 3, the control system 300 comprises an environmental sensor unit 302 which uses e.g. GPS, camera, radar or the like to determine the vehicle position, a motion planner 304 which performs strategic and tactic motion planning, e.g. determines an acceleration/deceleration profile. The control system 300

further comprises a vehicle state estimator 306 which determines the motion states of the vehicle, e.g. vehicle speed over ground and tire-to-road friction, a friction measurement monitor 308 which determines when to start the a friction measurement, a vehicle motion controller 310 which receives motion requests and outputs requests to actuators e.g. powertrain and brakes to execute the motion requests, and finally a friction measurement executer 312 which determines actuation, e.g. wheel torques, to perform a friction measurement.

[0046] The present description is based on a simplified model of the curve and it should be noted that it is further possible to modify the described method and system to control the vehicle to have one vehicle speed when entering the curve, and to modify the vehicle speed while in the curve. This may for example be desirable for curves having a complex shape deviating from a simple arc, for long curves or for multiple consecutive curves.

[0047] Accordingly, the described method is intended to maximize the probability that the vehicle will be able to stay on the road under the assumption that the friction in the curve is not significantly lower than the friction just before the curve, given the current speed of the vehicle, the shape of the forward roadway and a priori knowledge of the minimum available tire-to-road friction.

Claims

1. A method for controlling a vehicle (200) traveling on a road (202), the method comprising:

    identifying (100) an upcoming curve (204) and determining (102) properties of the curve;
    determining (104) a current vehicle speed, v_v;
    estimating (106) a friction, μ_e, between a tire of the vehicle and the road;
    estimating (108) a maximum allowable vehicle speed, v_{max_e}, when entering the curve based on the curve properties, vehicle speed and estimated friction;
    if the current vehicle speed is higher than the estimated maximum allowable vehicle speed, determining (112) that a friction measurement is required;
    if a distance, d_v, between the vehicle and a curve entrance is higher than a predetermined threshold distance, d_T, and if a braking action is detected, performing (116) a friction measurement during the braking action to determine a current friction, μ_c;
    if a distance between the vehicle and the curve entrance is lower than the predetermined threshold distance, performing (118) a friction measurement to determine a current friction; and
    determining (120) a maximum allowable vehicle speed, v_{max_d}, based on the curve radius, vehi-

cle speed and current friction.

2. The method according to claim 1, further comprising, if the current vehicle speed is higher than the determined maximum allowable vehicle speed, braking the vehicle so that the vehicle speed when reaching the curve is lower than or equal to the determined maximum allowable vehicle speed.

3. The method according to claim 1 or 2, further comprising, if the current vehicle speed is higher than the maximum allowable vehicle speed, braking the vehicle with a constant deceleration from the current location of the vehicle to the curve entrance so that the vehicle speed is equal to or lower than the determined maximum allowable vehicle speed when the vehicle reaches the curve entrance.

4. The method according to claim 1, further comprising, if the current vehicle speed is higher than the determined maximum allowable vehicle speed, alerting the driver, indicating that there is a risk of leaving the road unless the vehicle speed is reduced to the determined maximum allowable vehicle speed.

5. The method according to any one of the preceding claims, wherein the predetermined threshold distance is based on a distance required to reduce the vehicle speed from a current speed to the estimated maximum allowable vehicle speed when entering the curve.

6. The method according to any one of the preceding claims, wherein estimating a friction between a tire of the vehicle and the road comprises acquiring a previously measured friction value for the curve, and estimating the friction to be lower than the previously measured friction.

7. The method according to any one of claims 1 to 5, wherein estimating a friction between a tire of the vehicle and the road comprises acquiring a most recently measured friction value for the road on which the vehicle travels, and estimating the friction to be lower than the a most recently measured friction value.

8. The method according to any one of claims 1 to 5, wherein an estimated friction is at least two standard deviations lower than an expected friction.

9. The method according to any one of the preceding claims, wherein determining properties of the curve comprises determining a curve radius.

10. The method according to any one of the preceding claims, wherein determining properties of the curve comprises determining a curve shape.

11. The method according to any one of the preceding claims, wherein determining properties of the curve comprises determining at least one of a road width, a lane width and a road camber.

