METHOD AND APPARATUS FOR DETERMINING ADHESION COEFFICIENT, VEHICLE, MEDIUM AND PROGRAM PRODUCT

[0001] The present application claims priority to Chinese patent application No. 202410301415.6, filed with the China National Intellectual Property Administration on March 15, 2024, and entitled "METHOD AND APPARATUS FOR DETERMINING ADHESION COEFFICIENT, VEHICLE, MEDIUM AND PROGRAM PRODUCT", which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] Embodiments of the present application relate to, but are not limited to, the technical field of vehicles, and more particularly, to a method and apparatus for determining an adhesion coefficient, a vehicle, a medium and a program product.

BACKGROUND

[0003] An adhesion coefficient of a vehicle plays a key role in longitudinal drive anti-slip control of the vehicle. Therefore, accurately determining the adhesion coefficient of the vehicle is crucial to the anti-slip control of the vehicle.

SUMMARY

[0004] The following is an overview of a subject described in detail in this paper. This summary is not intended to limit the protection scope of the claims.

[0005] Embodiments of the present application provide a method and apparatus for determining an adhesion coefficient, a vehicle, a medium and a program product. According to the method in the embodiments of the present application, a target adhesion coefficient and a confidence level of the target adhesion coefficient can be accurately determined, so as to

improve a matching degree between the adhesion coefficient and an actual situation of the vehicle, and further improve the anti-slip control ability of the vehicle.

[0006] In a first aspect, an embodiment of the present application provides a method for determining an adhesion coefficient. The method includes:

acquiring sensor data collected by at least one sensor of a vehicle;

determining travel information of the vehicle according to the sensor data, the travel information including at least one of the followings: a slip rate, a longitudinal stiffness, a tire longitudinal force, a tire lateral force, a tire vertical load, a front-axle lateral force and a rack force;

determining at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information, the at least one reference adhesion coefficient including at least one of the followings: a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient; and

determining a target adhesion coefficient of the vehicle and a confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient.

[0007] In an implementation, the travel information includes a slip rate of each wheel, a longitudinal stiffness of each wheel, and a tire longitudinal force of each wheel; the reference adhesion coefficient includes a longitudinal adhesion coefficient; and

the determining at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information includes:

determining the longitudinal adhesion coefficient of each wheel according to the slip rate of each wheel, the longitudinal stiffness of each wheel, the tire longitudinal force of each wheel, and a plurality of acquired scenario adhesion coefficients;

determining a first longitudinal adhesion coefficient and a first longitudinal confidence level of the vehicle in a low-adhesion state, and a second longitudinal adhesion coefficient and a second longitudinal confidence level of the vehicle in a high-adhesion state,

according to the longitudinal adhesion coefficients of a plurality of wheels; and

determining the longitudinal adhesion coefficient of the vehicle and a confidence level of the longitudinal adhesion coefficient according to the first longitudinal adhesion coefficient, the first longitudinal confidence level, the second longitudinal adhesion coefficient, and the second longitudinal confidence level.

[0008] In an implementation, the sensor data includes a vehicle speed, and the travel information includes a plurality of front-axle lateral forces and a plurality of rack forces of the vehicle at a plurality of moments; the reference adhesion coefficient includes the lateral adhesion coefficient; and

the determining at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information includes:

determining first statistical information according to the plurality of front-axle lateral forces;

determining second statistical information according to the plurality of front-axle lateral forces and the plurality of rack forces;

fitting the first statistical information and the second statistical information by means of a least square method to obtain the lateral adhesion coefficient;

determining at least one influence factor according to the vehicle speed, the lateral adhesion coefficient and/or the front-axle lateral force at a current moment, the plurality of moments including the current moment; and

determining a confidence level of the lateral adhesion coefficient according to the at least one influence factor.

[0009] In an implementation, the travel information includes a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel, and the sensor data includes accelerations; the reference adhesion coefficient includes a steady-state adhesion coefficient; and

the determining at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data

and the travel information includes:

determining an instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel;

acquiring an activation intervention duration of a stability control system of the vehicle; and

determining the steady-state adhesion coefficient of the vehicle at a current moment and a confidence level of the steady-state adhesion coefficient according to the instantaneous adhesion coefficients at a plurality of moments and the activation intervention duration of the vehicle, the plurality of moments including a plurality of historical moments and the current moment.

[0010] In an implementation, the travel information includes a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel, and the sensor data includes accelerations; the reference adhesion coefficient includes a dynamic adhesion coefficient; and

the determining at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information includes:

determining an instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel;

determining a longitudinal stability factor and a lateral stability factor;

determining a first dynamic adhesion coefficient and a first dynamic confidence level of the vehicle in a high-adhesion state, and a second dynamic adhesion coefficient and a second dynamic confidence level of the vehicle in a low-adhesion state, according to the instantaneous adhesion coefficient, the longitudinal stability factor and the lateral stability factor; and

determining a dynamic adhesion coefficient of the vehicle and a confidence level of the dynamic adhesion coefficient according to the first dynamic adhesion coefficient, the

first dynamic confidence level, the second dynamic adhesion coefficient, and the second dynamic confidence level.

[0011] In an implementation, the sensor data include a tire driving force, vehicle mass, a wheel speed, a wheel acceleration, a wheel steering angle, a slope, a longitudinal acceleration and a lateral acceleration; and the travel information includes the tire longitudinal force, the tire lateral force, the tire vertical load and the longitudinal stiffness; and

the determining travel information of the vehicle according to the sensor data includes:

determining a tire longitudinal force, a tire lateral force and a tire vertical load of each wheel, based on a three-degree-of-freedom model and according to the tire driving force, the vehicle mass, the wheel speed, the wheel acceleration, the wheel steering angle, the slope, the longitudinal acceleration and the lateral acceleration; and

determining the longitudinal stiffness using a least square method, according to a plurality of tire longitudinal forces and a plurality of slip rates of each wheel at a plurality of moments.

[0012] In a second aspect, an embodiment of the present application provides an apparatus for determining an adhesion coefficient. The apparatus includes:

an acquisition module, configured to acquire sensor data collected by at least one sensor of a vehicle;

a processing module, configured to determine travel information of the vehicle according to the sensor data, the travel information including at least one of the followings: a slip rate, a longitudinal stiffness, a tire longitudinal force, a tire lateral force, a tire vertical load, a front-axle lateral force and a rack force;

the processing module being further configured to determine at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information, the at least one reference adhesion coefficient including at least one of the followings: a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient; and

a fusion module, configured to determine a target adhesion coefficient of the vehicle and a confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient.

[0013] In an implementation, the travel information includes a slip rate of each wheel, a longitudinal stiffness of each wheel, and a tire longitudinal force of each wheel; the reference adhesion coefficient includes a longitudinal adhesion coefficient;

the processing module is specifically configured to:

determine the longitudinal adhesion coefficient of each wheel according to the slip rate of each wheel, the longitudinal stiffness of each wheel, the tire longitudinal force of each wheel, and a plurality of acquired scenario adhesion coefficients;

determine a first longitudinal adhesion coefficient and a first longitudinal confidence level of the vehicle in a low-adhesion state, and a second longitudinal adhesion coefficient and a second longitudinal confidence level of the vehicle in a high-adhesion state, according to the longitudinal adhesion coefficients of a plurality of wheels; and

determine the longitudinal adhesion coefficient of the vehicle and a confidence level of the longitudinal adhesion coefficient according to the first longitudinal adhesion coefficient, the first longitudinal confidence level, the second longitudinal adhesion coefficient, and the second longitudinal confidence level.

[0014] In an implementation, the sensor data includes a vehicle speed, and the travel information includes a plurality of front-axle lateral forces and a plurality of rack forces of the vehicle at a plurality of moments; the reference adhesion coefficient includes the lateral adhesion coefficient; and

the processing module is specifically configured to:

determine first statistical information according to the plurality of front-axle lateral forces;

determine second statistical information according to the plurality of front-axle lateral forces and the plurality of rack forces;

fit the first statistical information and the second statistical information by means of a least square method to obtain the lateral adhesion coefficient;

determine at least one influence factor according to the vehicle speed, the lateral adhesion coefficient and/or the front-axle lateral force at a current moment, the plurality of moments including the current moment; and

determine a confidence level of the lateral adhesion coefficient according to the at least one influence factor.

[0015] In an implementation, the travel information includes a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel, and the sensor data includes accelerations; the reference adhesion coefficient includes a steady-state adhesion coefficient; and

the processing module is specifically configured to:

determine an instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel;

acquire an activation intervention duration of a stability control system of the vehicle; and

determine the steady-state adhesion coefficient of the vehicle at a current moment and a confidence level of the steady-state adhesion coefficient according to the instantaneous adhesion coefficients at a plurality of moments and the activation intervention duration of the vehicle, the plurality of moments including a plurality of historical moments and the current moment.

[0016] In an implementation, the travel information includes a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel, and the sensor data includes accelerations; the reference adhesion coefficient includes a dynamic adhesion coefficient; and

the processing module is specifically configured to:

determine an instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel;

determine a longitudinal stability factor and a lateral stability factor;

determine a first dynamic adhesion coefficient and a first dynamic confidence level of the vehicle in a high-adhesion state, and a second dynamic adhesion coefficient and a second dynamic confidence level of the vehicle in a low-adhesion state, according to the instantaneous adhesion coefficient, the longitudinal stability factor and the lateral stability factor; and

determine the dynamic adhesion coefficient of the vehicle and a confidence level of the dynamic adhesion coefficient according to the first dynamic adhesion coefficient, the first dynamic confidence level, the second dynamic adhesion coefficient, and the second dynamic confidence level.

[0017] In an implementation, the sensor data include a tire driving force, vehicle mass, a wheel speed, a wheel acceleration, a wheel steering angle, a slope, a longitudinal acceleration and a lateral acceleration; and the travel information includes a tire longitudinal force, a tire lateral force, a tire vertical load and a longitudinal stiffness; and

the processing module is specifically configured to:

determine a tire longitudinal force, a tire lateral force and a tire vertical load of each wheel, based on a three-degree-of-freedom model and according to the tire driving force, the vehicle mass, the wheel speed, the wheel acceleration, the wheel steering angle, the slope, the longitudinal acceleration and the lateral acceleration; and

determine the longitudinal stiffness using a least square method, according to a plurality of tire longitudinal forces and a plurality of slip rates of each wheel at a plurality of moments.

[0018] In a third aspect, an embodiment of the present application provides a vehicle. The vehicle includes:

a processor, and a memory being in communication connection with the processor, wherein

the memory is configured to store computer-executable instructions therein; and

the processor is configured to execute the computer-executable instructions stored in the memory, so as to implement the method for determining the adhesion coefficient in the first aspect.

[0019] In a fourth aspect, an embodiment of the present application provides a computer-readable storage medium. The computer-readable storage medium has computer-executable instructions stored therein, wherein the computer-executable instructions, when being executed by a processor, implement the method for determining the adhesion coefficient in the first aspect.

[0020] In a fifth aspect, an embodiment of the present application provides a computer program product. The computer program product includes a computer program, which, when executed by a processor, implements the method for determining the adhesion coefficient in the first aspect.

[0021] Embodiments of the present application provide a method and apparatus for determining an adhesion coefficient, a vehicle, a medium and a program product. In this method, the vehicle may acquire sensor data collected by at least one sensor of a vehicle, and determine travel information of the vehicle according to the sensor data. The vehicle may determine at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information, the at least one reference adhesion coefficient including at least one of the followings: a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient. The vehicle may determine the target adhesion coefficient of the vehicle and the confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient. By means of the above manner, the target adhesion coefficient and the confidence level of the target adhesion coefficient can be accurately determined, so as to improve a matching degree between the adhesion coefficient and an actual situation of the vehicle, and further improve the anti-slip control ability of the vehicle.

[0022] Other aspects will become apparent after reading and understanding the accompanying drawings and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The accompanying drawings in the following description are some embodiments

of the present application, and a person of ordinary skill in the art may still derive other accompanying drawings from these accompanying drawings without creative efforts.

[0024] FIG. 1 is an architecture schematic diagram of an application scenario applicable to an embodiment of the present application.

[0025] FIG. 2a is a schematic flowchart of Embodiment 1 of a method for determining an adhesion coefficient provided by an embodiment of the present application.

[0026] FIG. 2b is a schematic flowchart of a determination of an adhesion coefficient provided by an embodiment of the present application.

[0027] FIG. 2c is a schematic diagram of a determination of travel information provided by an embodiment of the present application.

[0028] FIG. 3 is a schematic flowchart of Embodiment 2 of a method for determining an adhesion coefficient provided by an embodiment of the present application.

[0029] FIG. 4 is a schematic flowchart of Embodiment 3 of a method for determining an adhesion coefficient provided by an embodiment of the present application.

[0030] FIG. 5 is a schematic flowchart of Embodiment 4 of a method for determining an adhesion coefficient provided by an embodiment of the present application.

[0031] FIG. 6 is a schematic flowchart of Embodiment 5 of a method for determining an adhesion coefficient provided by an embodiment of the present application.

[0032] FIG. 7 is a schematic structural diagram of an apparatus for determining an adhesion coefficient provided by an embodiment of the present application.

[0033] FIG. 8 is a structural diagram of a vehicle provided by an embodiment of the present application.

DESCRIPTION OF EMBODIMENTS

[0034] The described embodiments are some embodiments, rather than all embodiments, of the present application. Based on the embodiments in the present application, all other embodiments derived by a person of ordinary skill in the art under the inspiration of the present embodiment shall fall within the protection scope of the present application.

