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(54) **LOADING CALCULATION MODULE, VEHICLE ANTI-RUNAWAY SYSTEM, VEHICLE AND METHOD USING THE SAME**

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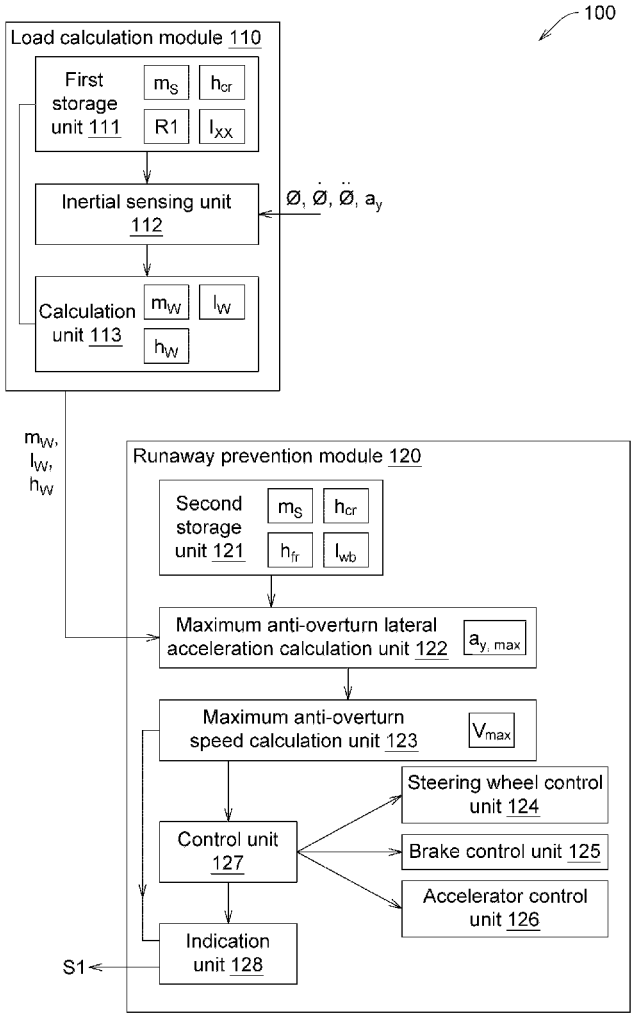
(57) **ABSTRACT**

A loading calculation module includes a storage unit, an inertial sensing unit and a calculation unit. The first storage unit is configured to store a relationship between an engine performance and a load, a sprung mass, a centroid distance between a sprung centroid, a rotation center and a moment of inertia. The inertial sensing unit is configured to detect a tilt angle, a tilt angular velocity, a tilt angular acceleration and a lateral acceleration. The calculation unit is configured to obtain a load corresponding to the engine performance according to the relationship between the engine performance and the load; and obtain a load position according to the moment of inertia, the tilt angle, the tilt angular velocity, the tilt angular acceleration, the lateral acceleration, the load and the centroid distance.