12. The method according to any one of the preceding claims, wherein determining properties of the curve comprises acquiring curve properties from a remote server.

13. The method according to any one of the preceding claims, further comprising estimating a vehicle path through the curve based on the curve properties.

14. The method according to any one of the preceding claims, wherein determining properties of the curve comprises acquiring information from a previously established map.

15. A vehicle control system (300) comprising a vehicle control unit (200) configured to:

identify an upcoming curve (204) and determining (102) properties of the curve;
determine a current vehicle speed, v_v;
estimate a friction, μ_e, between a tire of the vehicle and the road;
estimate a maximum allowable vehicle speed, v_{max_e}, when entering the curve based on the curve properties, vehicle speed and estimated friction;
if the current vehicle speed is higher than the estimated maximum allowable vehicle speed, determine that a friction measurement is required;
if a distance, d_v, between the vehicle and a curve entrance is higher than a predetermined threshold distance, d_T, and if a braking action is detected, performing (116) a friction measurement during the braking action to determine a current friction μ_c;
if a distance between the vehicle and the curve entrance is lower than the predetermined threshold distance, performing (118) a friction measurement to determine a current friction; and
determining (120) a maximum allowable vehicle speed v_{max_d} based on the curve radius, vehicle speed and current friction.

Patentansprüche

1. Verfahren zum Steuern eines Fahrzeugs (200), das auf einer Straße (202) fährt, wobei das Verfahren umfasst:

Identifizieren (100) einer bevorstehenden Kurve

(204) und Bestimmen (102) von Eigenschaften der Kurve;

Bestimmen (104) einer aktuellen Fahrzeuggeschwindigkeit, v_v;

Schätzen (106) einer Reibung, μ_e, zwischen einem Reifen des Fahrzeugs und der Straße;

Schätzen (108) einer maximal zulässigen Fahrzeuggeschwindigkeit, v_{max_e}, bei Eintreten in die Kurve basierend auf den Kurveneigenschaften, der Fahrzeuggeschwindigkeit und der geschätzten Reibung;

wenn die aktuelle Fahrzeuggeschwindigkeit höher als die geschätzte maximal zulässige Fahrzeuggeschwindigkeit ist, Bestimmen (112), dass eine Reibungsmessung erforderlich ist;

wenn eine Distanz, d_v, zwischen dem Fahrzeug und einem Kurveneingang höher als eine vorbestimmte Schwellendistanz, d_T, ist und wenn ein Bremsvorgang detektiert wird, Durchführen (116) einer Reibungsmessung während des Bremsvorgangs, um eine aktuelle Reibung, μ_c, zu bestimmen;

wenn eine Distanz zwischen dem Fahrzeug und dem Kurveneingang kleiner als die vorbestimmte Schwellendistanz ist, Durchführen (118) einer Reibungsmessung, um eine aktuelle Reibung zu bestimmen; und

Bestimmen (120) einer maximal zulässigen Fahrzeuggeschwindigkeit, v_{max_d}, basierend auf dem Kurvenradius, der Fahrzeuggeschwindigkeit und der aktuellen Reibung.

2. Verfahren nach Anspruch 1, ferner umfassend, wenn die aktuelle Fahrzeuggeschwindigkeit höher als die bestimmte maximal zulässige Fahrzeuggeschwindigkeit ist, Bremsen des Fahrzeugs derart, dass die Fahrzeuggeschwindigkeit bei Erreichen der Kurve kleiner als oder gleich der bestimmten maximal zulässigen Fahrzeuggeschwindigkeit ist.

3. Verfahren nach Anspruch 1 oder 2, ferner umfassend, wenn die aktuelle Fahrzeuggeschwindigkeit höher als die maximal zulässige Fahrzeuggeschwindigkeit ist, Bremsen des Fahrzeugs mit einer konstanten Verzögerung von dem aktuellen Standort des Fahrzeugs zum Kurveneingang derart, dass die Fahrzeuggeschwindigkeit gleich oder kleiner als die bestimmte maximal zulässige Fahrzeuggeschwindigkeit ist, wenn das Fahrzeug den Kurveneingang erreicht.