[0035] The terms “first”, “second”, “third”, “fourth” and the like (if any) in the

description and claims, as well as the above-mentioned accompanying drawings, of the present application are used to distinguish similar objects, but not necessarily used to describe a specific order or precedence order. It should be understood that data used in this way may be interchanged where appropriate so that the embodiments of the present application described herein can be implemented in a sequence other than those illustrated or described herein. In addition, the terms "comprising/including" and "having" and any variations thereof are intended to cover non-exclusive inclusions, e.g., processes, methods, systems, products or devices containing a series of steps or units need not be limited to those steps or units that are clearly listed, but may include other steps or units that are not clearly listed or are inherent to those processes, methods, products or devices.

[0036] An adhesion coefficient of a vehicle plays a key role in longitudinal drive anti-slip control of the vehicle. In related technologies, it is common for a vehicle to estimate an adhesion coefficient directly according to a ratio of a longitudinal driving force to a vertical load, so as to implement anti-slip control of the vehicle based on this adhesion coefficient. However, the method for estimating the adhesion coefficient directly according to the ratio of the longitudinal driving force to the vertical load may cause the adhesion coefficient to mismatch with an actual situation of the vehicle, resulting in inaccurate anti-slip control of the vehicle and affecting the safety of passengers.

[0037] An embodiment of the present application provides a method for determining an adhesion coefficient. A vehicle may acquire sensor data collected by at least one sensor of a vehicle, and determine travel information of the vehicle according to the sensor data. The vehicle may determine at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information, the at least one reference adhesion coefficient including at least one of the followings: a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient. The vehicle may determine a target adhesion coefficient of the vehicle and a confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient. By means of the above manner, the

target adhesion coefficient and the confidence level of the target adhesion coefficient can be accurately determined, so as to improve a matching degree between the adhesion coefficient and an actual situation of the vehicle, and further improve the anti-slip control ability of the vehicle.

[0038] The principles and features in the embodiments of the present application will be described below with reference to the accompanying drawings. The examples are only used to explain the embodiments of the present application, and are not intended to limit the scope of the embodiments of the present application.

[0039] FIG. 1 is a schematic diagram of an application scenario applicable to an embodiment of the present application. This application scenario includes a vehicle 10, the vehicle 10 including a plurality of wheels. Exemplarily, FIG. 1 shows four wheels, which are a left front wheel 101, a right front wheel 102, a left rear wheel 103, and a right rear wheel 104, respectively. In addition, a plurality of sensors (not shown in FIG. 1) may also be mounted on the vehicle 10. For example, a wheel speed sensor, an inertial measurement unit (inertial measurement unit, IMU for short) sensor (a motion sensor), and a steering wheel angle sensor may be mounted on the vehicle 10. Other sensors may also be mounted on the vehicle 10, and will not be limited in the embodiments of the present application, depending on sensor data and travel information which are used to calculate reference adhesion coefficients and their confidence levels in an actual situation.

[0040] In this application scenario, the vehicle 10 may acquire sensor data collected by at least one sensor of the vehicle 10 and determine travel information of the vehicle 10 according to the sensor data. The vehicle 10 may determine at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information, the at least one reference adhesion coefficient including at least one of the followings: a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient. The vehicle 10 may determine a target adhesion coefficient of the vehicle 10 and a confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion

coefficient.

[0041] An actual form of the vehicle included in FIG. 1 is not limited in the embodiments of the present application, and may be set according to actual requirements in the application of a scheme.

[0042] The technical solutions of the present application will be further described below in conjunction with specific embodiments. It needs to be noted that the following specific embodiments may be combined with each other, and the same or similar concepts or processes may not be repeated in some embodiments.

[0043] FIG. 2a is a schematic flowchart of Embodiment 1 of a method for determining an adhesion coefficient provided by an embodiment of the present application. Referring to FIG. 2a, the method may specifically include the following steps.

[0044] S201: Acquire sensor data collected by at least one sensor of a vehicle.

[0045] In the present embodiment, the vehicle may acquire the sensor data collected by the at least one sensor of the vehicle.

[0046] For example, the sensor data may include one or more of the followings:

a vehicle speed, a tire driving force, vehicle mass, a wheel speed, a wheel steering angle, a slope, and accelerations (a wheel acceleration, a longitudinal acceleration, and a lateral acceleration).

[0047] In addition, the sensor data may also include the number of teeth in wheel rotation, a rolling direction, an angular velocity (including a roll angular velocity, a yaw angular velocity, etc.), a steering wheel angle, a load, a tire torque, an Euler angle, etc.

[0048] In an implementation, the vehicle may preprocess the sensor data after acquiring the sensor data. For example, the vehicle may perform low-pass filtering, differential filtering and compensation processing on the sensor data. As another example, the vehicle may also calculate a change rate of the sensor data according to the sensor data. Exemplarily, the vehicle may calculate a longitudinal acceleration change rate according to the longitudinal acceleration.

[0049] For example, the vehicle may calculate a variance value of an acceleration (or angular velocity) after acquiring the acceleration (or angular speed) collected by the inertial

measurement unit sensor under static and dynamic conditions, and use the variance value as zero drift to perform compensation processing on the data collected by the inertial measurement unit sensor.

[0050] For another example, after acquiring a brake torque of each wheel, the vehicle may calculate, according to brake torques of a plurality of wheels, corrected values of the brake torques based on a least mean square algorithm, and perform compensation processing on the brake torque of each wheel according to the corrected values of the brake torques.

[0051] S202: Determine travel information of the vehicle according to the sensor data.

[0052] In the present embodiment, the vehicle may determine the travel information of the vehicle according to the sensor data.

[0053] The travel information includes at least one of the followings: a slip rate, a longitudinal stiffness, a tire longitudinal force, a tire lateral force, a tire vertical load, a front-axle lateral force and a rack force. In an implementation, the travel information may also include a travel direction of the vehicle.

[0054] Specifically, the vehicle may determine a tire longitudinal force, a tire lateral force and a tire vertical load of each wheel, based on a three-degree-of-freedom model according to vehicle mass, a tire driving force (a tire driving force of each wheel), a wheel speed (a wheel speed of each wheel), a wheel acceleration (a wheel acceleration of each wheel), a wheel steering angle (a steering angle of each wheel), a slope, a longitudinal acceleration and a lateral acceleration corresponding to the vehicle at the current moment.

[0055] The vehicle may determine the longitudinal stiffness of each wheel using a least square method according to a plurality of tire longitudinal forces and a plurality of slip rates of each wheel at a plurality of moments. In addition, the vehicle may also determine a longitudinal slip stiffness of each wheel.

[0056] In addition, in the case where the vehicle fails to acquire a vehicle speed based on the sensor, the vehicle may also calculate a slope and a vehicle speed (a longitudinal vehicle speed of the vehicle), based on an extended Kalman filtering method according to a vertical acceleration and a longitudinal acceleration detected by the IMU sensor and a wheel speed detected by the wheel speed sensor. In addition, the vehicle may also calculate a longitudinal

vehicle speed mass factor according to the longitudinal vehicle speed.

[0057] The vehicle may also calculate a rolling radius of a wheel, based on a least square method according to vehicle speeds (the longitudinal vehicle speed, and a vehicle speed detected by a global positioning system (Global Positioning System, GPS for short)). The vehicle may determine that a tire mode of a wheel is a spare tire mode in the case of recognizing that the rolling radius of this wheel is less than a preset rolling radius; and the vehicle may determine that the tire mode of the wheel is not a spare tire mode in the case of recognizing that the rolling radius of the wheel is greater than or equal to the preset rolling radius.

[0058] The vehicle may also determine the vehicle mass based on a least square method according to the tire driving force and the vehicle accelerations (e.g., a lateral acceleration, and a longitudinal acceleration).

[0059] The vehicle may determine a travel direction (forward, backward or stationary) of the vehicle according to the number of teeth in wheel rotation and a rolling direction.

[0060] The vehicle may also calculate an acceleration and an angular velocity based on a tire brush model according to a vehicle speed and a longitudinal force in the case of not acquiring the acceleration and the angular velocity based on the sensor. After calculating the acceleration, the vehicle may also calculate an acceleration fluctuation value based on the acceleration.

[0061] In addition, it should also be noted that the vehicle may also calculate a slip rate deviation of each wheel after acquiring a plurality of slip rates of each wheel. The vehicle may also calculate a yaw angular acceleration according to a yaw angular velocity.

[0062] FIG. 2c is a schematic diagram of the determination of travel information provided by an embodiment of the present application. Exemplarily, FIG. 2c shows the determination of a travel direction, a longitudinal stiffness, a tire longitudinal force, a tire lateral force, a tire vertical load, an acceleration, an angular velocity, a tire mode, vehicle mass, a travel direction, a slope, a vehicle speed, and a longitudinal slip stiffness.

[0063] S203: Determine at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data

and the travel information.

[0064] In the present embodiment, the vehicle may determine at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information.

[0065] The at least one reference adhesion coefficient includes at least one of the followings: a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient.

[0066] Correspondingly, the confidence level of the at least one reference adhesion coefficient includes at least one of the followings: a confidence level of the steady-state adhesion coefficient, a confidence level of the dynamic adhesion coefficient, a confidence level of the longitudinal adhesion coefficient and a confidence level of the lateral adhesion coefficient.

[0067] S204: Determine a target adhesion coefficient of the vehicle and a confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient.

[0068] In the present embodiment, the vehicle may determine a target adhesion coefficient of the vehicle and a confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient.

[0069] In an implementation, the vehicle may acquire a sensor state of at least one sensor and also acquire a tire mode of at least one wheel. The vehicle may determine a target adhesion coefficient as a first preset value and a confidence level of the target adhesion coefficient as a second preset value in the case of determining that the sensor state of at least one sensor is an invalid state and/or that a tire mode of at least one wheel is a spare tire mode. Exemplarily, the first preset value may be 1, and the second preset value may be 0. In addition, the vehicle may also determine that the confidence level is Level 0.

[0070] In an implementation, in the case where the reference adhesion coefficient includes a dynamic adhesion coefficient, a lateral adhesion coefficient and a longitudinal adhesion coefficient, the vehicle may determine the target adhesion coefficient as a third preset value

and a confidence level of the target adhesion coefficient as a fourth preset value in the case of determining that the confidence levels of the dynamic adhesion coefficient, the longitudinal adhesion coefficient and the lateral adhesion coefficient are all less than or equal to 0. Exemplarily, the third preset value may be 1, and the fourth preset value may be 1. In addition, the vehicle may determine the confidence level as Level 1 in the case of determining that the confidence levels of the dynamic adhesion coefficient, the longitudinal adhesion coefficient and the lateral adhesion coefficient are all less than or equal to 0.

[0071] In an implementation, in the case where the reference adhesion coefficient includes a dynamic adhesion coefficient, a lateral adhesion coefficient and a longitudinal adhesion coefficient, the vehicle may determine a target number of reference adhesion coefficients which are greater than a first preset threshold and each have a corresponding confidence level greater than a second preset threshold.

[0072] In the case where the target number is greater than 1, the vehicle may determine the target adhesion coefficient based on the following formula:

$$\mathrm{FusionMue(t)} = \frac{\mathrm{LatRfeMue(t)} + \mathrm{LongRfeMue(t)} + \mathrm{MueFromVehDyn(t)}}{\mathrm{MaxConfdIdx_B(i)}}$$

in which, $\mathrm{FusionMue(t)}$ is the target adhesion coefficient, $\mathrm{LatRfeMue(t)}$ is the lateral adhesion coefficient, $\mathrm{LongRfeMue(t)}$ is the longitudinal adhesion coefficient, $\mathrm{MueFromVehDyn(t)}$ is the dynamic adhesion coefficient, and $\mathrm{MaxConfdIdx_B(i)}$ is the target number.

[0073] In addition, the vehicle may determine the confidence level of the target adhesion coefficient as a fifth preset value. Exemplarily, the fifth preset value may be 0.01.

[0074] In the case where the target number is 1, the vehicle may determine the target adhesion coefficient based on the following formula:

$$\mathrm{FusionMue(t)} = \frac{\mathrm{LatConfd(t)} * \mathrm{LatRfeMue(t)} + \mathrm{LongConfd(t)} * \mathrm{LongRfeMue(t)} + \mathrm{VehDynConfd(t)} * \mathrm{MueFromVehDyn(t)}}{\mathrm{LatConfd(t)} + \mathrm{LongConfd(t)} + \mathrm{VehDynConfd(t)}}$$

in which, $\mathrm{FusionMue(t)}$ is the target adhesion coefficient, $\mathrm{LatRfeMue(t)}$ is the lateral adhesion coefficient, $\mathrm{LatConfd(t)}$ is the confidence level of the lateral adhesion coefficient, $\mathrm{LongRfeMue(t)}$ is the longitudinal adhesion coefficient, $\mathrm{LongConfd(t)}$ is the confidence level of the longitudinal adhesion coefficient, $\mathrm{MueFromVehDyn(t)}$ is the

dynamic adhesion coefficient, and $\mathrm{VehDynConfd(t)}$ is the confidence level of the dynamic adhesion coefficient.

[0075] The vehicle may determine a mean square value of the confidence level of the dynamic adhesion coefficient, the confidence level of the longitudinal adhesion coefficient and the confidence level of the lateral adhesion coefficient as the confidence level of the target adhesion coefficient.

[0076] In addition, the vehicle may also determine a confidence level according to each reference adhesion coefficient whose confidence level is greater than a second preset threshold. Exemplarily, the vehicle may determine the confidence level as Level 2 in the case of determining that the confidence level of the lateral adhesion coefficient is greater than the second preset threshold. The vehicle may determine the confidence level as Level 3 in the case of determining that the confidence level of the longitudinal adhesion coefficient is greater than the second preset threshold. The vehicle may determine the confidence level as Level 4 in the case of determining that the confidence level of the dynamic adhesion coefficient is greater than the second preset threshold. The vehicle may determine the confidence level as Level 5 in the case of determining that the confidence levels of two reference adhesion coefficients are both greater than the second preset threshold. The vehicle may determine the confidence level as Level 6 in the case of determining that the confidence levels of three reference adhesion coefficients are all greater than the second preset threshold.