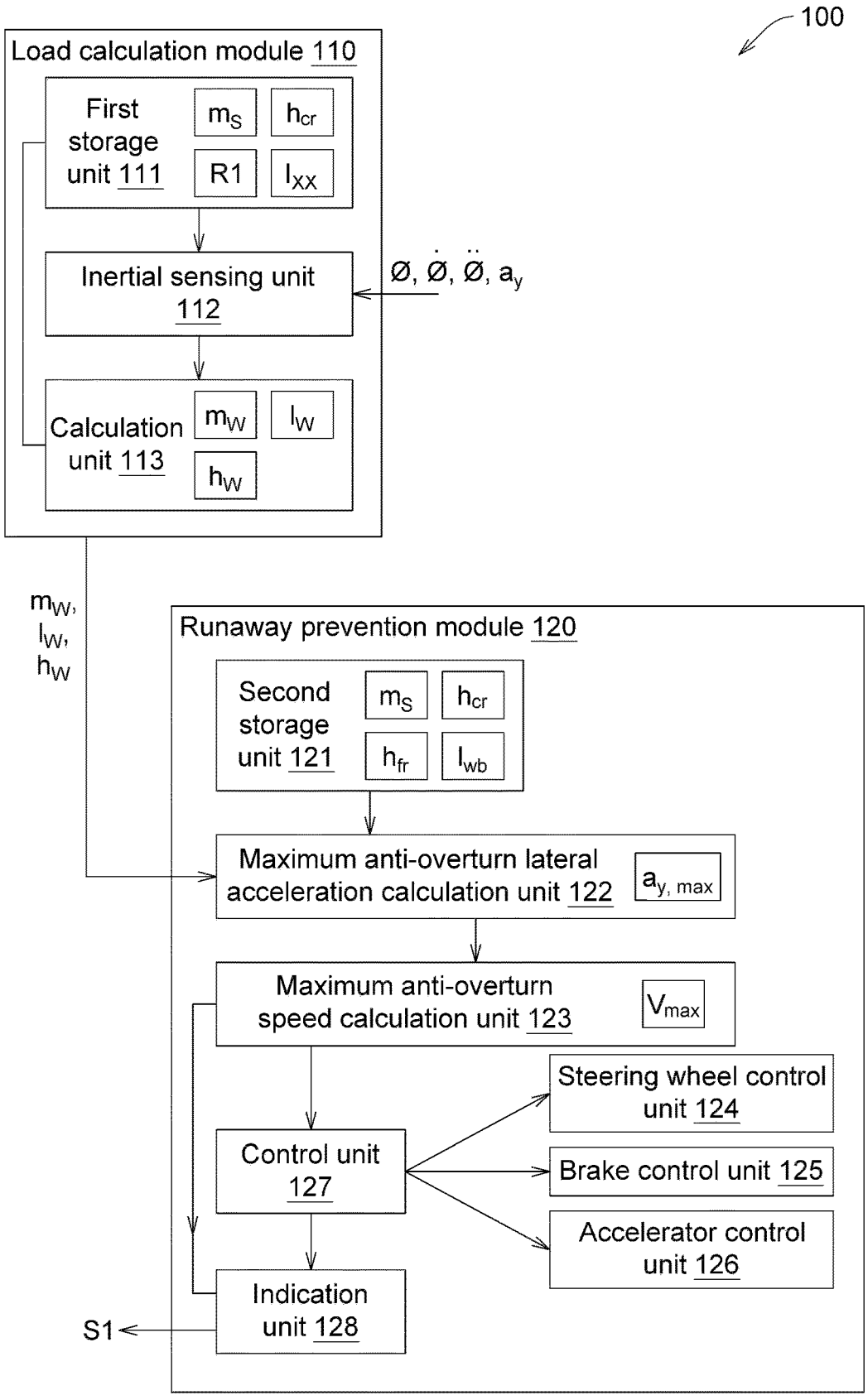

100
Load calculation module 110
First storage unit 111
m_S
h_{cr}
R1
I_{XX}
Inertial sensing unit 112
$\ddot{\varnothing}, \dot{\varnothing}, \varnothing, a_y$
Calculation unit 113
m_W
l_W
h_W
m_W, l_W, h_W
Runaway prevention module 120
Second storage unit 121
m_S
h_{cr}
h_{fr}
l_{wb}
Maximum anti-overturn lateral acceleration calculation unit 122
$a_{y, max}$
Maximum anti-overturn speed calculation unit 123
V_{max}
Steering wheel control unit 124
Control unit 127
Brake control unit 125
Accelerator control unit 126
Indication unit 128
S1