4. Verfahren nach Anspruch 1, ferner umfassend, wenn die aktuelle Fahrzeuggeschwindigkeit höher als die bestimmte maximal zulässige Fahrzeuggeschwindigkeit ist, Warnen des Fahrers, wobei angezeigt wird, dass eine Gefahr eines Verlassens der Straße besteht, sofern die Fahrzeuggeschwindigkeit nicht auf die bestimmte maximal zulässige Fahr-

zeuggeschwindigkeit reduziert wird.

5. Verfahren nach einem der vorhergehenden Ansprüche, wobei die vorbestimmte Schwellendistanz auf einer Distanz basiert, die erforderlich ist, um die Fahrzeuggeschwindigkeit von einer aktuellen Geschwindigkeit auf die geschätzte maximal zulässige Fahrzeuggeschwindigkeit bei Eintreten in die Kurve zu reduzieren.

6. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Schätzen einer Reibung zwischen einem Reifen des Fahrzeugs und der Straße Beschaffen eines zuvor gemessenen Reibungswerts für die Kurve und Schätzen, dass die Reibung kleiner als die zuvor gemessene Reibung ist, umfasst.

7. Verfahren nach einem der Ansprüche 1 bis 5, wobei das Schätzen einer Reibung zwischen einem Reifen des Fahrzeugs und der Straße Beschaffen eines zuletzt gemessenen Reibungswerts für die Straße, auf der das Fahrzeug fährt, und Schätzen, dass die Reibung kleiner als der eine zuletzt gemessene Reibungswert ist, umfasst.

8. Verfahren nach einem der Ansprüche 1 bis 5, wobei eine geschätzte Reibung mindestens zwei Standardabweichungen kleiner als eine erwartete Reibung ist.

9. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Bestimmen von Eigenschaften der Kurve Bestimmen eines Kurvenradius umfasst.

10. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Bestimmen von Eigenschaften der Kurve Bestimmen einer Kurvenform umfasst.

11. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Bestimmen von Eigenschaften der Kurve Bestimmen von mindestens einem einer Straßenbreite, einer Spurbreite und einer Straßenwölbung umfasst.

12. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Bestimmen von Eigenschaften der Kurve Beschaffen von Kurveneigenschaften von einem entfernten Server umfasst.

13. Verfahren nach einem der vorhergehenden Ansprüche, ferner umfassend Schätzen eines Fahrzeugpfads durch die Kurve basierend auf den Kurveneigenschaften.

14. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Bestimmen von Eigenschaften der Kurve Beschaffen von Information von einer zuvor erstellten Karte umfasst.

15. Fahrzeugsteuerungssystem (300), das eine Fahrzeugsteuerungseinheit (200) umfasst, die zu Folgendem ausgelegt ist:

Identifizieren einer bevorstehenden Kurve (204) und Bestimmen (102) von Eigenschaften der Kurve;

Bestimmen einer aktuellen Fahrzeuggeschwindigkeit, v_v;

Schätzen einer Reibung, μ_e, zwischen einem Reifen des Fahrzeugs und der Straße;

Schätzen einer maximal zulässigen Fahrzeuggeschwindigkeit, v_{max_e}, bei Eintreten in die Kurve basierend auf den Kurveneigenschaften, der Fahrzeuggeschwindigkeit und der geschätzten Reibung;

wenn die aktuelle Fahrzeuggeschwindigkeit höher als die geschätzte maximal zulässige Fahrzeuggeschwindigkeit ist, Bestimmen, dass eine Reibungsmessung erforderlich ist;

wenn eine Distanz, d_v, zwischen dem Fahrzeug und einem Kurveneingang höher als eine vorbestimmte Schwellendistanz, d_T, ist und wenn ein Bremsvorgang detektiert wird, Durchführen (116) einer Reibungsmessung während des Bremsvorgangs, um eine aktuelle Reibung, μ_c, zu bestimmen;

wenn eine Distanz zwischen dem Fahrzeug und dem Kurveneingang kleiner als die vorbestimmte Schwellendistanz ist, Durchführen (118) einer Reibungsmessung, um eine aktuelle Reibung zu bestimmen; und

Bestimmen (120) einer maximal zulässigen Fahrzeuggeschwindigkeit, v_{max_d}, basierend auf dem Kurvenradius, der Fahrzeuggeschwindigkeit und der aktuellen Reibung.