[0077] In an implementation, in the case where the reference adhesion coefficients include the steady-state adhesion coefficient, the vehicle may acquire a historical target adhesion coefficient of the vehicle at the previous moment. The vehicle may determine the target adhesion coefficient based on the following formula:

$$\mathrm{FusionMue(t)} = \mathrm{FusionMue(t-1)} + \frac{1}{\mathrm{AvgCtr}} * [\mathrm{MueFromStabCtrl(t)} - \mathrm{FusionMue(t-1)}]$$

$$\frac{1}{\mathrm{AvgCtr}} = \frac{\mathrm{TS}}{\mathrm{TC}}$$

in which, $\mathrm{FusionMue(t)}$ is the target adhesion coefficient, $\mathrm{MueFromStabCtrl(t)}$ is the steady-state adhesion coefficient, $\mathrm{FusionMue(t-1)}$ is the historical target adhesion coefficient, $\frac{1}{\mathrm{AvgCtr}}$ is an adjustment coefficient, TS is a numerical value corresponding to an

activation duration, and TC is a time constant.

[0078] In addition, the vehicle may also determine the confidence level of the target adhesion coefficient as a sixth preset value. Exemplarily, the sixth preset value may be 7.

[0079] FIG. 2b is a schematic flowchart of the determination of an adhesion coefficient provided by an embodiment of the present application. As shown in FIG. 2b, the vehicle may determine at least one reference adhesion coefficient (FIG. 2b shows a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient), and a confidence level of each reference adhesion coefficient. The vehicle may determine the target adhesion coefficient of the vehicle and the confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient. It should be noted that, in the case of determining the steady-state adhesion coefficient and the dynamic adhesion coefficient, the vehicle may determine the instantaneous adhesion coefficient first, and then determine the steady-state adhesion coefficient and the dynamic adhesion coefficient according to the instantaneous adhesion coefficient.

[0080] The present embodiment has the following beneficial effect: the vehicle may acquire the sensor data collected by at least one sensor of the vehicle, and determine the travel information of the vehicle according to the sensor data. The vehicle may determine at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information, the at least one reference adhesion coefficient including at least one of the followings: a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient. The vehicle may determine the target adhesion coefficient of the vehicle and the confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient. By means of the above manner, the target adhesion coefficient and the confidence level of the target adhesion coefficient can be accurately determined, so as to improve a matching degree between the adhesion coefficient and an actual situation of the vehicle, and further improve the anti-slip control ability of the vehicle.

[0081] The process of the vehicle determining the longitudinal adhesion coefficient and the confidence level thereof is described in Embodiment 2 of the method.

[0082] FIG. 3 is a schematic flowchart of Embodiment 2 of a method for determining an adhesion coefficient provided by an embodiment of the present application. Referring to FIG. 3, the method may specifically include the following steps.

[0083] S301: Determine the longitudinal adhesion coefficient of each wheel according to the slip rate of each wheel, the longitudinal stiffness of each wheel, the tire longitudinal force of each wheel, and a plurality of acquired scenario adhesion coefficients.

[0084] In the present embodiment, the vehicle may determine the longitudinal adhesion coefficient of each wheel according to the slip rate of each wheel, the longitudinal stiffness of each wheel, the tire longitudinal force of each wheel, and a plurality of acquired scenario adhesion coefficients.

[0085] Specifically, for any wheel, the vehicle may calculate the longitudinal adhesion coefficient of the wheel using the following formula:

$$P(1) = \frac{1}{\sum_{i=1}^{6} P(i)} * \exp\left(-160 * \left(FxNorm(k) - 0.15 * \tanh\left(\frac{LongStfns(k) * Slip(k)}{0.15}\right)\right)^2 - \max(P)\right)$$

$$P(2) = \frac{1}{\sum_{i=1}^{6} P(i)} * \exp\left(-160 * \left(FxNorm(k) - 0.35 * \tanh\left(\frac{LongStfns(k) * Slip(k)}{0.35}\right)\right)^2 - \max(P)\right)$$

$$P(3) = \frac{1}{\sum_{i=1}^{6} P(i)} * \exp\left(-160 * \left(FxNorm(k) - 0.45 * \tanh\left(\frac{LongStfns(k) * Slip(k)}{0.45}\right)\right)^2 - \max(P)\right)$$

$$P(4) = \frac{1}{\sum_{i=1}^{6} P(i)} * \exp\left(-160 * \left(FxNorm(k) - 0.6 * \tanh\left(\frac{LongStfns(k) * Slip(k)}{0.6}\right)\right)^2 - \max(P)\right)$$

$$P(5) = \frac{1}{\sum_{i=1}^{6} P(i)} * \exp\left(-160 * \left(FxNorm(k) - 0.75 * \tanh\left(\frac{LongStfns(k) * Slip(k)}{0.75}\right)\right)^2 - \max(P)\right)$$

$$P(6) = \frac{1}{\sum_{i=1}^{6} P(i)} * \exp\left(-160 * \left(FxNorm(k) - 0.9 * \tanh\left(\frac{LongStfns(k) * Slip(k)}{0.9}\right)\right)^2 - \max(P)\right)$$

$$MueInst(k) = E(X) = P(1) * 0.15 + P(2) * 0.3 + P(3) * 0.45 + P(4) * 0.6 + P(5) * 0.75 + P(6) * 0.9.$$

[0086] It should be noted that $P(1)$ is a probability corresponding to a first scenario adhesion coefficient, 0.15 being the first scenario adhesion coefficient; $P(2)$ is a probability

corresponding to a second scenario adhesion coefficient, 0.35 being the second scenario adhesion coefficient; $P(3)$ is a probability corresponding to a third scenario adhesion coefficient, 0.45 being the third scenario adhesion coefficient; $P(4)$ is a probability corresponding to a fourth scenario adhesion coefficient, 0.6 being the fourth scenario adhesion coefficient; $P(5)$ is a probability corresponding to a fifth scenario adhesion coefficient, 0.75 being the fifth scenario adhesion coefficient; and $P(6)$ is a probability corresponding to a sixth scenario adhesion coefficient, 0.9 being the sixth scenario adhesion coefficient.

[0087] It should also be noted that $\mathrm{MueInst}(k)$ is the longitudinal adhesion coefficient of the wheel, $\mathrm{FxNorm}(k)$ is the tire longitudinal force (it should be noted that the tire longitudinal force here is a nominalized longitudinal force), $\mathrm{LongStfns}(k)$ is the longitudinal stiffness, and $\mathrm{Slip}(k)$ is the slip rate; and values of k are 1, 2, 3, and 4, which represent a left front wheel, a right front wheel, a left rear wheel, and a right rear wheel in turn. It should also be noted that when the probability corresponding to each scenario adhesion coefficient is calculated, an initial value of 1/6 may be used for $\max(P)$, and an initial value of 1 may be used for $\sum_{i=1}^{6} P(i)$.

[0088] S302: Determine a first longitudinal adhesion coefficient and a first longitudinal confidence level of the vehicle in a low-adhesion state, and a second longitudinal adhesion coefficient and a second longitudinal confidence level of the vehicle in a high-adhesion state, according to the longitudinal adhesion coefficients of a plurality of wheels.

[0089] In the present embodiment, the vehicle may determine a first longitudinal adhesion coefficient and a first longitudinal confidence level of the vehicle in a low-adhesion state, and a second longitudinal adhesion coefficient and a second longitudinal confidence level of the vehicle in a high-adhesion state, according to the longitudinal adhesion coefficients of a plurality of wheels.

[0090] In the process of determining a first dynamic adhesion coefficient and a first longitudinal confidence level:

the vehicle may acquire an activation duration of a stability control system and a longitudinal acceleration change rate. The vehicle may also acquire a slip rate deviation of

each wheel. It should be noted that the vehicle may determine that the vehicle activates the stability control system in the case of recognizing that there is a brake flag position bit of a wheel (tire) and a brake torque of the wheel (tire) is greater than zero. The vehicle may also determine that the vehicle activates the stability control system in the case of recognizing that there is a control flag position bit of an anti-lock brake system of a wheel (tire) and a brake torque of the wheel (tire) is greater than zero. The vehicle may also determine that the vehicle activates the stability control system in the case of recognizing that there is a wheel (tire) corresponding to an identifier of a wheel (tire) in an up/down torque request and the slip rate of the wheel (tire) is greater than zero.

[0091] For any wheel, the vehicle analyzes the wheel according to a slip rate deviation of the wheel and a tire longitudinal force (nominalized longitudinal force) of the wheel to determine whether the wheel satisfies a first condition or the wheel satisfies a second condition, in the case of determining that the wheel satisfies a plurality of low-adhesion estimation conditions. The plurality of low-adhesion estimation conditions include: a longitudinal adhesion coefficient of the wheel is greater than a first threshold, an estimated flag bit of the wheel is a valid flag bit, an activation duration is greater than a second threshold, and a longitudinal acceleration change rate is less than a third threshold. It should be noted that, in the case of determining that an adhesion coefficient variance corresponding to the wheel is less than a sixth threshold, the vehicle may determine that the estimated flag bit of the wheel is a valid flag bit; and in the case of determining that the adhesion coefficient variance corresponding to the wheel is greater than or equal to a fifth threshold, the vehicle may determine that the estimated flag bit of the wheel is an invalid flag bit. In addition, it should also be noted that the first threshold may be any numerical value between 0 and 0.4, the third threshold may be any numerical value between 200 ms and 500 ms, and the fourth threshold may be any numerical value between 3000 and 5000.

[0092] After analyzing all wheels, the vehicle may determine the number of wheels that satisfy the first condition and the number of wheels that satisfy the second condition.

[0093] The vehicle may determine a first longitudinal adhesion coefficient under the first condition and a first longitudinal confidence level under the first condition using the

following formula:

$$\text{mueFastTrack} = \frac{\sum_{k=1}^{\text{nofMidWheels}} \text{MueInst(k)}}{\text{nofMidWheels}}$$

$$\text{mueFastTrackConfd} = \text{cnfdLvlMidWheels}$$

in which, nofMidWheels is the number of wheels that satisfy the first condition, mueFastTrack is the first longitudinal adhesion coefficient under the first condition, mueFastTrackConfd is the first confidence level under the first condition, and cnfdLvlMidWheels is a first calibration parameter.

[0094] The vehicle may determine a first longitudinal adhesion coefficient under the second condition and a first longitudinal confidence level under the second condition using the following formula:

$$\text{mueFastTrack} = \frac{\sum_{k=1}^{\text{nofLargeWheels}} \text{MueInst(k)}}{\text{nofLargeWheels}}$$

$$\text{mueFastTrackConfd} = \text{cnfdLvlLargeWheels}$$

in which, nofLargeWheels is the number of wheels that satisfy the second condition, mueFastTrack is the first longitudinal adhesion coefficient under the second condition, mueFastTrackConfd is the first longitudinal confidence level under the second condition, and cnfdLvlLargeWheels is a second calibration parameter.

[0095] The vehicle may analyze the number of wheels that satisfy the first condition and the number of wheels that satisfy the second condition.

[0096] The vehicle may determine the first longitudinal adhesion coefficient under the second condition as the first longitudinal adhesion coefficient and the first longitudinal confidence level under the second condition as the first longitudinal confidence level in the case of determining that the number of wheels that satisfy the second condition is greater than 0 and the number of wheels that satisfy the first condition is 0.

[0097] The vehicle may determine the first longitudinal adhesion coefficient under the first condition as the first longitudinal adhesion coefficient and the first longitudinal confidence level under the first condition as the first longitudinal confidence level in the case of determining that the number of wheels that satisfy the first condition is greater than 0 and

the number of wheels that satisfy the second condition is 0.

[0098] The vehicle may determine a maximum value of the first longitudinal adhesion coefficient under the first condition and the first longitudinal adhesion coefficient under the second condition as the first longitudinal adhesion coefficient and a confidence level corresponding to the maximum value as the first longitudinal confidence level in the case of determining that the number of wheels that satisfy the first condition is greater than 0 and the number of wheels that satisfy the second condition is greater than 0. In an implementation, the vehicle may also adjust the first longitudinal confidence level after determining the confidence level corresponding to the maximum value as the first longitudinal confidence level. Exemplarily, the vehicle may add the first longitudinal confidence level and the third calibration parameter so as to adjust the first longitudinal confidence level.

[0099] The vehicle may determine a preset longitudinal adhesion coefficient as the first longitudinal adhesion coefficient and a preset confidence level as the first longitudinal confidence level in the case of determining that the number of wheels that satisfy the first condition is 0 and the number of wheels that satisfy the second condition is 0. Exemplarily, the preset longitudinal adhesion coefficient may be 1 and the preset confidence level may be 0.

[0100] In the process of determining a second dynamic adhesion coefficient and a second longitudinal confidence level:

[0101] For any wheel, the vehicle determines whether the wheel satisfies a third condition or the wheel satisfies a fourth condition, according to a tire longitudinal force (nominalized longitudinal force) of the wheel, in the case of determining that the wheel satisfies a plurality of high-adhesion estimation conditions. The plurality of high-adhesion estimation conditions include: a longitudinal adhesion coefficient of the wheel is greater than a fourth threshold, an estimated flag bit of the wheel is a valid flag bit, and an activation duration is greater than a fifth threshold. It should also be noted that the fourth threshold may be any numerical value between 0.4 and 1, and the fifth threshold may be any numerical value between 300 ms and 500 ms.

[0102] After analyzing all wheels, the vehicle may determine the number of wheels that satisfy the third condition and the number of wheels that satisfy the fourth condition.