FIG. 1

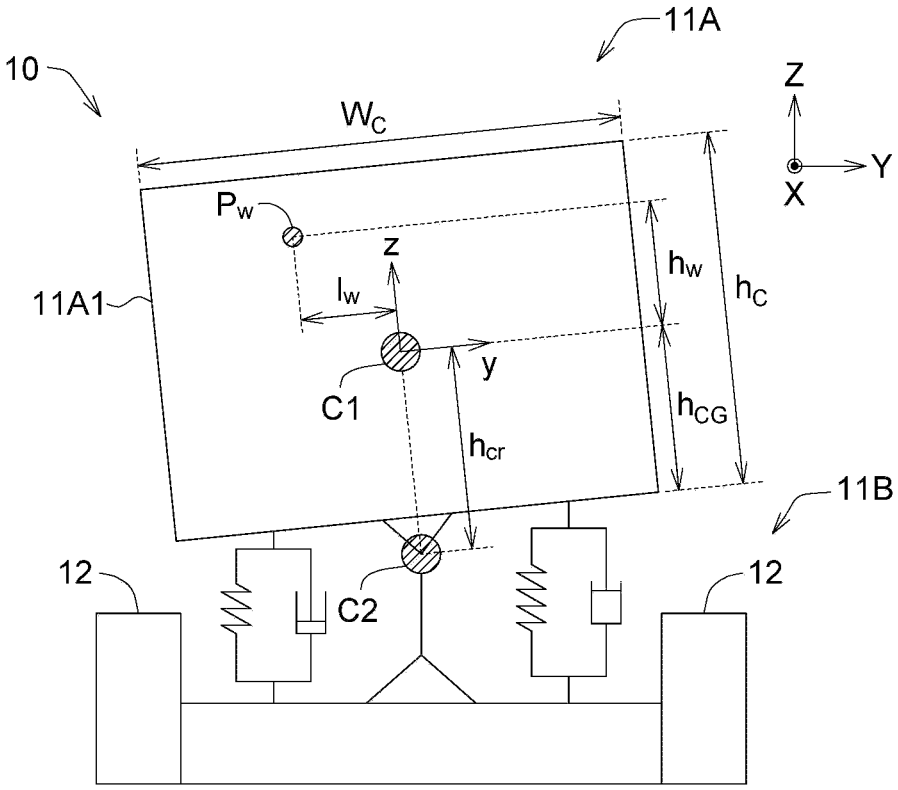

10
11A
11B
11A1
12
12
W_C
P_w
z
l_w
h_w
h_C
y
C1
h_{CG}
h_{cr}
C2
Z
Y
X

FIG. 2

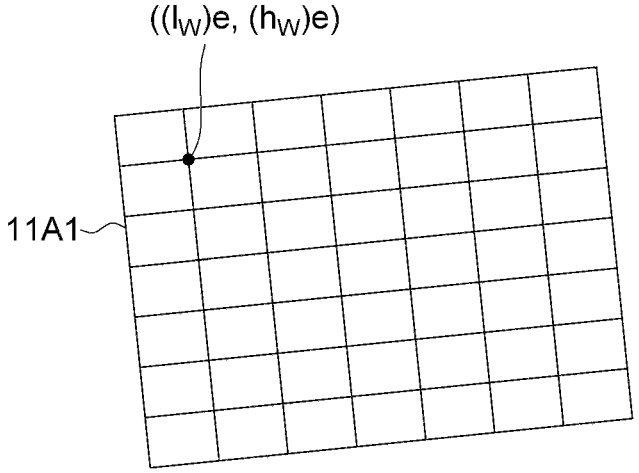

$((l_W)e, (h_W)e)$
11A1

FIG. 3

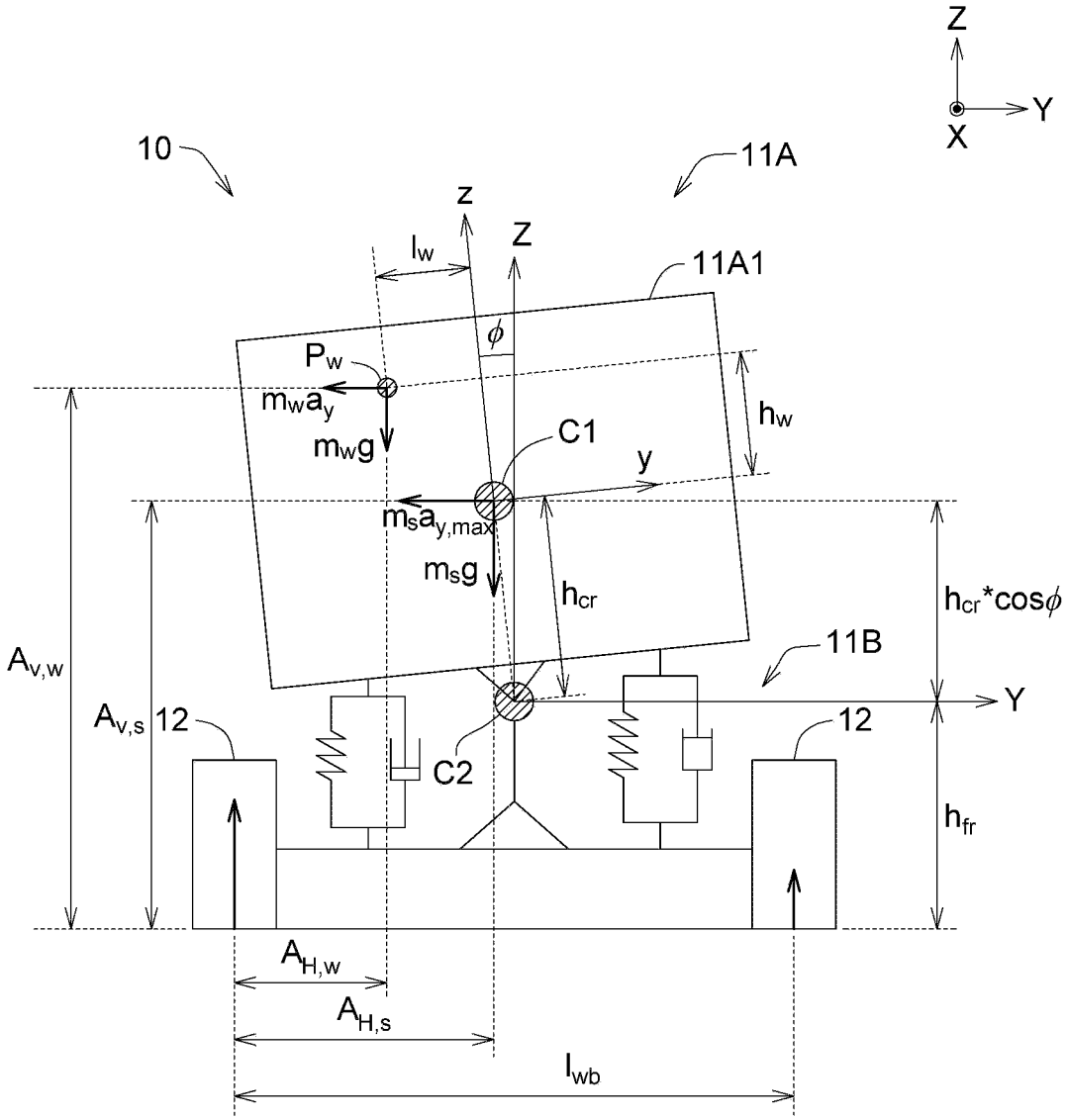

Z
Y
X
10
11A
z
Z
l_w
11A1
ϕ
P_w
$m_w a_y$
$m_w g$
h_w
C1
y
$m_s a_{y,max}$
$m_s g$
h_{cr}
$h_{cr}*\cos\phi$
11B
$A_{v,w}$
$A_{v,s}$
12
C2
12
Y
h_{fr}
$A_{H,w}$
$A_{H,s}$
l_{wb}