Revendications

1. Procédé de commande d'un véhicule (200) circulant sur une route (202), le procédé comprenant :

l'identification (100) d'une courbe imminente (204) et la détermination (102) de propriétés de la courbe ;

la détermination (104) d'une vitesse actuelle, v_v, du véhicule ;

l'estimation (106) d'un frottement, μ_e, entre un pneu du véhicule et la route ;

l'estimation (108) d'une vitesse maximale admissible, v_{max_e}, du véhicule lorsqu'il entre dans la courbe sur la base des propriétés de la courbe, de la vitesse du véhicule et du frottement estimé ;

si la vitesse actuelle du véhicule est supérieure à la vitesse maximale admissible estimée du véhicule, la détermination (112) qu'une mesure de

frottement est nécessaire ;

si une distance, d_v, entre le véhicule et une entrée de la courbe est supérieure à une distance-seuil prédéterminée, d_T, et si une action de freinage est détectée, la réalisation (116) d'une mesure de frottement durant l'action de freinage afin de déterminer un frottement actuel, μ_c ;

si une distance entre le véhicule et l'entrée de la courbe est inférieure à la distance-seuil prédéterminée, la réalisation (118) d'une mesure de frottement afin de déterminer un frottement actuel ; et

la détermination (120) d'une vitesse maximale admissible, v_{max_d}, du véhicule sur la base du rayon de la courbe, de la vitesse du véhicule et du frottement actuel.

2. Procédé selon la revendication 1, comprenant en outre, si la vitesse actuelle du véhicule est supérieure à la vitesse maximale admissible déterminée du véhicule, le freinage du véhicule de façon à ce que la vitesse du véhicule, lorsqu'il atteint la courbe, soit inférieure ou égale à la vitesse maximale admissible déterminée du véhicule.

3. Procédé selon la revendication 1 ou 2, comprenant en outre, si la vitesse actuelle du véhicule est supérieure à la vitesse maximale admissible du véhicule, le freinage du véhicule avec une décélération constante depuis la position actuelle du véhicule jusqu'à l'entrée de la courbe de façon à ce que la vitesse du véhicule soit inférieure ou égale à la vitesse maximale admissible déterminée du véhicule lorsque le véhicule atteint l'entrée de la courbe.

4. Procédé selon la revendication 1, comprenant en outre, si la vitesse actuelle du véhicule est supérieure à la vitesse maximale admissible déterminée du véhicule, l'alerte du conducteur, indiquant qu'il existe un risque de sortie de route à moins que la vitesse du véhicule soit réduite jusqu'à la vitesse maximale admissible déterminée du véhicule.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel la distance-seuil prédéterminée est basée sur une distance nécessaire pour réduire la vitesse du véhicule depuis une vitesse actuelle jusqu'à la vitesse maximale admissible estimée du véhicule lorsqu'il entre dans la courbe.

6. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'estimation d'un frottement entre un pneu du véhicule et la route comprend l'acquisition d'une valeur de frottement précédemment mesurée pour la courbe, et l'estimation du frottement comme étant inférieur au frottement précédemment mesuré.
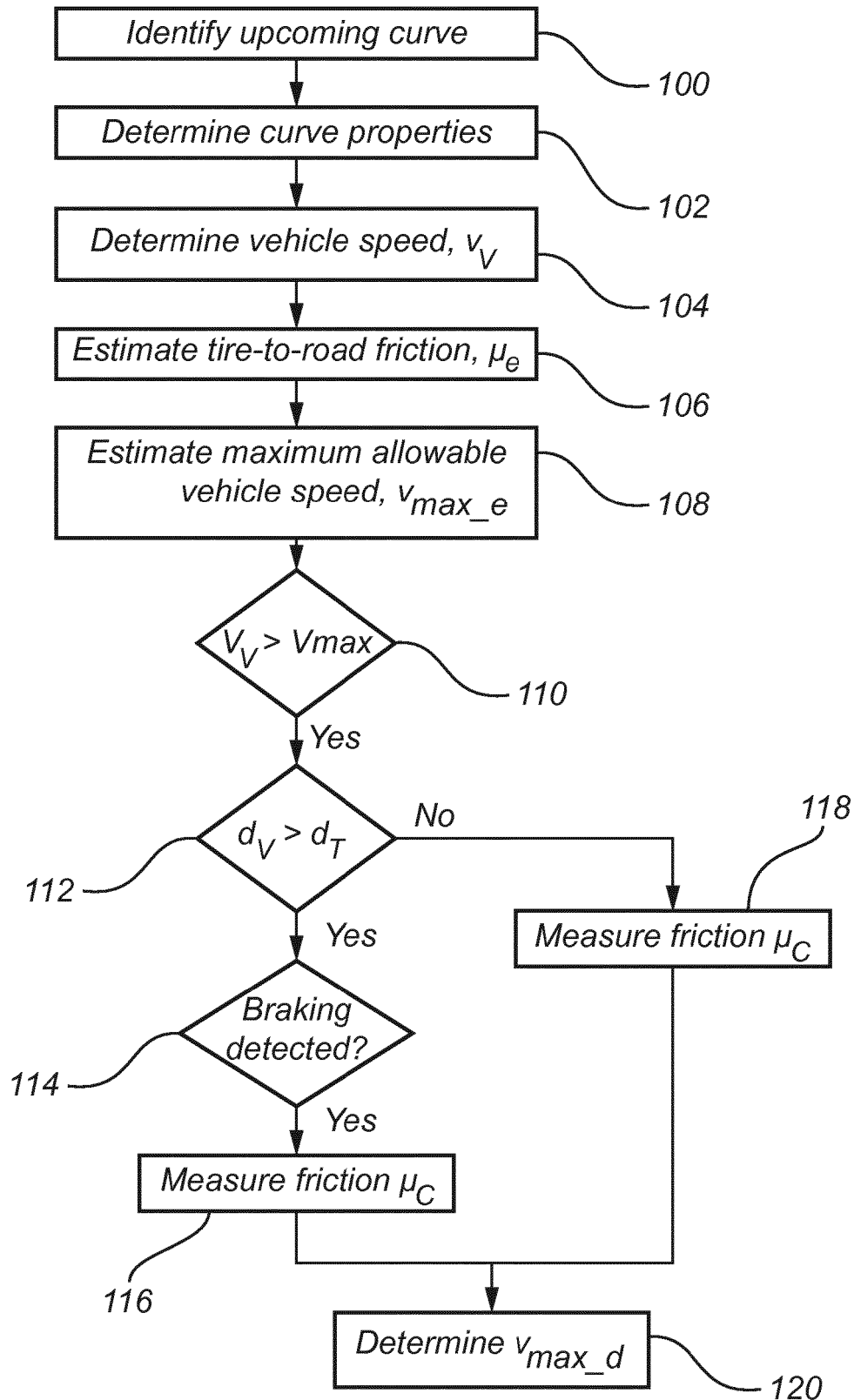
7. Procédé selon l'une quelconque des revendications 1 à 5, dans lequel l'estimation d'un frottement entre un pneu du véhicule et la route comprend l'acquisition d'une valeur de frottement la plus récemment mesurée pour la route sur laquelle le véhicule circule, et l'estimation du frottement comme étant inférieur à la une valeur de frottement la plus précédemment mesurée.

8. Procédé selon l'une quelconque des revendications 1 à 5, dans lequel un frottement estimé est inférieur d'au moins deux écarts-types à un frottement prévu.

9. Procédé selon l'une quelconque des revendications précédentes, dans lequel la détermination de propriétés de la courbe comprend la détermination d'un rayon de la courbe.

10. Procédé selon l'une quelconque des revendications précédentes, dans lequel la détermination de propriétés de la courbe comprend la détermination d'une forme de la courbe.

11. Procédé selon l'une quelconque des revendications précédentes, dans lequel la détermination de propriétés de la courbe comprend la détermination d'une largeur de la route et/ou d'une largeur de voie et/ou d'un dévers de la route.

12. Procédé selon l'une quelconque des revendications précédentes, dans lequel la détermination de propriétés de la courbe comprend l'acquisition de propriétés de la route auprès d'un serveur distant.

13. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre l'estimation d'une trajectoire du véhicule dans la courbe sur la base des propriétés de la courbe.

14. Procédé selon l'une quelconque des revendications précédentes, dans lequel la détermination de propriétés de la courbe comprend l'acquisition d'informations à partir d'une carte précédemment établie.