[0103] The vehicle may determine a second longitudinal adhesion coefficient under the third condition and a second longitudinal confidence level under the third condition using the following formula:

$$\text{mueFastTrack} = \frac{\sum_{k=1}^{\text{nofMidWheels}} \text{MueInst(k)}}{\text{nofMidWheels}}$$

$$\text{mueFastTrackConfd} = \text{cnfdLvlMidWheels}$$

in which, nofMidWheels is the number of wheels that satisfy the third condition, mueFastTrack is the second longitudinal adhesion coefficient under the third condition, mueFastTrackConfd is the second longitudinal confidence level under the third condition, and cnfdLvlMidWheels is a fourth calibration parameter.

[0104] The vehicle may determine a second longitudinal adhesion coefficient under the fourth condition and a second longitudinal confidence level under the fourth condition using the following formula:

$$\text{mueFastTrack} = \frac{\sum_{k=1}^{\text{nofLargeWheels}} \text{MueInst(k)}}{\text{nofLargeWheels}}$$

$$\text{mueFastTrackConfd} = \text{cnfdLvlLargeWheels}$$

in which, nofLargeWheels is the number of wheels that satisfy the fourth condition, mueFastTrack is the second longitudinal adhesion coefficient under the fourth condition, mueFastTrackConfd is the second longitudinal confidence level under the fourth condition, and $\text{cnfdLvlLargeWheels}$ is a fifth calibration parameter.

[0105] The vehicle may analyze the number of wheels that satisfy the third condition and the number of wheels that satisfy the fourth condition.

[0106] The vehicle may determine the second longitudinal adhesion coefficient under the fourth condition as the second longitudinal adhesion coefficient and the second longitudinal confidence level under the fourth condition as the second longitudinal confidence level in the case of determining that the number of wheels that satisfy the fourth condition is greater than 0 and the number of wheels that satisfy the third condition is 0.

[0107] The vehicle may determine the second longitudinal adhesion coefficient under the third condition as the second longitudinal adhesion coefficient and the second longitudinal

confidence level under the third condition as the second longitudinal confidence level in the case of determining that the number of wheels that satisfy the third condition is greater than 0 and the number of wheels that satisfy the fourth condition is 0.

[0108] The vehicle may determine a maximum value of the second longitudinal adhesion coefficient under the third condition and the second longitudinal adhesion coefficient under the fourth condition as the second longitudinal adhesion coefficient and a confidence level corresponding to the maximum value as the second longitudinal confidence level in the case of determining that the number of wheels that satisfy the third condition is greater than 0 and the number of wheels that satisfy the fourth condition is greater than 0. In an implementation, the vehicle may also adjust the second longitudinal confidence level after determining the confidence level corresponding to the maximum value as the second longitudinal confidence level. Exemplarily, the vehicle may add the second longitudinal confidence level and a sixth calibration parameter so as to adjust the second longitudinal confidence level.

[0109] The vehicle may determine a preset longitudinal adhesion coefficient as the second longitudinal adhesion coefficient and the preset confidence level as the second longitudinal confidence level in the case of determining that the number of wheels that satisfy the third condition is 0 and the number of wheels that satisfy the fourth condition is 0. Exemplarily, the preset longitudinal adhesion coefficient may be 1 and the preset confidence level may be 0.

[0110] S303: Determine a longitudinal adhesion coefficient of the vehicle and a confidence level of the longitudinal adhesion coefficient according to the first longitudinal adhesion coefficient, the first longitudinal confidence level, the second longitudinal adhesion coefficient, and the second longitudinal confidence level.

[0111] Specifically, the vehicle may determine an adhesion coefficient variance corresponding to each wheel according to the longitudinal adhesion coefficient of the wheel, the probability corresponding to each scenario adhesion coefficient and a plurality of scenario adhesion coefficients.

[0112] Exemplarily, the vehicle may calculate the adhesion coefficient variance corresponding to each wheel using the following formula:

$$\mathrm{MueVarInst(k)} = \mathrm{D(x)} = \mathrm{p_1[x_1 - E(X)]^2 + p_2[x_2 - E(X)]^2 + \cdots + p_n[x_n - E(X)]^2}$$

in which, $\mathrm{MueVarInst(k)}$ is the adhesion coefficient variance corresponding to the wheel; n is the number of scenario adhesion coefficients; $\mathrm{E(X)}$ is $\mathrm{MueInst(k)}$, which is an adhesion coefficient (expected value) of the wheel; x is the scenario adhesion coefficient; and P is the probability corresponding to each scenario adhesion coefficient.

[0113] The vehicle may determine scenario adhesion coefficient variance of the vehicle using the following formula:

$$\mathrm{MueVarCmn} = \mathrm{offset1} + \mathrm{offset2} + \mathrm{offset3} + \mathrm{offset4} + \mathrm{offset5}$$

$$\mathrm{MueVarInst(k)} = \mathrm{MueVarInst(k)} * \mathrm{Factor1} * \mathrm{Factor2} * \mathrm{Factor3} * \mathrm{MueVarCmn}$$

$$\mathrm{InstLongRfeMueVar} = \frac{1}{\sum_{1}^{\mathrm{k}} \frac{1}{\mathrm{MueVarInst(k)}}}$$

in which, $\mathrm{MueVarInst(k)}$ is the adhesion coefficient variance corresponding to the wheel; k takes values of 1, 2, 3 and 4, which represent a left front wheel, a right front wheel, a left rear wheel and a right rear wheel in turn; $\mathrm{InstLongRfeMueVar}$ is the scenario adhesion coefficient variance of the vehicle; $\mathrm{Factor1}$ is a correction coefficient determined by the vehicle according to a slip rate look-up table; $\mathrm{Factor2}$ is a correction coefficient determined by the vehicle according to a load look-up table; $\mathrm{Factor3}$ is a correction coefficient determined by the vehicle according to a tire longitudinal force (nominalized longitudinal force) look-up table; $\mathrm{offset1}$ is a correction coefficient determined by the vehicle according to a tire torque look-up table; $\mathrm{offset2}$ is a correction coefficient determined by the vehicle according to an acceleration fluctuation value look-up table; $\mathrm{offset3}$ is a correction coefficient determined by the vehicle according to a longitudinal vehicle speed mass factor look-up table; $\mathrm{offset4}$ is a correction coefficient determined by the vehicle according to an Euler angle look-up table; and $\mathrm{offset5}$ is a correction coefficient determined by the vehicle according to a longitudinal vehicle speed.

[0114] The vehicle compares the first longitudinal confidence level with the second longitudinal confidence level, in the case of determining that the scenario adhesion coefficient variance of the vehicle is less than a variance threshold.

[0115] If the first longitudinal confidence level is greater than or equal to the second longitudinal confidence level, the vehicle may determine the first longitudinal adhesion

coefficient as the longitudinal adhesion coefficient. In addition, the vehicle may also determine the first longitudinal confidence level as a confidence level of the longitudinal adhesion coefficient.

[0116] If the first longitudinal confidence level is less than the second longitudinal confidence level, the vehicle may determine the second longitudinal adhesion coefficient as the longitudinal adhesion coefficient. In addition, the vehicle may also determine the second longitudinal confidence level as a confidence level of the longitudinal adhesion coefficient.

[0117] The vehicle may determine a preset longitudinal adhesion coefficient as the longitudinal adhesion coefficient, in the case of determining that the scenario adhesion coefficient variance of the vehicle is greater than or equal to the variance threshold. In addition, the vehicle may also determine the preset confidence level as a confidence level of the longitudinal adhesion coefficient. Exemplarily, the preset longitudinal adhesion coefficient may be 1 and the preset confidence level may be 0.

[0118] The present embodiment has the following beneficial effect: the vehicle may determine the first longitudinal adhesion coefficient and the first longitudinal confidence level of the vehicle in a low-adhesion state, and the second longitudinal adhesion coefficient and the second longitudinal confidence level of the vehicle in a high-adhesion state, according to the longitudinal adhesion coefficients of a plurality of wheels. The vehicle may determine the longitudinal adhesion coefficient of the vehicle according to the first longitudinal adhesion coefficient, the first longitudinal confidence level, the second longitudinal adhesion coefficient, and the second longitudinal confidence level. By means of the above manner, the longitudinal adhesion coefficient can be accurately determined to improve the accuracy of determining the adhesion coefficients of the vehicle, and further improve the control ability of the vehicle under driving conditions, thereby improving the safety of passengers.

[00100] The process of the vehicle determining the lateral adhesion coefficient and the confidence level thereof is described in Embodiment 3 of the method.

[00101] FIG. 4 is a schematic flowchart of Embodiment 3 of a method for determining an adhesion coefficient provided by an embodiment of the present application. Referring to FIG. 4, the method may specifically include the following steps.

[0119] S401: Determine first statistical information according to the plurality of front-axle lateral forces.

[0120] In the present embodiment, the vehicle may acquire a plurality of rack forces and a plurality of front-axle lateral forces of the vehicle at a plurality of historical moments.

[0121] It should be noted that the vehicle satisfies at least one of the following conditions at the historical moments:

the vehicle speed (longitudinal vehicle speed) is within a preset range; a vertical acceleration of the vehicle is less than or equal to a vertical acceleration threshold; a roll angular velocity of the vehicle is less than or equal to a roll angular velocity threshold; and a signal state of the sensor signal is a normal state.

[0122] The process of acquiring the rack forces by the vehicle is described below.

[0123] In the present embodiment, for any historical moment, the vehicle may acquire a steering resistance torque, an aligning torque and a valid moment arm of the vehicle at that historical moment. It should be noted that the steering resistance torque, the aligning torque and the valid moment arm may be the sensor data.

[0124] The vehicle may determine the rack force based on the following formula:

$$F_{frack} = \frac{M_r + M_g}{l}$$

in which, F_{frack} is the rack force, M_r is the steering resistance torque, M_g is the aligning torque, and l is the valid moment arm.

[0125] The process of acquiring the front-axle lateral force by the vehicle is described below.

[0126] The vehicle may determine a front-axle lateral force of the left front wheel and a front-axle lateral force of the right front wheel based on the following formula:

$$F_{yfr} = \frac{L_f}{L_f + L_r}[ma_y - \sin\delta * (F_{xfl} + F_{xfr})] - \frac{I_z\dot{\omega}_r - T_{yaw}}{L_f + L_r}$$

$$F_{yfl} = \frac{L_f}{L_f + L_r}[ma_y - \sin\delta * (F_{xfl} + F_{xfr})] - \frac{I_z\dot{\omega}_r - T_{yaw}}{L_f + L_r}$$

in which, m is the vehicle mass, a_y is the lateral acceleration, $\dot{\omega}_r$ is a yaw angular acceleration, I_z is a moment of inertia (a moment of inertia of the entire vehicle around a z axis), L_f is a first distance from a center of mass to a front axle, L_r is a second

distance from the center of mass to a rear axle, δ is a front wheel steering angle, T_{yaw} is a yaw moment (a yaw moment generated by differential braking/traction), F_{xfr} is a longitudinal force of the right front wheel, and F_{xfl} is a longitudinal force of the left front wheel. It should be noted that the above parameters may be the sensor data acquired by the vehicle.

[0127] After determining the front-axle lateral force of the left front wheel and the front-axle lateral force of the right front wheel, the vehicle may determine a sum of the front-axle lateral force of the left front wheel and the front-axle lateral force of the right front wheel as the front-axle lateral force of the vehicle at the historical moment.

[0128] After acquiring a plurality of front-axle lateral forces, the vehicle may determine first initial statistical information according to the plurality of front-axle lateral forces.

[0129] The process of determining the first initial statistical information by the vehicle will be described below.

[0130] The vehicle may determine the number n of the plurality of front-axle lateral forces, n being an integer greater than 1. The vehicle may determine a first accumulated value of the plurality of front-axle lateral forces and a second accumulated value of the squares of the plurality of front-axle lateral forces. The vehicle may determine the first initial statistical information according to the number n, the first accumulated value, and the second accumulated value.

[0131] In an implementation, the first initial statistical information may be expressed in the form of a matrix:

$$H^T H = \begin{bmatrix} \sum_{i=1}^{n} F_{yf,i}^2 & -\sum_{i=1}^{n} F_{yf,i} \\ -\sum_{i=1}^{n} F_{yf,i} & n \end{bmatrix}$$

in which, $H^T H$ is a first initial matrix, F_{yf} is the front-axle lateral force, n is the number of the plurality of front-axle lateral forces, $\sum_{i=1}^{n} F_{yf,i}$ is the first accumulated value of the plurality of front-axle lateral forces, and $\sum_{i=1}^{n} F_{yf,i}^2$ is the second accumulated value

of the squares of the plurality of front-axle lateral forces.

[00102] Next, the process of determining a difference coefficient of the plurality of front-axle lateral forces and a standard deviation of the plurality of front-axle lateral forces by the vehicle will be described first.

[0132] Specifically, the vehicle may determine the difference coefficient of the plurality of tire longitudinal forces using the following formula:

$$rb = \frac{(F_{yf,1} - F_{yf,2})^2 + \cdots (F_{yf,1} - F_{yf,n})^2 + (F_{yf,2} - F_{yf,3})^2 + \cdots (F_{yf,2} - F_{yf,n})^2 \ldots + (F_{yf,n-1} - F_{yf,n})^2}{n^2}$$

in which, F_{yf} is the front-axle lateral force, rb is the difference coefficient, and n is the number of the plurality of tire longitudinal forces.

[0133] The vehicle may determine the standard deviation of the plurality of front-axle lateral forces using the following formula:

$$\sigma_{F_{yf}} = \sqrt{E(F_{yf}{}^2) - E(F_{yf})^2}$$

in which, $\sigma_{F_{yf}}$ is the standard deviation, $E(F_{yf}{}^2)$ is an expected value of the square of the front-axle lateral force, and $E(F_{yf})^2$ is the square of the expected value of the front-axle lateral force.