FIG. 4

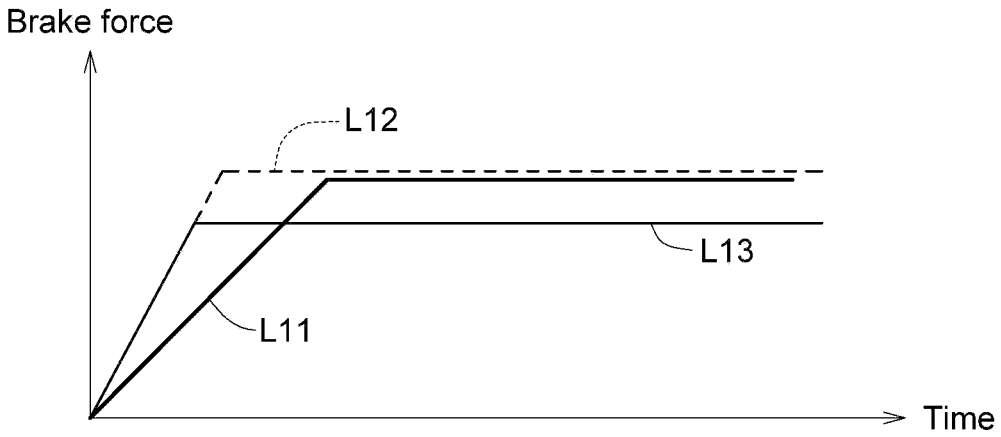

Brake force
L12
L13
L11
Time

FIG. 5

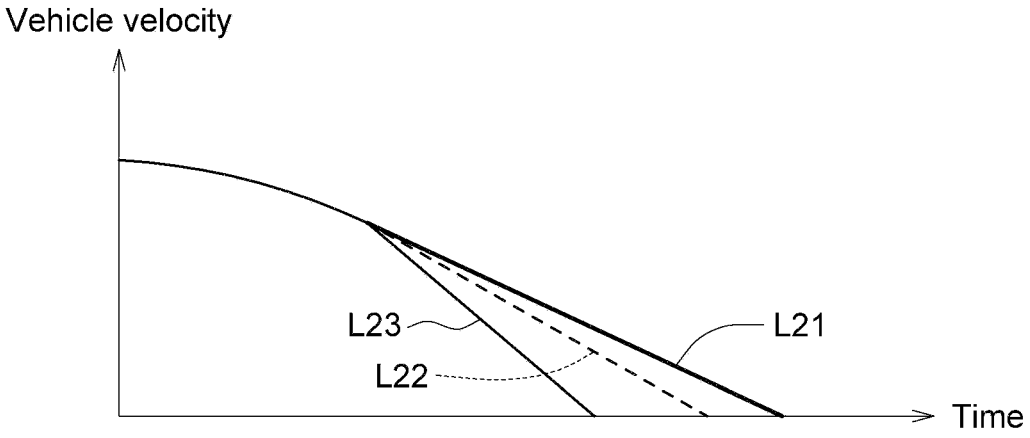

Vehicle velocity
L23
L21
L22
Time

FIG. 6

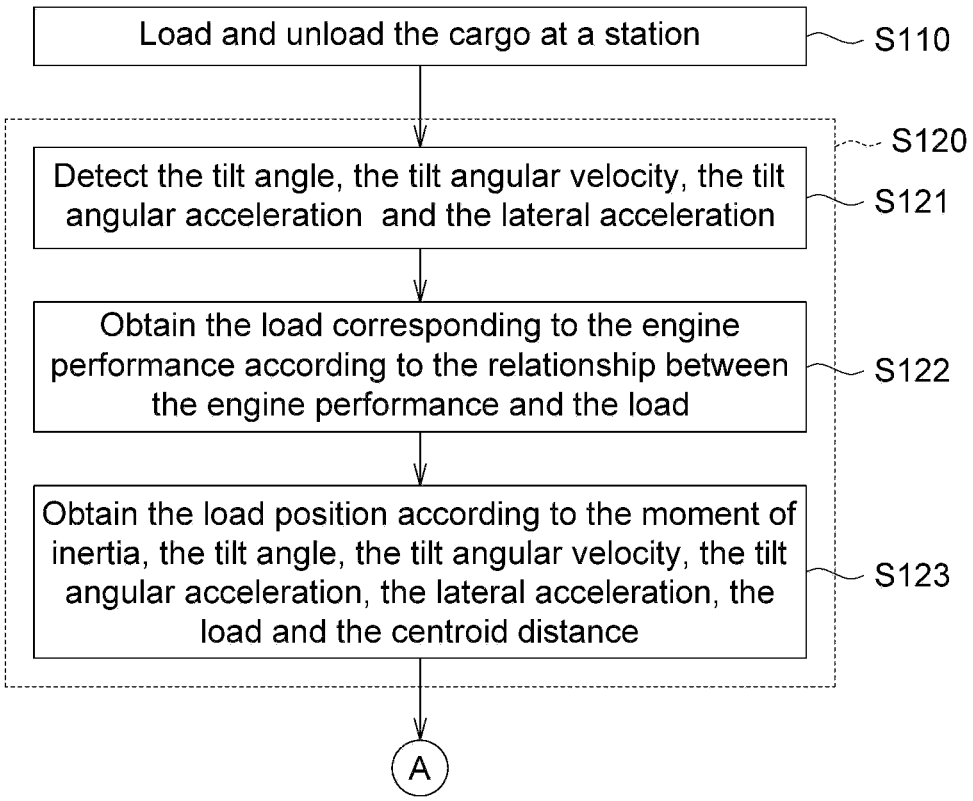

Load and unload the cargo at a station
S110
S120
Detect the tilt angle, the tilt angular velocity, the tilt angular acceleration and the lateral acceleration
S121
Obtain the load corresponding to the engine performance according to the relationship between the engine performance and the load
S122
Obtain the load position according to the moment of inertia, the tilt angle, the tilt angular velocity, the tilt angular acceleration, the lateral acceleration, the load and the centroid distance
S123
A