15. Système de commande (300) d'un véhicule comprenant une unité de commande (200) d'un véhicule configurée pour :

identifier une courbe imminente (204) et la détermination (102) de propriétés de la courbe ;
déterminer une vitesse actuelle, v_v, du véhicule ;
estimer un frottement, μ_e, entre un pneu du véhicule et la route ;
estimer une vitesse maximale admissible, v_{max_e}, du véhicule lorsqu'il entre dans la courbe sur la base des propriétés de la courbe, de la vitesse du véhicule et du frottement estimé ;
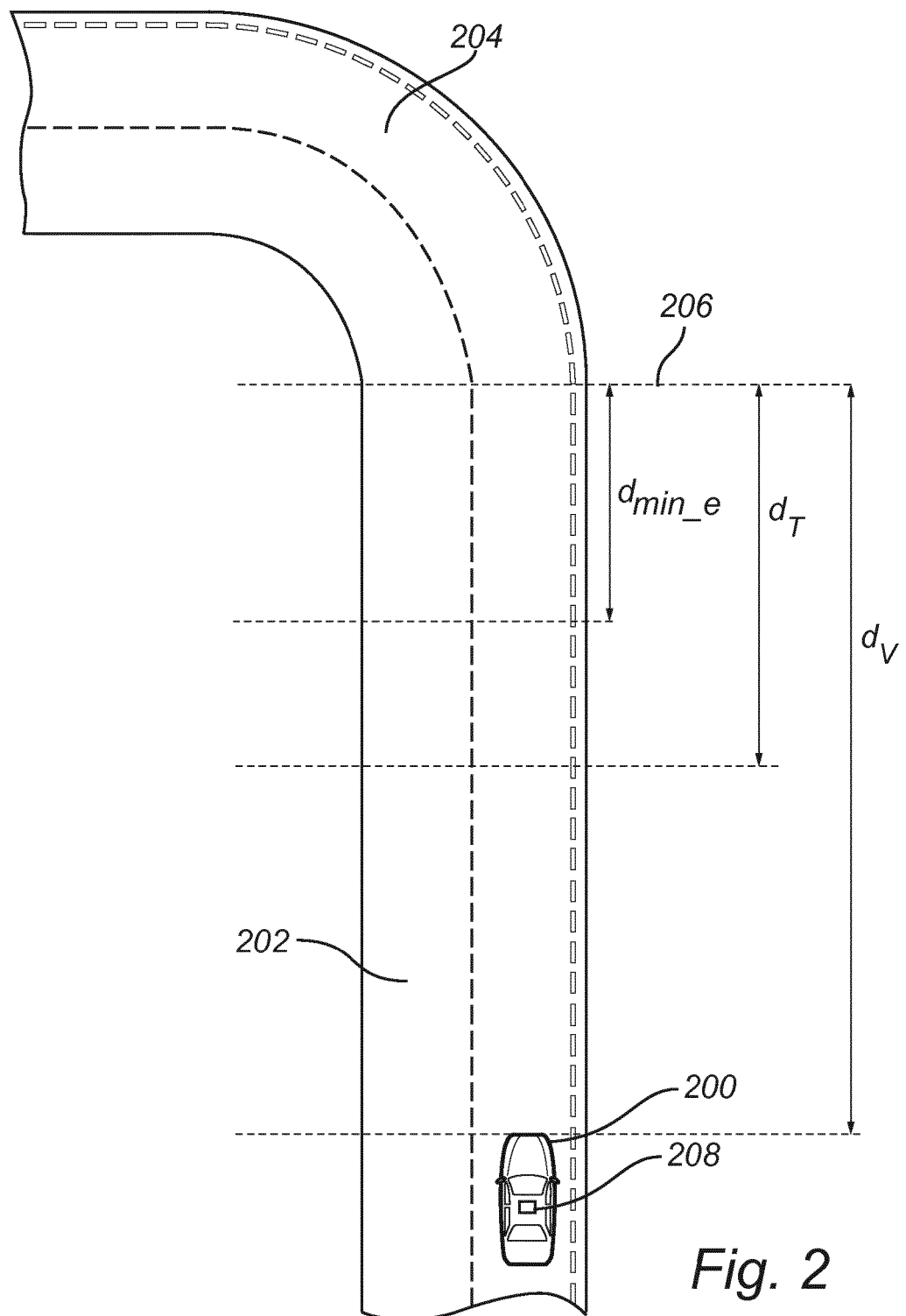si la vitesse actuelle du véhicule est supérieure