[0134] After determining the first initial statistical information, the vehicle may compare the difference coefficient of the plurality of front-axle lateral forces with a preset difference threshold, compare the standard deviation of the plurality of front-axle lateral forces with a preset standard deviation threshold, and determine whether a steering angle of the vehicle is 0.

[0135] If the difference coefficient of the plurality of front-axle lateral forces is less than the preset difference threshold, the standard deviation of the plurality of front-axle lateral forces is less than the standard deviation threshold, and/or the steering angle of the vehicle is 0, the vehicle determines an adjustment coefficient and determines a product of the first initial statistical information and the adjustment coefficient as the first statistical information.

[0136] If the difference coefficient of the plurality of front-axle lateral forces is greater than or equal to the preset difference threshold, the standard deviation of the plurality of front-axle lateral forces is greater than or equal to the standard deviation threshold, and the steering angle of the vehicle is not 0, the vehicle may determine the first initial statistical

information as the first statistical information.

[0137] S402: Determine second statistical information according to the plurality of front-axle lateral forces and the plurality of rack forces.

[0138] In the present embodiment, the vehicle may determine the second statistical information according to the plurality of front-axle lateral forces and the plurality of rack forces.

[0139] Specifically, the vehicle may determine second initial statistical information according to the plurality of front-axle lateral forces and the plurality of rack forces.

[0140] The process of determining the second initial statistical information by the vehicle will be described below.

[0141] The vehicle may determine a product of the front-axle lateral force and the rack force corresponding to each historical moment to obtain a plurality of products, and acquire a third accumulated value of the plurality of products. The vehicle may determine a fourth accumulated value of the plurality of rack forces. The vehicle may determine the second initial statistical information according to the third accumulated value and the fourth accumulated value.

[0142] In an implementation, the second initial statistical information may be expressed in the form of a matrix:

$$H^{T}Y = \begin{bmatrix} \sum_{i=1}^{n} F_{yf,i}F_{frack,i} \\ \sum_{i=1}^{n} F_{frack,i} \end{bmatrix}$$

in which, $H^{T}Y$ is a second initial matrix, F_{yf} is the front-axle lateral force, F_{frack} is the rack force, n is the number of the plurality of front-axle lateral forces, $\sum_{i=1}^{n} F_{yf,i}F_{frack,i}$ is the third accumulated value, and $\sum_{i=1}^{n} F_{frack,i}$ is the fourth accumulated value.

[0143] After determining the second initial statistical information, the vehicle may compare the difference coefficient of the plurality of front-axle lateral forces with a preset difference threshold, compare the standard deviation of the plurality of front-axle lateral

forces with a preset standard deviation threshold, and determine whether the steering angle of the vehicle is 0.

[0144] If the difference coefficient of the plurality of front-axle lateral forces is less than the preset difference threshold, the standard deviation of the plurality of front-axle lateral forces is less than the standard deviation threshold, and/or the steering angle of the vehicle is 0, the vehicle determines an adjustment coefficient and determines a product of the second initial statistical information and the adjustment coefficient as the second statistical information.

[0145] If the difference coefficient of the plurality of front-axle lateral forces is greater than or equal to the preset difference threshold, the standard deviation of the plurality of front-axle lateral forces is greater than or equal to the standard deviation threshold, and the steering angle of the vehicle is not 0, the vehicle may determine the second initial statistical information as the second statistical information.

[0146] S403: Fit the first statistical information and the second statistical information by means of a least square method to obtain a lateral adhesion coefficient.

[0147] In the present embodiment, the vehicle may fit the first statistical information and the second statistical information by means of the least square method to obtain the lateral adhesion coefficient.

[0148] Exemplarily, in the case where the first statistical information is the first initial statistical information and the second statistical information is the second initial statistical information, the vehicle may calculate a candidate lateral adhesion coefficient based on the following formula:

$$\beta = (H^T H)^{-1} H^T Y$$

$$\beta = \begin{bmatrix} Mue_y \\ 0 \end{bmatrix}.$$

[0149] In the case where the vehicle determines the first matrix ($H^T H$) and the second matrix ($H^T Y$), the vehicle may acquire an inverse matrix ($(H^T H)^{-1}$) of the first matrix. The vehicle may determine a product of the inverse matrix ($(H^T H)^{-1}$) of the first matrix and the second matrix ($H^T Y$) as a target matrix (β). The vehicle may determine a first bit in the target matrix (β) as the candidate lateral adhesion coefficient (Mue_y).

[0150] The process of determining the inverse matrix ($(H^TH)^{-1}$) of the first matrix by the vehicle will be described below.

[0151] The vehicle may calculate the inverse matrix $(H^TH)^{-1}$ of the first matrix based on the following formula:

$$(H^TH)^{-1} = \frac{1}{\det(H^TH)}(H^TH)^*$$

$$(H^TH)^* = \begin{bmatrix} n & -\sum_{i=1}^{n} F_{yf,i} \\ -\sum_{i=1}^{n} F_{yf,i} & \sum_{i=1}^{n} F_{yf,i}^2 \end{bmatrix}$$

$$\det(H^TH) = \left(F_{yf,1} - F_{yf,2}\right)^2 + \cdots \left(F_{yf,1} - F_{yf,n}\right)^2 + \left(F_{yf,2} - F_{yf,3}\right)^2 + \cdots \left(F_{yf,2} - F_{yf,n}\right)^2 \ldots + \left(F_{yf,n-1} - F_{yf,n}\right)^2$$

in which, H^TH is the first matrix, $(H^TH)^{-1}$ is the inverse matrix of the first matrix, $(H^TH)^*$ is an adjoint matrix of the first matrix, and $\det(H^TH)$ is a determinant of the first matrix.

[0152] The vehicle may determine an average residual according to the candidate lateral adhesion coefficient, the plurality of front-axle lateral forces and the plurality of rack forces.

[0153] Specifically, the vehicle may calculate the residual based on the following formula:

$$Y^TY = \sum_{i=1}^{n} F_{frack,i}^2$$

$$Y^TH = \begin{bmatrix} \sum_{i=1}^{n} F_{fy,i}F_{frack,i} & \sum_{i=1}^{n} F_{frack,i} \end{bmatrix}$$

$$\beta = \begin{bmatrix} Mue_y \\ 0 \end{bmatrix}$$

$$\|H\beta - Y\|^2 = Y^TY - (Y^TH)\beta$$

in which, $\|H\beta - Y\|^2$ is the residual, F_{frack} is the rack force, F_{fy} is the front-axle lateral force, and Mue_y is the candidate lateral adhesion coefficient.

[0154] The vehicle may determine a ratio of the residual to the number of the front-axle lateral forces as an average residual.

[0155] After calculating the average residual, the vehicle may compare the average residual with a preset residual threshold.

[0156] If the average residual is greater than or equal to the preset residual threshold, the vehicle may determine that the lateral adhesion coefficient is 1 and that a confidence level of the lateral adhesion coefficient is 0.

[0157] If the average residual is less than the preset residual threshold, the vehicle may determine the candidate lateral adhesion coefficient as the lateral adhesion coefficient.

[0158] S404: Determine at least one influence factor according to the vehicle speed, the lateral adhesion coefficient and/or the front-axle lateral force at the current moment.

[0159] In the present embodiment, if the average residual is less than the preset residual threshold, the vehicle may determine a change rate of the lateral adhesion coefficient according to the lateral adhesion coefficient; determine a ratio of the front-axle lateral force to the load according to the front-axle lateral force at the current moment; and determine an average vehicle speed and a standard vehicle speed deviation according to the vehicle speeds.

[0160] The vehicle may query a table stored by the vehicle according to the change rate of the lateral adhesion coefficient to determine a first influence factor. It should be noted that the change rate of the lateral adhesion coefficient is determined by the vehicle according to the lateral adhesion coefficient at the current moment, the lateral adhesion coefficient at the previous moment, and a time interval.

[0161] The vehicle may query a table stored by the vehicle according to a ratio of the front-axle lateral force to the load to determine a second influence factor. It should be noted that the front-axle lateral force refers to a front-axle lateral force at one of the plurality of moments. Exemplarily, it may be the front-axle lateral force at the current moment (the last moment).

[0162] The vehicle may query a table stored by the vehicle according to the average vehicle speed to determine a third influence factor.

[0163] The vehicle may query a table stored by the vehicle according to the standard vehicle speed deviation to determine a fourth influence factor.

[0164] S405: Determine a confidence level of the lateral adhesion coefficient according to

the at least one influence factor.

[0165] In the present embodiment, the vehicle may determine the confidence level of the lateral adhesion coefficient according to the at least one influence factor.

[0166] Exemplarily, the vehicle may determine the confidence level of the lateral adhesion coefficient according to the first influence factor, the second influence factor, the third influence factor and the fourth impact factor based on the following formula:

$$\mathrm{Cond_y} = \mathrm{Factor_1} * \mathrm{Factor_2} * \mathrm{Factor_3} * \mathrm{Factor_4}$$

in which, $\mathrm{Cond_y}$ represents the confidence level of the lateral adhesion coefficient. $\mathrm{Factor_1}$ represents the first influence factor. $\mathrm{Factor_2}$ represents the second influence factor. $\mathrm{Factor_3}$ represents the third influence factor. $\mathrm{Factor_4}$ represents the fourth influence factor.

[0167] In the embodiments of the present application, the vehicle may determine the first statistical information according to the plurality of front-axle lateral forces and determine the second statistical information according to the plurality of rack forces and the plurality of front-axle lateral forces. The vehicle may fit the first statistical information and the second statistical information by means of a least square method to obtain the lateral adhesion coefficient. By means of the above manner, the accuracy of determining the lateral adhesion coefficient is improved to improve the accuracy of determining the adhesion coefficients of the vehicle, and further improve a stability control effect of the vehicle, thereby improving the safety of passengers.

[0168] The process of the vehicle determining the steady-state adhesion coefficient and the confidence level thereof is described below in Embodiment 4 of the method.

[0169] FIG. 5 is a schematic flowchart of a method for determining an adhesion coefficient provided by an embodiment of the present application. Referring to FIG. 5, the method may specifically include the following steps.

[0170] S501: Determine an instantaneous adhesion coefficient according to accelerations as well as a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel.

[0171] In the present embodiment, the vehicle information may include the accelerations

as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel.

[0172] The vehicle may determine the instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel.

[0173] The process of determining the instantaneous adhesion coefficient by the vehicle is described below.

[0174] Specifically, for any moment, the vehicle may determine a first adhesion coefficient of the vehicle according to the tire longitudinal force, the tire lateral force and the tire vertical load of each wheel.

[0175] Firstly, the vehicle may determine the adhesion coefficient of each wheel using the following formula:

$$\mathrm{MueUtilWhl(k)} = \frac{\sqrt{\mathrm{Fx_N(k)}^2 + \mathrm{Fy_N(k)}^2}}{\mathrm{Fz_N(k)}}$$

in which, $\mathrm{MueUtilWhl(k)}$ represents the adhesion coefficient of the wheel. $\mathrm{Fx_N(k)}$ represents the tire longitudinal force, $\mathrm{Fy_N(k)}$ represents the tire lateral force, and $\mathrm{Fz_N(k)}$ represents the tire vertical load. $\mathrm{k} = 1$ represents the left front wheel, $\mathrm{k} = 2$ represents the right front wheel, $\mathrm{k} = 3$ represents the left rear wheel and $\mathrm{k} = 4$ represents the right rear wheel.

[0176] The vehicle may determine whether a stability control system is activated.

[0177] If the stability control system is activated, the vehicle may calculate the first adhesion coefficient according to the adhesion coefficient of each wheel, the tire longitudinal force and the tire lateral force corresponding to each wheel based on the following formula:

$$\mathrm{MueUtilFromTqMdl} = \frac{\sum_{\mathrm{k=1}}^{4} \frac{\mathrm{Fx_N(k)}^2 + \mathrm{Fy_N(k)}^2}{\mathrm{Fz_N(k)}}}{\sum_{\mathrm{k=1}}^{4} \sqrt{\mathrm{Fx_N(k)}^2 + \mathrm{Fy_N(k)}^2}}$$

in which, $\mathrm{MueUtilFromTqMdl}$ represents the first adhesion coefficient.

[0178] If the stability control system is not activated, the vehicle determines a turning state of the vehicle and, according to the turning state and the adhesion coefficient of each tire,

determines the first adhesion coefficient. Specifically, if the turning state is a left turning state, a maximum value of an adhesion coefficient of a right front tire and an adhesion coefficient of a right rear tire is determined as the first adhesion coefficient. If the turning state is a right turning state or a straight state, a maximum value of an adhesion coefficient of a left front tire and an adhesion coefficient of a left rear tire is determined as the first adhesion coefficient.

[0179] After determining the first adhesion coefficient, the vehicle may determine a gain coefficient according to the first adhesion coefficient, as well as the tire longitudinal force, the tire lateral force and the tire vertical load of each wheel.

[0180] Specifically, the vehicle may determine the gain coefficient based on the following formula:

$$\mathrm{Gain} = \frac{\mathrm{MueUtilFromTqMdl} * 4}{\sum_{k=1}^{4} \frac{\sqrt{\mathrm{Fx_N(k)}^2 + \mathrm{Fy_N(k)}^2}}{\mathrm{Fz_N(k)}}}$$

in which, Gain represents the gain coefficient. MueUtilFromTqMdl represents the first adhesion coefficient.

[0181] The vehicle may determine a second adhesion coefficient according to the gain coefficient and the accelerations (a longitudinal acceleration, a lateral acceleration and a gravitational acceleration) of the vehicle.

[0182] Specifically, the vehicle may determine the second adhesion coefficient based on the following formula:

$$\mathrm{MueUtilWhlIMU} = \mathrm{Gain} * \frac{\sqrt{a_x{}^2 + a_y{}^2}}{g}$$

in which, MueUtilWhlIMU represents the second adhesion coefficient, Gain represents the gain coefficient, g represents the gravitational acceleration, a_x represents the longitudinal acceleration, and a_y represents the lateral acceleration. It should be noted that a_x and a_y are detected by an inertial motion unit (IMU) sensor.