FIG. 7A

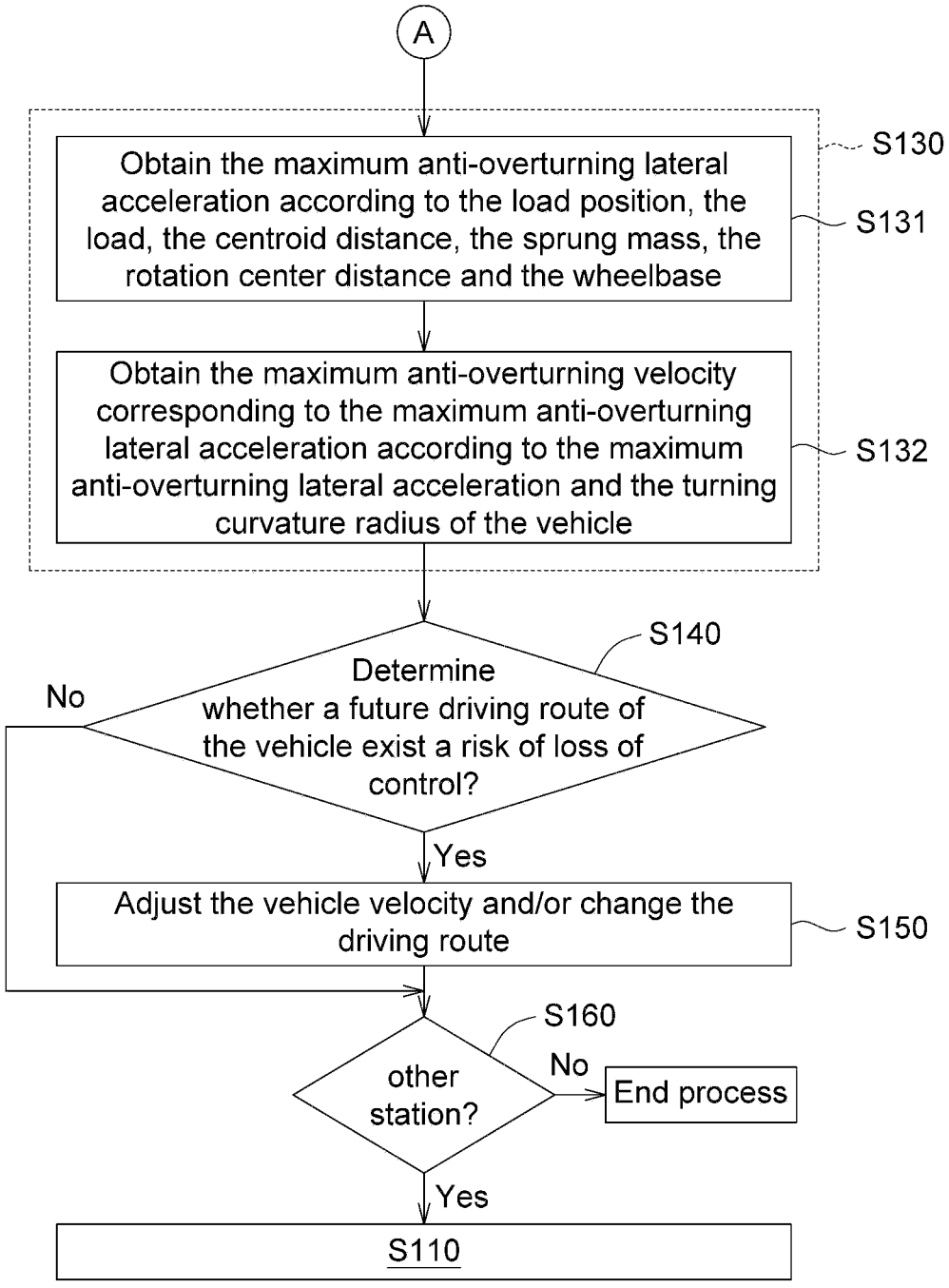

A
S130
Obtain the maximum anti-overturning lateral acceleration according to the load position, the load, the centroid distance, the sprung mass, the rotation center distance and the wheelbase
S131
Obtain the maximum anti-overturning velocity corresponding to the maximum anti-overturning lateral acceleration according to the maximum anti-overturning lateral acceleration and the turning curvature radius of the vehicle
S132
S140
Determine whether a future driving route of the vehicle exist a risk of loss of control?
No
Yes
Adjust the vehicle velocity and/or change the driving route
S150
S160
other station?
No
End process
Yes
S110

FIG. 7B

LOADING CALCULATION MODULE, VEHICLE ANTI-RUNAWAY SYSTEM, VEHICLE AND METHOD USING THE SAME

TECHNICAL FIELD

[0001] The disclosure relates in general to a loading calculation module, a vehicle anti-runaway system, a vehicle using the same, a load calculation method using the same and a vehicle anti-runaway method using the same.

BACKGROUND

[0002] Whether the vehicle is a bus or a truck of various types, its handling stability will be affected by high loads. In general, the driver makes a judgment based on the rule of thumb. Consequently, if driver is inexperienced, mentally ill or little careless, the vehicle will easily lose control, and accordingly it cause harm to driver himself and surrounding vehicles. Therefore, how to improve the aforementioned conventional problem is one of the goals of those skilled in the art.

SUMMARY

[0003] The present disclosure provides an electric-leakage detection device, an electric-leakage detection system using the same and an electric-leakage detection method using the same capable of resolving the above problems.

[0004] According to an embodiment of the present disclosure, a load calculation module is provided. The load calculation module includes a first storage unit, an inertial sensing unit and a calculation unit. The first storage unit is configured to store a relationship between an engine performance and a load, a sprung mass and a centroid distance between a sprung centroid and a rotation center. The inertial sensing unit is configured to detect a tilt angle, a tilt angular velocity, a tilt angular acceleration and a lateral acceleration. The calculation unit is configured to obtain a load corresponding to the engine performance according to the relationship between the engine performance and the load; and obtain a load position according to a moment of inertia, the tilt angle, the tilt angular velocity, the tilt angular acceleration, the lateral acceleration, the load and the centroid distance.