à la vitesse maximale admissible estimée du véhicule, déterminer qu'une mesure de frottement est nécessaire ;
si une distance, d_v, entre le véhicule et une entrée de la courbe est supérieure à une distance-seuil prédéterminée, d_T, et si une action de freinage est détectée, la réalisation (116) d'une mesure de frottement durant l'action de freinage afin de déterminer un frottement actuel, μ_c ;
si une distance entre le véhicule et l'entrée de la courbe est inférieure à la distance-seuil prédéterminée, la réalisation (118) d'une mesure de frottement afin de déterminer un frottement actuel ; et
la détermination (120) d'une vitesse maximale admissible, v_{max_d}, du véhicule sur la base du rayon de la courbe, de la vitesse du véhicule et du frottement actuel.

Identify upcoming curve — 100

Determine curve properties — 102

Determine vehicle speed, v_V — 104

Estimate tire-to-road friction, μ_e — 106

Estimate maximum allowable vehicle speed, v_{max_e} — 108

$V_V > Vmax$ — 110

Yes

112 — $d_V > d_T$ — No — Measure friction μ_C — 118

Yes

114 — Braking detected?

Yes

Measure friction μ_C

116

Determine v_{max_d} — 120
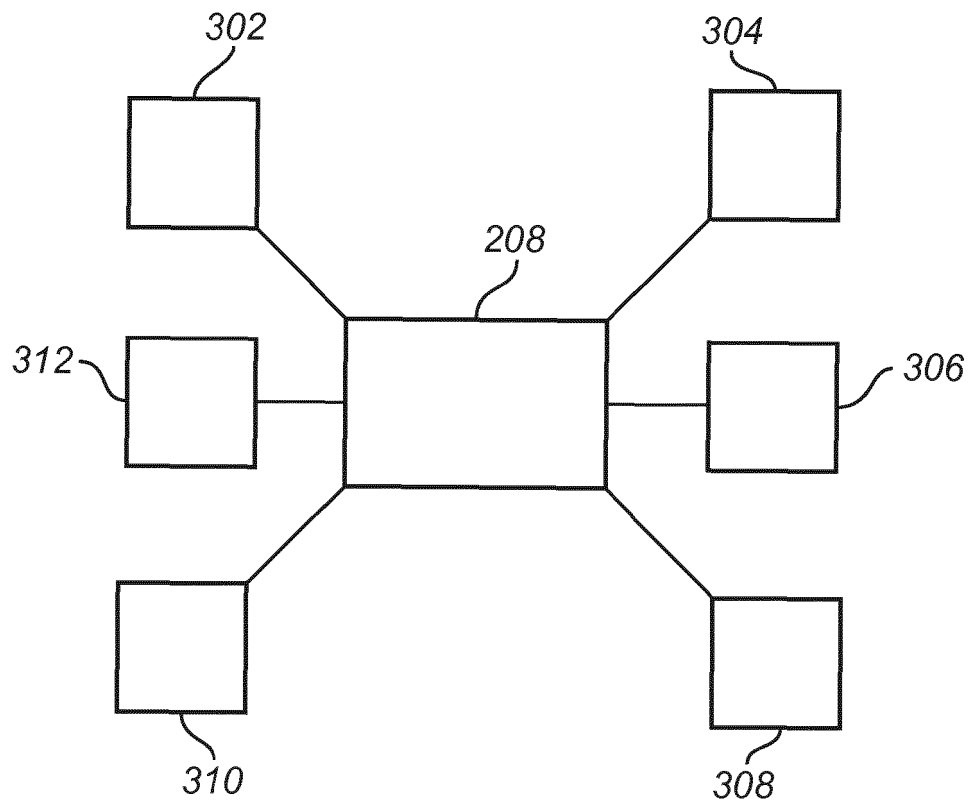
Fig. 1

Fig. 2

Fig. 3

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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- EP 2082936 A **[0006]**