[0183] After determining the first adhesion coefficient and the second adhesion coefficient, the vehicle fuses the first adhesion coefficient and the second adhesion coefficient to determine an instantaneous adhesion coefficient of the vehicle at this moment.

[0184] Specifically, the vehicle may determine a first weight value of the first adhesion coefficient and a second weight value of the second adhesion coefficient according to an actual yaw angle, a tire slip rate, a longitudinal vehicle speed, and/or the second adhesion coefficient.

[0185] For example, the vehicle may determine the first weight value of the first adhesion coefficient and the second weight value of the second adhesion coefficient according to the actual yaw angle, the tire slip rate, the longitudinal vehicle speed, and the second adhesion coefficient.

[0186] The vehicle may determine a first correction weight coefficient, a second correction weight coefficient, a third correction weight coefficient, and a fourth correction weight coefficient respectively according to the actual yaw angle, the tire slip rate, the longitudinal vehicle speed, and the second adhesion coefficient.

[0187] The vehicle may determine the first weight value according to the first correction weight coefficient, the second correction weight coefficient, the third correction weight coefficient, and the fourth correction weight coefficient based on the following formula:

$$\lambda_1 = \mathrm{Factor1} * \mathrm{Factor2} * \mathrm{Factor3} * \mathrm{Factor4}$$

in which, λ_1 represents the first weight value. $\mathrm{Factor1}$ represents the first correction weight coefficient. $\mathrm{Factor2}$ represents the second correction weight coefficient. $\mathrm{Factor3}$ represents the third correction weight coefficient. $\mathrm{Factor4}$ represents the fourth correction weight coefficient.

[0188] After determining the first weight value, the vehicle may determine the second weight value based on the following formula:

$$\lambda_1 = 1 - \lambda_2$$

in which, λ_1 represents the first weight value, λ_2 represents the second weight value.

[0189] The vehicle may determine the target adhesion coefficient based on the following formula:

$$\mathrm{MueUtilizedInst} = \lambda_2 * \mathrm{MueUtilWhlIMU} + \lambda_1 * \mathrm{MueUtilFromTqMdl}$$

in which, λ_1 represents the first weight value, λ_2 represents the second weight value, $\mathrm{MueUtilFromTqMdl}$ represents the first adhesion coefficient, and $\mathrm{MueUtilWhlIMU}$

represents the second adhesion coefficient.

[0190] S502: Acquire an activation intervention duration of the stability control system of the vehicle.

[0191] In the present embodiment, the vehicle may acquire the activation intervention duration of the stability control system of the vehicle.

[0192] Specifically, the vehicle may determine an instantaneous adhesion coefficient and a vertical acceleration change rate of the vehicle and a road bump coefficient at each moment.

[0193] The vehicle may determine a fifth correction weight coefficient, a sixth correction weight coefficient, and a seventh correction weight coefficient respectively based on the instantaneous adhesion coefficient, the vertical acceleration change rate, and the road bump coefficient.

[0194] The vehicle may determine a weight coefficient of the instantaneous adhesion coefficient of the vehicle at a moment according to the fifth correction weight coefficient, the sixth correction weight coefficient and the seventh correction weight coefficient based on the following formula:

$$\mathrm{sWeight} = \mathrm{Factor5} * \mathrm{Factor6} * \mathrm{Factor7}$$

in which, $\mathrm{sWeight}$ represents the weight coefficient of the instantaneous adhesion coefficient. $\mathrm{Factor5}$ represents the fifth correction weight coefficient. $\mathrm{Factor6}$ represents the sixth correction weight coefficient. $\mathrm{Factor7}$ represents the seventh correction weight coefficient.

[0195] After calculating the weight coefficients of the instantaneous adhesion coefficients of the vehicle at a plurality of moments, the vehicle may determine the activation intervention duration of the stability control system of the vehicle according to the weight coefficients of the instantaneous adhesion coefficients of the vehicle at the plurality of moments and a duration of a time period based on the following formula:

$$\mathrm{batchTimefirst} = \mathrm{TS} * \sum_{t=1}^{n} \mathrm{sWeight(t)}$$

in which, $\mathrm{batchTimefirst}$ represents the activation intervention duration of the stability control system of the vehicle. TS represents the duration of the time period.

sWeight represents the weight coefficient of the instantaneous adhesion coefficient of the vehicle at a moment.

[0196] S503: Determine a steady-state adhesion coefficient of the vehicle at the current moment and a confidence level of the steady-state adhesion coefficient according to the instantaneous adhesion coefficients at a plurality of moments and the activation intervention duration of the vehicle.

[0197] In the present embodiment, the vehicle may determine the steady-state adhesion coefficient of the vehicle at the current moment and the confidence level of the steady-state adhesion coefficient according to the instantaneous adhesion coefficients at a plurality of moments and the activation intervention duration of the vehicle. The plurality of moments include a plurality of historical moments and the current moment.

[0198] Firstly, the vehicle may determine an average instantaneous adhesion coefficient according to a plurality of instantaneous adhesion coefficients and a weight coefficient of each instantaneous adhesion coefficient.

[0199] Exemplarily, the vehicle may determine the average instantaneous adhesion coefficient according to the plurality of instantaneous adhesion coefficients and the weight coefficient of each instantaneous adhesion coefficient based on the following formula:

$$\mathrm{MueMean} = \frac{\sum_{t=1}^{n} \mathrm{sWeight}(t) * \mathrm{MueUtilizedInst}(t)}{\sum_{t=1}^{n} \mathrm{sWeight}(t)}$$

in which, MueMean represents the average adhesion coefficient. MueUtilizedInst represents the instantaneous adhesion coefficient. sWeight represents the weight coefficient of the instantaneous adhesion coefficient of the vehicle at a moment.

[0200] Then, the vehicle may determine a candidate steady-state adhesion coefficient of the vehicle at the current moment and a confidence level of the candidate steady-state adhesion coefficient, according to the plurality of instantaneous adhesion coefficients and the activation intervention duration.

[0201] Specifically, the vehicle may compare the activation intervention duration with a first duration and a second duration. The second duration is greater than the first duration.

[0202] If the activation intervention duration is greater than or equal to the first duration

and less than the second duration, the vehicle may determine a standard deviation of the instantaneous adhesion coefficients according to the plurality of instantaneous adhesion coefficients and the average instantaneous adhesion coefficient.

[0203] Exemplarily, the vehicle may determine the standard deviation of the instantaneous adhesion coefficients according to the plurality of instantaneous adhesion coefficients and the average instantaneous adhesion coefficient based on the following formula:

$$\mathrm{MueStd} = \sqrt{\frac{\sum_{t=1}^{n} \mathrm{sWeight}(t) * \mathrm{MueUtilizedInst}(t)^2}{\sum_{t=1}^{n} \mathrm{sWeight}(t)} - \left(\frac{\sum_{t=1}^{n} \mathrm{sWeight}(t) * \mathrm{MueUtilizedInst}(t)}{\sum_{t=1}^{n} \mathrm{sWeight}(t)}\right)^2}$$

in which, MueStd represents the standard deviation of the instantaneous adhesion coefficients. $\mathrm{MueUtilizedInst}$ represents the instantaneous adhesion coefficient. $\mathrm{sWeight}$ represents the weight coefficient of the instantaneous adhesion coefficient of the vehicle at a moment.

[0204] After determining the standard deviation of the instantaneous adhesion coefficients, the vehicle may determine whether the average instantaneous adhesion coefficient is greater than or equal to a preset average instantaneous adhesion coefficient, or whether the standard deviation of the instantaneous adhesion coefficients is less than or equal to a preset adhesion coefficient standard deviation. If yes, the vehicle determines a maximum value of the average instantaneous adhesion coefficient and the instantaneous adhesion coefficient at the current moment as the candidate steady-state adhesion coefficient, and determines a confidence level as a first steady-state confidence level. If not, the vehicle may determine that the candidate steady-state adhesion coefficient is 0 and that the confidence level is 0.

[0205] If the activation intervention duration is greater than or equal to the second duration, the vehicle may determine the candidate steady-state adhesion coefficient and the confidence level according to the instantaneous adhesion coefficient, the average instantaneous adhesion coefficient and the preset adhesion coefficient at the current moment.

[0206] Exemplarily, the vehicle may determine the candidate steady-state adhesion coefficient using the following formula:

$$\mathrm{MueFromStabCtrl} = \mathrm{MueMean} + \max(\min((\mathrm{MueUtilizedInst} - \mathrm{MueMean}), \mathrm{Ratelimit}), -\mathrm{Ratelimit})$$

in which, $\mathrm{MueFromStabCtrl}$ represents the candidate steady-state adhesion

coefficient. MueUtilizedInst represents the instantaneous adhesion coefficient at the current moment. MueMean represents the average instantaneous adhesion coefficient. Ratelimit represents the preset adhesion coefficient.

[0207] In addition, the vehicle may determine that the confidence level is a second steady-state confidence level. The second steady-state confidence level is greater than 0.

[0208] Finally, the vehicle may determine the steady-state adhesion coefficient according to the average instantaneous adhesion coefficient, the candidate steady-state adhesion coefficient and the confidence level.

[0209] Specifically, the vehicle may determine whether the candidate steady-state adhesion coefficient is within a first value range, the confidence level is within a second value range, and the average instantaneous adhesion coefficient is within a third value range. For example, the first value range may be 0.7 to 1, the second value range may be 0 to 1, and the third value range may be 0.2 to 1.

[0210] If yes, the vehicle determines an adjustment step size. After determining the adjustment step size of the vehicle, the vehicle may determine a sum of the candidate steady-state adhesion coefficient and the adjustment step size as the steady-state adhesion coefficient. If not, the vehicle may directly determine the candidate steady-state adhesion coefficient as the steady-state adhesion coefficient.

[0211] The present embodiment has the following beneficial effect: the vehicle acquires the instantaneous adhesion coefficients of the vehicle at a plurality of moments, the plurality of moments including a plurality of historical moments and the current moment; acquires an activation intervention duration of a stability control system of the vehicle; and determines a steady-state adhesion coefficient of the vehicle at the current moment according to the plurality of instantaneous adhesion coefficients and activation intervention duration. According to the method of the present application, the determined steady-state adhesion coefficient of the vehicle at the current moment is enabled to match an actual situation of the vehicle at the current moment, thereby improving the accuracy of determining the adhesion coefficients.

[0212] The process of determining the dynamic adhesion coefficient and the confidence

level by the vehicle is described below in Embodiment 5 of the method.

[0213] FIG. 6 is a schematic flowchart of Embodiment 5 of a method for determining an adhesion coefficient provided by an embodiment of the present application. Referring to FIG. 6, the method may specifically include the following steps.

[0214] S601: Determine an instantaneous adhesion coefficient according to accelerations as well as a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel.

[0215] In the present embodiment, the instantaneous adhesion coefficient is determined according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel.

[0216] S602: Determine a longitudinal stability factor and a lateral stability factor.

[0217] In the present embodiment, the vehicle may determine the longitudinal stability factor and the lateral stability factor.

[0218] In the process of determining the longitudinal stability factor and the lateral stability factor by the vehicle:

the vehicle may determine a slip rate error of each wheel using the following formula:

$$\mathrm{SlipError(k)} = \mathrm{Slip(k)} - \frac{\mathrm{Fxnorm(k)}}{\mathrm{LongStfns(k)}}$$

in which, $\mathrm{SlipError(k)}$ is the slip rate error; $\mathrm{Slip(k)}$ is a slip rate calculated according to a wheel rolling speed and a linear speed; $\mathrm{LongStfns(k)}$ is a longitudinal stiffness of the wheel; $\mathrm{Fxnorm(k)}$ is a nominalized longitudinal force of the wheel; and k takes values of 1, 2, 3 and 4, which represent a left front wheel, a right front wheel, a left rear wheel and a right rear wheel in turn.

[0219] The vehicle may determine a left slip rate variance and a left slip rate change rate variance of a left wheel of the vehicle, and a right slip rate variance and a right slip rate change rate variance of a right wheel of the vehicle using the following formula:

$$\mathrm{SlipVarianceLeft} = \mathrm{SlipError}(1)^2 + \mathrm{SlipError}(3)^2$$

$$\mathrm{SlipVarianceRight} = \mathrm{SlipError}(2)^2 + \mathrm{SlipError}(4)^2$$

$$\text{SlipDotVarianceLeft} = \left(\frac{\text{dSlipError}(1)}{\text{dt}}\right)^2 + \left(\frac{\text{dSlipError}(3)}{\text{dt}}\right)^2$$

$$\text{SlipDotVarianceRight} = \left(\frac{\text{dSlipError}(2)}{\text{dt}}\right)^2 + \left(\frac{\text{dSlipError}(4)}{\text{dt}}\right)^2$$

in which, $\text{SlipError}(1)$ is a slip rate error of the left front wheel, $\text{SlipError}(2)$ is a slip rate error of the right front wheel, $\text{SlipError}(3)$ is a slip rate error of the left rear wheel, $\text{SlipError}(4)$ is a slip rate error of the right rear wheel, SlipVarianceLeft is a left slip rate variance of the left wheel, $\text{SlipDotVarianceLeft}$ is a left slip rate change rate variance of the left wheel, SlipVarianceRight is a right slip rate variance of the right wheel, and $\text{SlipDotVarianceRight}$ is a right slip rate change rate variance of the right wheel.

[0220] The vehicle may determine a longitudinal correction factor and a lateral correction factor of the vehicle.