[0005] According to another embodiment of the present disclosure, a vehicle anti-runaway system is provided. The vehicle anti-runaway system includes a load calculation module, a runaway prevention module. The load calculation module includes a first storage unit, an inertial sensing unit and a calculation unit. The first storage unit is configured to store a relationship between an engine performance and a load, a sprung mass, a centroid distance between a sprung centroid and a rotation center. The inertial sensing unit is configured to detect a tilt angle, a tilt angular velocity, a tilt angular acceleration and a lateral acceleration. The calculation unit is configured to obtain a load corresponding to the engine performance according to the relationship between the engine performance and the load; and obtain a load position according to a moment of inertia, the tilt angle, the tilt angular velocity, the tilt angular acceleration, the lateral acceleration, the load and the centroid distance. The runaway prevention module includes a second storage unit and a maximum anti-overturn lateral acceleration calculation unit. The second storage unit is configured to store the centroid distance, the sprung mass, a rotation center distance and a wheelbase. The maximum anti-overturn lateral acceleration calculation unit is configured to obtain a maximum anti-overturning lateral acceleration according to the load position, the load, the centroid distance, the sprung mass, the rotation center distance and the wheelbase.

[0006] According to another embodiment of the present disclosure, a vehicle is provided. The vehicle includes an unsprung system, a sprung system and a vehicle anti-runaway system. The unsprung system has a rotation center. The sprung system is disposed on the unsprung system and has a sprung centroid. The vehicle anti-runaway system is configured to obtain the maximum anti-overturning lateral acceleration of the vehicle. The vehicle anti-runaway system includes a load calculation module, a runaway prevention module and a maximum anti-overturn lateral acceleration calculation unit. The load calculation module includes a first storage unit, an inertial sensing unit and a calculation unit. The first storage unit is configured to store a relationship between an engine performance and a load, a sprung mass, a centroid distance between a sprung centroid, a rotation center and a moment of inertia. The inertial sensing unit is configured to detect a tilt angle, a tilt angular velocity, a tilt angular acceleration and a lateral acceleration. The calculation unit is configured to obtain a load corresponding to the engine performance according to the relationship between the engine performance and the load; and obtain a load position according to the moment of inertia, the tilt angle, the tilt angular velocity, the tilt angular acceleration, the lateral acceleration, the load and the centroid distance. The runaway prevention module includes a second storage unit and a maximum anti-overturn lateral acceleration calculation unit. The second storage unit is configured to store the centroid distance, the sprung mass, a rotation center distance and a wheelbase. The maximum anti-overturn lateral acceleration calculation unit is configured to obtain a maximum anti-overturning lateral acceleration according to the load position, the load, the centroid distance, the sprung mass, the rotation center distance and the wheelbase.

[0007] According to another embodiment of the present disclosure, a load calculation method is provided. The load calculation method includes the following steps: detecting a tilt angle, a tilt angular velocity, a tilt angular acceleration and a lateral acceleration by an inertial sensing unit; obtaining a load corresponding to an engine performance according to a relationship between an engine performance and a load by a calculation unit; and obtaining a load position according to a moment of inertia, the tilt angle, the tilt angular velocity, the tilt angular acceleration, the lateral acceleration, the load and a centroid distance by the calculation unit.

[0008] According to another embodiment of the present disclosure, a vehicle anti-runaway method is provided. The vehicle anti-runaway method includes the following steps: using the load calculation method as described above to obtain the load and the load position; and obtaining a maximum anti-overturning lateral acceleration according to the load position, the load, the centroid distance, the sprung mass, a rotation center distance and a wheelbase.

[0009] The above and other aspects of the disclosure will become better understood with regard to the following detailed description of the preferred but non-limiting embodiment(s). The following description is made with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1** shows a functional block diagram of a vehicle anti-runaway system according to an embodiment of the present disclosure;

[0011] FIG. **2** shows an equivalent system diagram of mass-damping-spring (MCK) of the vehicle of the vehicle anti-runaway system **100**;

[0012] FIG. **3** shows a schematic diagram of a plurality of trial-and-error coordinate groups of a sprung system of FIG. **1**;

[0013] FIG. **4** shows a schematic diagram of the MCK equivalent system when the vehicle of FIG. **2** being turning;

[0014] FIG. **5** shows a schematic diagram of a relationship between time and brake force which is achieved by the vehicle anti-runaway system of FIG. **1**;

[0015] FIG. **6** shows a schematic diagram of a relationship between time and velocity which is achieved by the vehicle anti-runaway system of FIG. **1**; and

[0016] FIGS. **7**A and **7**B show a flowchart of a vehicle anti-runaway method for the vehicle according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

[0017] Referring to FIGS. **1** to **4**, FIG. **1** shows a functional block diagram of a vehicle anti-runaway system **100** according to an embodiment of the present disclosure, FIG. **2** shows an equivalent system diagram of mass-damping-spring (MCK) of the vehicle **10** of the vehicle anti-runaway system **100**, FIG. **3** shows a schematic diagram of a plurality of trial-and-error coordinate groups ($(l_w)_e$, $(h_w)_e$) of a sprung system **11**A of FIG. **1**, and FIG. **4** shows a schematic diagram of the MCK equivalent system when the vehicle **10** of FIG. **2** being turning.

[0018] As shown in FIG. **1**, the vehicle runaway prevention system **100** includes a load calculation module **110** and a runaway prevention module **120**. The vehicle anti-runaway system **100** could be applied to the vehicle **10**, such as a van, a truck, etc. The vehicle **10** includes a sprung system **11**A, an unsprung system **11**B and a vehicle anti-runaway system **100**. The sprung system **11**A includes, for example, a frame of the vehicle **10**, a container **11**A**1**, a power system, etc., and has a sprung centroid (center of mass) C**1**. The unsprung system **11**B includes, for example, a suspension of the vehicle **10**, a plurality of wheels **12** of the vehicle **10** or tracks (if any) of the vehicle **10** and other parts directly connected thereto. When the vehicle **10** turns, the sprung system **11**A tilts. For example, the sprung system **11**A turns about a rotation center C**2**. The rotation center C**2** here may coincide with an unsprung centroid (unsprung mass) or deviate from the unsprung centroid.

[0019] The load calculation module **110** is configured to obtain a load m_W and a load position P_W. The load m_W is, for example, the mass (weight) of the cargo (not shown) carried by the vehicle **10**. The load position P_W is, for example, the centroid of the cargo carried by the vehicle. The runaway prevention module **120** could perform a vehicle runaway evaluation according to the load m_W and the load position P_W. When an evaluation result is that the vehicle may, is about to or has lost control (for example, overturned), the runaway prevention module **120** could perform a corresponding anti-runaway control.

[0020] The following firstly introduces the load calculation module **110** and the process of obtaining the load m_W and the load position P_W using the load calculation module **110**.

[0021] The load calculation module **110** includes a first storage unit **111**, an inertial sensing unit **112** and a calculation unit **113**. The first storage unit **111** is configured to store a relationship R**1** between an engine performance and the load, a sprung mass m_S and a centroid distance her between the sprung centroid C**1** and the rotation center C**2**. The inertial sensing unit **112** is configured to detect a tilt angle Ø, a tilt angular velocity $\dot{Ø}$, a tilt angular acceleration $\ddot{Ø}$ and a lateral acceleration a_y. The calculation unit **113** is configured to obtain the load m_W corresponding to the engine performance according to the relationship R**1** between the engine performance and the load; and obtain the load position P_W according to a moment of inertia I_{XX}, the tilt angle Ø, the tilt angular velocity $\dot{Ø}$, the tilt angular acceleration $\ddot{Ø}$, the lateral acceleration a_y, the load m_W and the centroid distance h_{cr}. In an embodiment, "unit" herein could be "physical circuit".

[0022] The aforementioned inertial sensing unit **112** is, for example, a gyroscope, an acceleration sensor or a combination thereof. The sprung mass m_S is, for example, a mass of the sprung system **11**A in an empty state (no cargo).

[0023] The load position P_W could be expressed as (l_W, h_W) which could be referred to a coordinate system y-z, wherein an origin of the coordinate system y-z is, for example, established on the sprung centroid C**1**. l_W is a first load distance between the load position P_W and the sprung centroid C**1** in a first axis y, and h_W is a second load distance between the load position P_W and the sprung centroid C**1** in a second axis z.

[0024] In addition, the aforementioned moment of inertia I_{XX} is, for example, the moment of inertia of the sprung system **11**A. The relationship R**1** is, for example, a relationship between engine performance and load. The relationship R**1** records the load mw corresponding to different engine performances (for example, the performance of a throttle pedal depth and starting acceleration, etc.). The relationship R**1** could be measured in advance through simulation or actual measurement, and stored in the first storage unit **111**. The sprung mass m_S, the centroid distance h_{cr} and the moment of inertia I_{XX} could also be measured in advance and stored in the first storage unit **111**.

[0025] In an embodiment, the calculation unit **113** could obtain the load position P_W according to the following formulas (1) to (1D). In the formula, g is a gravitational acceleration, K_R is an elastic coefficient of the equivalent system of the vehicle **10**, and C_R is a damping coefficient of the equivalent system of the vehicle **10**. Coefficients A, B, C and D of formula (1) could be obtained according to formulas (1A) to (1D).

$$A((l_w)_e + (h_w)_e)^2 + B(l_w)_e + C(h_w)_e + D = RV1; \quad (1)$$

$$A = m_w\ddot{\phi}; \quad (1A)$$

$$B = m_w a_y \sin\phi - m_w g\cos\phi; \quad (1B)$$

$$C = -(m_w g\sin\phi + m_w a_y \cos\phi) \quad (1C)$$

-continued

$$D = I_{XX}\ddot{\phi} + C_R\dot{\phi} + K_R\phi - \quad (1D)$$
$$(m_s a_y h_{cr}\cos\phi + m_s g h_{cr}\sin\phi + m_w a_y h_{cr}\cos\phi + m_w g h_{fr}\sin\phi)$$

[0026] One of the methods for obtaining the load distances l_W and h_W is described below, such as the trial-and-error method or the exhaustive method.

[0027] The calculation unit **113** is further configured to: obtain a plurality of result values RV**1** of formula (1) by substituting a plurality of first trial-and-error values $(l_w)_e$ along the first axis y and a plurality of second trial-and-error values $(h_w)_e$ along the second axis z in formulas (1) to (1D); select the result value of the result values RV**1** that is less than a preset value; and use the first trial-and-error values $(l_w)_e$ and the second trial-and-error values $(h_w)_e$ corresponding to the result value less than the preset value as the first load distance l_W and the second load distance h_W respectively to satisfy $A(l_w+h_w)^2+Bl_w+Ch_w+D\cong 0$. As shown in FIG. **3**, the calculation unit **113** could divide the container **11**A**1** into a plurality of grids along the first axis y and the second axis z with a plurality of grid lines, and an intersection point of the grid lines has one trial-and-error coordinate groups $((l_w)_e, (h_w)_e)$. The foregoing preset value depends on the number of grids in FIG. **3**, which is not limited in the embodiments of the present disclosure. In an embodiment, the aforementioned preset value may be inversely proportional to the number of grids. In other embodiments, the preset value may range between 0.01 centimeter (cm) to 10 cm, a greater value, or other values closer to 0.