[0221] Specifically, the vehicle may determine correction factors according to the left slip rate change rate variance, the right slip rate change rate variance, a wheel steering angle, a longitudinal force (a tire longitudinal force), a wheel acceleration, a lateral acceleration, a yaw angular velocity, a longitudinal vehicle speed, and an acceleration detected by an inertial measurement unit sensor. The vehicle may determine a longitudinal correction factor according to the correction coefficients, the yaw angular velocity, the longitudinal vehicle speed, and the acceleration detected by the inertial measurement unit sensor. The vehicle may determine a lateral correction factor according to the correction coefficients, the lateral acceleration, and the longitudinal force.

[0222] The vehicle may determine the longitudinal stability factor using the following formula:

$$\text{SlipVariance} = \max\left(\text{SlipVarianceLeft}, \text{SlipVarianceRight}\right)$$

$$\text{SlipDotVariance} = \max\left(\text{SlipDotVarianceLeft}, \text{SlipDotVarianceRight}\right)$$

$$\text{indInst}(1) = \text{ScaleLongitudinal} * \max\left(\frac{\text{SlipVariance}}{\text{threshold1}}, \frac{\text{SlipDotVariance}}{\text{threshold2}}\right)$$

in which, $\text{indInst}(1)$ is the longitudinal stability factor, SlipVarianceLeft is a left slip rate variance of the left wheel, $\text{SlipDotVarianceLeft}$ is a left slip rate change rate

variance of the left wheel, $\mathrm{SlipVarianceRight}$ is a right slip rate variance of the right wheel, $\mathrm{SlipDotVarianceRight}$ is a right slip rate change rate variance of the right wheel, $\mathrm{threshold1}$ is a seventh calibration parameter, $\mathrm{threshold2}$ is an eighth calibration parameter, and $\mathrm{ScaleLongitudinal}$ is the longitudinal correction factor.

[0223] The vehicle may determine the lateral stability factor using the following formula:

$$\mathrm{indInst}(2) = \mathrm{ScaleLateral} * \sqrt{\mathrm{d1}^2 + \mathrm{d2}^2 + \mathrm{d3}^2}$$

in which, $\mathrm{indInst}(2)$ is the lateral stability factor, $\mathrm{ScaleLateral}$ is the lateral correction factor, $\mathrm{d1}$ is a lateral force offset, $\mathrm{d2}$ is a yaw angular velocity offset, and $\mathrm{d3}$ is a roll angular velocity offset.

[0224] S603: Determine a first dynamic adhesion coefficient and a first dynamic confidence level of the vehicle in a high-adhesion state, and a second dynamic adhesion coefficient and a second dynamic confidence level of the vehicle in a low-adhesion state, according to the instantaneous adhesion coefficient, the longitudinal stability factor and the lateral stability factor.

[0225] In the present embodiment, the vehicle may determine the first dynamic adhesion coefficient and the first dynamic confidence level of the vehicle in the high-adhesion state according to the instantaneous adhesion coefficient, the longitudinal stability factor and the lateral stability factor.

[0226] In an implementation of determining the first dynamic adhesion coefficient and the first dynamic confidence level:

[0227] the vehicle may acquire a sensor state and a vehicle speed (longitudinal) of the vehicle, and the sensor state is a valid state or an invalid state.

[0228] The vehicle may determine that the vehicle does not satisfy a high-adhesion estimation condition in the case of determining that the sensor state is the invalid state and/or the vehicle speed is less than a preset threshold. The vehicle may directly determine the first dynamic adhesion coefficient to be the dynamic adhesion coefficient of the vehicle at the previous moment, and determine that the first dynamic confidence level is 0.

[0229] The vehicle may determine that the vehicle satisfies the high-adhesion estimation condition in the case of determining that the sensor state is the valid state and the vehicle

speed is greater than or equal to the preset threshold.

[0230] The vehicle may determine the instantaneous adhesion coefficient as the first dynamic adhesion coefficient and the first dynamic confidence level to be 1 in the case of determining that the longitudinal stability factor and/or the lateral stability factor are/is greater than a first factor and the instantaneous adhesion coefficient is greater than a first coefficient. In addition, the vehicle may determine the first dynamic adhesion coefficient as a preset dynamic adhesion coefficient and the first dynamic confidence level as the preset confidence level, in the case of determining that the longitudinal stability factor and the lateral stability factor are both less than a second factor, the instantaneous adhesion coefficient is greater than a second coefficient, and a duration of the instantaneous adhesion coefficient that is greater than the second coefficient is greater than or equal to a preset duration.

[0231] It should be noted that the first factor is greater than the second factor, and the first coefficient is greater than the second coefficient. Exemplarily, the first factor may be 1 and the first coefficient may be any numerical number between 0.65 and 0.9. The second factor may be 0.6, the second coefficient may be any numerical value between 0.5 and 0.65, the preset duration may be any numerical value between 100 ms and 300 ms, the preset dynamic adhesion coefficient may be any numerical value between 0.75 and 1, and the preset confidence level may be any numerical value between 0.5 and 0.8.

[0232] In the present embodiment, the vehicle may determine a second dynamic adhesion coefficient and a second confidence level of the vehicle in a low-adhesion state according to the instantaneous adhesion coefficient, the longitudinal stability factor and the lateral stability factor.

[0233] In an implementation process of determining the second dynamic adhesion coefficient and the second dynamic confidence level:

in an implementation, the vehicle may determine whether a stability control system is activated. If the vehicle activates the stability control system, the vehicle determines the dynamic adhesion coefficient of the vehicle at the previous moment as the second dynamic adhesion coefficient and the confidence level of the vehicle at the previous moment as the second dynamic confidence level. If the vehicle does not activate the stability control

system, the vehicle may determine the dynamic adhesion coefficient of the vehicle at the previous moment as the second dynamic adhesion coefficient and determine that the second dynamic confidence level is 0.

[0234] In an implementation, the vehicle may determine whether the vehicle satisfies a plurality of conditions. If the vehicle satisfies the plurality of conditions, the vehicle determines the dynamic adhesion coefficient of the vehicle at the previous moment as the second dynamic adhesion coefficient and the confidence level of the vehicle at the previous moment as the second dynamic confidence level. If the vehicle does not satisfy at least one of the plurality of conditions, the vehicle may determine the dynamic adhesion coefficient of the vehicle at the previous moment as the second dynamic adhesion coefficient and determine that the second dynamic confidence level is 0.

[0235] The plurality of conditions include:

the instantaneous adhesion coefficient is greater than a third coefficient; and exemplarily, the third coefficient may be any numerical number between 0 and 0.35.

[0236] The longitudinal stability factor and the lateral stability factor are both greater than 1.

[0237] The vehicle speed (longitudinal vehicle speed) is greater than a preset speed; and exemplarily, the preset speed may be any numerical value between 5 kph and 10 kph, wherein kph is km/h.

[0238] The travel direction is a forward direction (a gear is a forward gear).

[0239] S604: Determine a dynamic adhesion coefficient of the vehicle and a confidence level of the dynamic adhesion coefficient according to the first dynamic adhesion coefficient, the first dynamic confidence level, the second dynamic adhesion coefficient, and the second dynamic confidence level.

[0240] In the present embodiment, the vehicle may determine the dynamic adhesion coefficient of the vehicle according to the first dynamic adhesion coefficient, the first dynamic confidence level, the second dynamic adhesion coefficient, and the second dynamic confidence level.

[0241] In particular, the vehicle may compare the first dynamic confidence level with the

second dynamic confidence level.

[0242] If the first dynamic confidence level is greater than or equal to the second dynamic confidence level, the vehicle may determine the dynamic adhesion coefficient as the first dynamic adhesion coefficient. In addition, the vehicle may determine the confidence level of the dynamic adhesion coefficient as the first dynamic confidence level.

[0243] If the first dynamic confidence level is less than the second dynamic confidence level, the vehicle may determine the dynamic adhesion coefficient as the second dynamic adhesion coefficient. In addition, the vehicle may also determine the confidence level of the dynamic adhesion coefficient as the second dynamic confidence level.

[0244] The present embodiment has the following beneficial effect: the vehicle may determine a first dynamic adhesion coefficient and a first dynamic confidence level of the vehicle in a high-adhesion state, and a second dynamic adhesion coefficient and a second dynamic confidence level of the vehicle in a low-adhesion state, according to the instantaneous adhesion coefficient, the longitudinal stability factor and the lateral stability factor. The vehicle may fuse the adhesion coefficients to acquire the dynamic adhesion coefficient of the vehicle according to the first dynamic adhesion coefficient, the first dynamic confidence level, the second dynamic adhesion coefficient, and the second dynamic confidence level. By means of the above manner, the dynamic adhesion coefficient can be accurately determined to improve the accuracy of determining the dynamic adhesion coefficient of the vehicle, and further improve the control ability of the vehicle under driving conditions, thereby improving the safety of passengers.

[0245] The following describes apparatus embodiments of the present application, which may be used for performing the method embodiments of the present application. For details not disclosed in the apparatus embodiments of the present application, refer to the method embodiments of the present application.

[0246] FIG. 7 is a schematic structural diagram of an apparatus for determining an adhesion coefficient provided by an embodiment of the present application. As shown in FIG. 7, the apparatus 70 for determining an adhesion coefficient includes an acquisition module 71, a processing module 72 and a fusion module 73.

[0247] The acquisition module 71 is configured to acquire sensor data collected by at least one sensor of a vehicle.

[0248] The processing module 72 is configured to determine travel information of the vehicle according to the sensor data, the travel information including at least one of the followings: a slip rate, a longitudinal stiffness, a tire longitudinal force, a tire lateral force, a tire vertical load, a front-axle lateral force and a rack force.

[0249] The processing module 72 is also configured to determine at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information, the at least one reference adhesion coefficient including at least one of the followings: a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient.

[0250] The fusion module 73 is configured to determine a target adhesion coefficient of the vehicle and a confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient.

[0251] The apparatus for determining the adhesion coefficient provided by the embodiment of the present application is capable of performing the technical solutions shown in the above method embodiments, which is implemented similarly in terms of principles and beneficial effects, and will not be repeated herein.

[0252] In an implementation, the travel information includes a slip rate of each wheel, a longitudinal stiffness of each wheel, and a tire longitudinal force of each wheel; and the reference adhesion coefficient includes a longitudinal adhesion coefficient.

[0253] The processing module 72 is specifically configured to:

determine the longitudinal adhesion coefficient of each wheel according to the slip rate of each wheel, the longitudinal stiffness of each wheel, the tire longitudinal force of each wheel, and a plurality of acquired scenario adhesion coefficients;

determine a first longitudinal adhesion coefficient and a first longitudinal confidence level of the vehicle in a low-adhesion state, and a second longitudinal adhesion

coefficient and a second longitudinal confidence level of the vehicle in a high-adhesion state, according to the longitudinal adhesion coefficients of a plurality of wheels; and

determine the longitudinal adhesion coefficient of the vehicle and the confidence level of the longitudinal adhesion coefficient according to the first longitudinal adhesion coefficient, the first longitudinal confidence level, the second longitudinal adhesion coefficient, and the second longitudinal confidence level.

[0254] The apparatus for determining the adhesion coefficient provided by the embodiment of the present application is capable of performing the technical solutions shown in the above method embodiments, which is implemented similarly in terms of principles and beneficial effects, and will not be repeated herein.

[0255] In an implementation, the sensor data includes a vehicle speed, and the travel information includes a plurality of front-axle lateral forces and a plurality of rack forces of the vehicle at a plurality of moments; and the reference adhesion coefficient includes the lateral adhesion coefficient.

[0256] The processing module 72 is specifically configured to:

determine first statistical information according to the plurality of front-axle lateral forces;

determining second statistical information according to the plurality of front-axle lateral forces and the plurality of rack forces;

fit the first statistical information and the second statistical information by means of a least square method to obtain the lateral adhesion coefficient;

determine at least one influence factor according to the vehicle speed, the lateral adhesion coefficient and/or the front-axle lateral force at the current moment, the plurality of moments including the current moment; and

determine a confidence level of the lateral adhesion coefficient according to the at least one influence factor.

[0257] The apparatus for determining the adhesion coefficient provided by the embodiment of the present application is capable of performing the technical solutions shown in the above method embodiments, which is implemented similarly in terms of principles and

beneficial effects, and will not be repeated herein.

[0258] In an implementation, the travel information includes a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel, and the sensor data includes accelerations; and the reference adhesion coefficient includes a steady-state adhesion coefficient.

[0259] The processing module 72 is specifically configured to:

determine an instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel;

acquire an activation intervention duration of a stability control system of the vehicle; and

determine the steady-state adhesion coefficient of the vehicle at the current moment and a confidence level of the steady-state adhesion coefficient according to the instantaneous adhesion coefficients at a plurality of moments and the activation intervention duration of the vehicle, the plurality of moments including a plurality of historical moments and the current moment.

[0260] The apparatus for determining the adhesion coefficient provided by the embodiment of the present application is capable of performing the technical solutions shown in the above method embodiments, which is implemented similarly in terms of principles and beneficial effects, and will not be repeated herein.

[0261] In an implementation, the travel information includes a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel, and the sensor data includes accelerations; and the reference adhesion coefficient includes a dynamic adhesion coefficient.

[0262] The processing module 72 is specifically configured to:

determine an instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel;

determine a longitudinal stability factor and a lateral stability factor;

determine a first dynamic adhesion coefficient and a first dynamic confidence level of the vehicle in a high-adhesion state, and a second dynamic adhesion coefficient and a second dynamic confidence level of the vehicle in a low-adhesion state, according to the instantaneous adhesion coefficient, the longitudinal stability factor and the lateral stability factor; and

determine a dynamic adhesion coefficient of the vehicle and a confidence level of the dynamic adhesion coefficient according to the first dynamic adhesion coefficient, the first dynamic confidence level, the second dynamic adhesion coefficient, and the second dynamic confidence level.

[0263] The apparatus for determining the adhesion coefficient provided by the embodiment of the present application is capable of performing the technical solutions shown in the above method embodiments, which is implemented similarly in terms of principles and beneficial effects, and will not be repeated herein.

[0264] In an implementation, the sensor data include a tire driving force, vehicle mass, a wheel speed, a wheel acceleration, a wheel steering angle, a slope, a longitudinal acceleration and a lateral acceleration; and the travel information includes a tire longitudinal force, a tire lateral force, a tire vertical load and a longitudinal stiffness.

[0265] The processing module 72 is specifically configured to:

determine the tire longitudinal force, the tire lateral force and the tire vertical load of each wheel, based on a three-degree-of-freedom model and according to the tire driving force, the vehicle mass, the wheel speed, the wheel acceleration, the wheel steering angle, the slope, the longitudinal acceleration and the lateral acceleration; and

determine the longitudinal stiffness using a least square method, according to a plurality of tire longitudinal forces and a plurality of slip rates of each wheel at a plurality of moments.

[0266] The apparatus for determining the adhesion coefficient provided by the embodiment of the present application is capable of performing the technical solutions shown in the above method embodiments, which is implemented similarly in terms of principles and beneficial effects, and will not be repeated herein.

[0267] FIG. 8 is a structural diagram of a vehicle provided by an embodiment of the present application. As shown in FIG. 8, the vehicle 80 includes a processor 81 and a memory 82. The processor 81 is communicatively connected to the memory 82 and the memory 82 is configured to store computer-executable instructions. The processor 81 is configured to perform the technical solutions in any of the foregoing method embodiments by executing the computer-executable instructions stored in the memory 82.

[0268] Optionally, the memory 82 may be arranged independently or integrated with the processor 81. Optionally, when the memory 82 is a device independent of the processor 81, the vehicle 80 may also include a bus configured to connect the above devices together.

[0269] The vehicle is provided to perform the technical solution in any of the foregoing method embodiments, which is implemented similarly in terms of principles and beneficial effects, and will not be repeated herein.

[0270] An embodiment of the present application further provides a computer-readable storage medium configured to store computer-executable instructions therein, the computer-executable instructions being executed by a processor to implement the technical solution provided by any of the foregoing method embodiments.

[0271] An embodiment of the present application further provides a computer program product. The computer program product includes a computer program, which, when being executed by a processor, implements the technical solution provided by any one of the foregoing embodiments.

[0272] It may be understood by a person of ordinary skill in the art that all or part of steps in the above methods may be completed by a program instructing relevant hardware (e.g., the processor). The program may be stored in a computer-readable storage medium which includes a read-only memory, a magnetic disk, an optical disc or the like. Optionally, all or part of the steps of the above embodiments may also be implemented using one or more integrated circuits. Accordingly, each module/unit in the above embodiments may be implemented in the form of hardware (e.g., an integrated circuit) to implement its corresponding functions, or in the form of software function module (e.g., a processor) to execute programs/instructions stored in the memory so as to implement its corresponding

functions. The present application is not limited to any specific hardware and software combination.

[0273] It should be eventually noted that: each of the above embodiments is merely used to illustrate the technical solutions of the present application, but is not limited thereto. Although the present application is described in detail with reference to each of the foregoing embodiments, a person of ordinary skill in the art should understand: the technical solution described in each of the foregoing embodiments may be modified, or some or all of the technical features may be equivalently replaced. However, these modifications and substitutions do not make the corresponding technical solutions essentially depart from the scope of the technical solution in each embodiment of the present application.

CLAIMS

1. A method for determining an adhesion coefficient, comprising:

acquiring sensor data collected by at least one sensor of a vehicle;

determining travel information of the vehicle according to the sensor data, the travel information comprising at least one of the followings: a slip rate, a longitudinal stiffness, a tire longitudinal force, a tire lateral force, a tire vertical load, a front-axle lateral force and a rack force;

determining at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information, the at least one reference adhesion coefficient comprising at least one of the followings: a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient; and

determining a target adhesion coefficient of the vehicle and a confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient.

2. The method according to claim 1, wherein the travel information comprises a slip rate of each wheel, a longitudinal stiffness of each wheel, and a tire longitudinal force of each wheel; the reference adhesion coefficient comprises the longitudinal adhesion coefficient;

wherein the determining at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information includes:

determining the longitudinal adhesion coefficient of each wheel according to the slip rate of each wheel, the longitudinal stiffness of each wheel, the tire longitudinal force of each wheel, and a plurality of acquired scenario adhesion coefficients;

determining a first longitudinal adhesion coefficient and a first longitudinal confidence level of the vehicle in a low-adhesion state, and a second longitudinal adhesion coefficient and a second longitudinal confidence level of the vehicle in a high-adhesion state, according to the longitudinal adhesion coefficients of a plurality of wheels; and

determining the longitudinal adhesion coefficient of the vehicle and a confidence level of the longitudinal adhesion coefficient according to the first longitudinal adhesion coefficient, the first longitudinal confidence level, the second longitudinal adhesion coefficient, and the second longitudinal confidence level.

3. The method according to claim 1, wherein the sensor data comprises a vehicle speed, and the travel information comprises a plurality of front-axle lateral forces and a plurality of rack forces of the vehicle at a plurality of moments; the reference adhesion coefficient comprises the lateral adhesion coefficient; and

wherein the determining at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information includes:

determining first statistical information according to the plurality of front-axle lateral forces;

determining second statistical information according to the plurality of front-axle lateral forces and the plurality of rack forces;

fitting the first statistical information and the second statistical information by means of a least square method to obtain the lateral adhesion coefficient;

determining at least one influence factor according to the vehicle speed, the lateral adhesion coefficient and/or the front-axle lateral force at a current moment, the plurality of moments comprising the current moment; and

determining a confidence level of the lateral adhesion coefficient according to the at least one influence factor.

4. The method according to claim 1, wherein the travel information comprises a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel, and the sensor data comprises accelerations; the reference adhesion coefficient includes a steady-state adhesion coefficient; and

wherein the determining at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information includes:

determining an instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel;

acquiring an activation intervention duration of a stability control system of the vehicle; and

determining the steady-state adhesion coefficient of the vehicle at a current moment and a confidence level of the steady-state adhesion coefficient according to the instantaneous adhesion coefficients at a plurality of moments and the activation intervention duration of the vehicle, the plurality of moments comprising a plurality of historical moments and the current moment.

5. The method according to claim 1, wherein the travel information comprises a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel, and the sensor data comprises accelerations; the reference adhesion coefficient comprises the dynamic adhesion coefficient; and

wherein the determining at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information includes:

determining an instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel;

determining a longitudinal stability factor and a lateral stability factor;

determining a first dynamic adhesion coefficient and a first dynamic confidence level of the vehicle in a high-adhesion state, and a second dynamic adhesion coefficient and a second dynamic confidence level of the vehicle in a low-adhesion state, according to the instantaneous adhesion coefficient, the longitudinal stability factor and the lateral stability factor; and

determining the dynamic adhesion coefficient of the vehicle and a confidence level of the dynamic adhesion coefficient according to the first dynamic adhesion coefficient, the first dynamic confidence level, the second dynamic adhesion coefficient, and the second dynamic

confidence level.

6. The method according to any one of claims 1 to 5, wherein the sensor data comprises a tire driving force, vehicle mass, a wheel speed, a wheel acceleration, a wheel steering angle, a slope, a longitudinal acceleration and a lateral acceleration; and the travel information comprises the tire longitudinal force, the tire lateral force, the tire vertical load and the longitudinal stiffness; and

wherein the determining travel information of the vehicle according to the sensor data includes:

determining the tire longitudinal force, the tire lateral force and the tire vertical load of each wheel, based on a three-degree-of-freedom model and according to the tire driving force, the vehicle mass, the wheel speed, the wheel acceleration, the wheel steering angle, the slope, the longitudinal acceleration and the lateral acceleration; and

determining the longitudinal stiffness using a least square method, according to a plurality of tire longitudinal forces and a plurality of slip rates of each wheel at a plurality of moments.

7. An apparatus for determining an adhesion coefficient, comprising:

an acquisition module, configured to acquire sensor data collected by at least one sensor of a vehicle;

a processing module, configured to determine travel information of the vehicle according to the sensor data, the travel information comprising at least one of the followings: a slip rate, a longitudinal stiffness, a tire longitudinal force, a tire lateral force, a tire vertical load, a front-axle lateral force and a rack force;

the processing module being also configured to determine at least one reference adhesion coefficient and a confidence level of each reference adhesion coefficient according to the travel information, or the sensor data and the travel information, the at least one reference adhesion coefficient comprising at least one of the followings: a steady-state adhesion coefficient, a dynamic adhesion coefficient, a longitudinal adhesion coefficient and a lateral adhesion coefficient; and

a fusion module, configured to determine a target adhesion coefficient of the vehicle

and a confidence level of the target adhesion coefficient according to the at least one reference adhesion coefficient and the confidence level of each reference adhesion coefficient.

8. The apparatus according to claim 7, wherein the travel information comprises a slip rate of each wheel, a longitudinal stiffness of each wheel, and a tire longitudinal force of each wheel; the reference adhesion coefficient comprises the longitudinal adhesion coefficient;

wherein the processing module is specifically configured to:

determine the longitudinal adhesion coefficient of each wheel according to the slip rate of each wheel, the longitudinal stiffness of each wheel, the tire longitudinal force of each wheel, and a plurality of acquired scenario adhesion coefficients;

determine a first longitudinal adhesion coefficient and a first longitudinal confidence level of the vehicle in a low-adhesion state, and a second longitudinal adhesion coefficient and a second longitudinal confidence level of the vehicle in a high-adhesion state, according to the longitudinal adhesion coefficients of a plurality of wheels; and

determine the longitudinal adhesion coefficient of the vehicle and a confidence level of the longitudinal adhesion coefficient according to the first longitudinal adhesion coefficient, the first longitudinal confidence level, the second longitudinal adhesion coefficient, and the second longitudinal confidence level.

9. The apparatus according to claim 7, wherein the sensor data comprises a vehicle speed, and the travel information comprises a plurality of front-axle lateral forces and a plurality of rack forces of the vehicle at a plurality of moments; the reference adhesion coefficient comprises the lateral adhesion coefficient; and

wherein the processing module is specifically configured to:

determine first statistical information according to the plurality of front-axle lateral forces;

determine second statistical information according to the plurality of front-axle lateral forces and the plurality of rack forces;

fit the first statistical information and the second statistical information by means of a least square method to obtain the lateral adhesion coefficient;

determine at least one influence factor according to the vehicle speed, the lateral

adhesion coefficient and/or the front-axle lateral force at a current moment, the plurality of moments comprising the current moment; and

determine a confidence level of the lateral adhesion coefficient according to the at least one influence factor.

10. The apparatus according to claim 7, wherein the travel information comprises a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel, and the sensor data comprises accelerations; the reference adhesion coefficient includes a steady-state adhesion coefficient; and

wherein the processing module is specifically configured to:

determine an instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel;

acquire an activation intervention duration of a stability control system of the vehicle; and

determine the steady-state adhesion coefficient of the vehicle at a current moment and a confidence level of the steady-state adhesion coefficient according to the instantaneous adhesion coefficients at a plurality of moments and the activation intervention duration of the vehicle, the plurality of moments comprising a plurality of historical moments and the current moment.

11. The apparatus according to claim 7, wherein the travel information comprises a tire longitudinal force, a tire lateral force and a tire vertical load corresponding to each wheel, and the sensor data comprises accelerations; the reference adhesion coefficient comprises the dynamic adhesion coefficient; and

wherein the processing module is specifically configured to:

determine an instantaneous adhesion coefficient according to the accelerations as well as the tire longitudinal force, the tire lateral force and the tire vertical load corresponding to each wheel;

determine a longitudinal stability factor and a lateral stability factor;

determine a first dynamic adhesion coefficient and a first dynamic confidence level of

the vehicle in a high-adhesion state, and a second dynamic adhesion coefficient and a second dynamic confidence level of the vehicle in a low-adhesion state, according to the instantaneous adhesion coefficient, the longitudinal stability factor and the lateral stability factor; and

determine the dynamic adhesion coefficient of the vehicle and a confidence level of the dynamic adhesion coefficient according to the first dynamic adhesion coefficient, the first dynamic confidence level, the second dynamic adhesion coefficient, and the second dynamic confidence level.

12. The apparatus according to any one of claims 7 to 11, wherein the sensor data comprises a tire driving force, vehicle mass, a wheel speed, a wheel acceleration, a wheel steering angle, a slope, a longitudinal acceleration and a lateral acceleration; and the travel information comprises the tire longitudinal force, the tire lateral force, the tire vertical load and the longitudinal stiffness; and

wherein the processing module is specifically configured to:

determine the tire longitudinal force, the tire lateral force and the tire vertical load of each wheel, based on a three-degree-of-freedom model and according to the tire driving force, the vehicle mass, the wheel speed, the wheel acceleration, the wheel steering angle, the slope, the longitudinal acceleration and the lateral acceleration; and

determine the longitudinal stiffness using a least square method, according to a plurality of tire longitudinal forces and a plurality of slip rates of each wheel at a plurality of moments.

13. A vehicle, comprising:

a processor, and a memory communicatively connected to the processor, wherein

the memory is configured to store computer-executable instructions; and

the processor is configured to execute the computer-executable instructions stored in the memory, so as to implement the method for determining the adhesion coefficient according to any one of claims 1 to 6.

14. A computer-readable storage medium, configured to store computer-executable instructions therein, the computer-executable instructions, when being executed by a processor, implementing the method for determining the adhesion coefficient according to any

one of claims 1 to 6.

15. A computer program product, comprising a computer program, wherein the computer program, when being executed by a processor, implements the method for determining the adhesion coefficient according to any one of claims 1 to 6.