[0028] At a first time point, if the number of the result values that are smaller than the preset value is plural, then at the second time point, the calculation unit **113** substitutes the trial-and-error coordinate groups $((l_w)_e, (h_w)_e)$ corresponding to the result values that are smaller than the preset value and the tilt angle Ø, the tilt angular velocity $\dot{Ø}$, the tilt angular acceleration $\ddot{Ø}$ and the lateral acceleration a_y that are currently (or latest) detected into the above formulas (1) to (1D), accordingly obtain a plurality of result values RV**1**, and uses the first trial-and-error values $(l_w)_e$ and the second trial-and-error values $(h_w)_e$ corresponding to the result values that are smaller than the preset value as the first load distance l_W and the second load distance h_W respectively. If at the second time point, the number of the result value less than the preset value is still plural, then repeat the above process at the next time point until the number of result values less than the preset value is single, and the first trial-and-error values $(l_w)_e$ and the second trial-and-error values $(h_w)_e$ corresponding to the single result value are used as the first load distance l_W and the second load distance h_W respectively.

[0029] In addition, the inertial sensing unit **112** detects the tilt angle Ø, the tilt angular velocity $\dot{Ø}$, the tilt angular acceleration $\ddot{Ø}$ and the lateral acceleration a_y at each time point. The tilt angle Ø, the tilt angular velocity $\dot{Ø}$, the tilt angular acceleration $\ddot{Ø}$ and the lateral acceleration ay detected by the inertial sensing unit **112** at each time point could be different due to the turning radius r of the vehicle and/or the vehicle velocity.

[0030] As shown in the following formulas (2A) to (2B), the numerical ranges of the aforementioned first trial-and-error values $(l_w)_e$ along the first axis y satisfy the following formula (2A), while the numerical ranges of the aforementioned second trial-and-error values $(h_w)_e$ along the second axis z satisfy the following formula (2B). In formula (2A), W_C is a length of the sprung system **11**A along the first axis y, and h_C is a length of the sprung system **11**A along the second axis z, wherein the length W_C and the length h_C are known values.

$$-w_c/2 \le (l_w)_e \le +w_c/2 \quad (2A)$$
$$-h_C/2 \le (h_w)_e \le +h_C/2 \quad (2B)$$

[0031] In addition, a set of the first trial-and-error values $(l_w)_e$ and the second trial-and-error values $(h_w)_e$ is a coordinate value $((l_w)_e, (h_w)_e)$ of a position point in the sprung system **11**A, the coordinate value $((l_w)_e, (h_w)_e)$ of different position points are different. In addition, the more the number of sets of the trial-and-error coordinate values $((l_w)_e, (h_w)_e)$ of FIG. **3** is (the number of divided grids is more), the less the difference between the load position P_W and the actual position of the centroid of the cargo carried by the vehicle **10** is. In an embodiment, the difference between the obtained load position P_W and the actual position of the centroid of the cargo carried by the vehicle **10** that is within a few centimeters (for example, within 10 cm) is within a tolerable range.

[0032] The runaway prevention module **120** and the runaway prevention method using the same are introduced below.

[0033] As shown in FIG. **1**, the runaway prevention module **120** includes a second storage unit **121**, a maximum anti-overturn lateral acceleration calculation unit **122**, a maximum anti-overturn velocity calculation unit **123**, a steering wheel control unit **124**, a brake control unit **125**, a throttle control unit **126**, a control unit **127** and an indication unit **128**.

[0034] As shown in FIG. **1**, the second storage unit **121** is configured to store the centroid distance h_{cr}, the sprung mass m_S, a rotation center distance h_{fr} and a wheelbase l_{wb}. As shown in FIG. **4**, the rotation center distance h_{fr} is, for example, the distance between the rotation center C**2** and a bottom surface (which contacts the ground) of the wheel **12** in the axis z, while the wheelbase l_{wb} is, for example, the distance between the two wheels **12** of the vehicle **10**. The maximum anti-overturn lateral acceleration calculation unit **122** is configured to obtain the maximum anti-overturning lateral acceleration $a_{y,max}$ according to the load position P_W (l_W, h_W), the load m_W, the centroid distance h_{cr}, the sprung mass m_S, the rotation center distance h_{fr}, and the wheelbase l_{wb}.

[0035] In an embodiment, the maximum anti-overturn lateral acceleration calculation unit **122** could obtain the maximum anti-overturning lateral acceleration $a_{y,max}$ according to the following formulas (3) to (3D). The coefficients $A_{V,s}$, $A_{H,s}$, $A_{V,w}$ and $A_{H,w}$ of formula (3) could be obtained according to formulas (3A) to (3D) respectively.

$$m_s A_{H,s} + m_w\cos\phi A_{H,w} + m_w g\sin\phi A_{V,w} - \quad (3)$$
$$m_s a_y A_{V,s} - m_w a_y\cos\phi A_{V,w} + m_w a_y\sin\phi A_{H,w} = 0$$
$$A_{V,s} = h_{cr}\cos\phi + h_{fr} \quad (3A)$$

-continued

$$A_{H,s} = \frac{l_{wb}}{2} - h_{cr}\sin\phi \tag{3B}$$

$$A_{V,w} = h_w\cos\phi - l_w\sin\phi + h_{cr}\cos\phi + h_{fr} \tag{3C}$$

$$A_{H,w} = \frac{l_{wv}}{2} - h_{cr}\sin\phi - h_w\sin\phi - l_w\cos\phi \tag{3D}$$

[0036] After obtaining the maximum anti-overturning lateral acceleration $a_{y,max}$, the maximum anti-overturn velocity calculation unit **123** is configured to obtain the maximum anti-overturning velocity V_{max} corresponding to the maximum anti-overturning lateral acceleration $a_{y,max}$ according to the maximum anti-overturning lateral acceleration $a_{y,max}$ and a turning curvature radius r of the vehicle. For example, the maximum anti-overturn velocity calculation unit **123** could obtain the maximum anti-overturn velocity V_{max} according to the following formula (4). In formula (4), r is the turning curvature radius of the vehicle **10**, and its value could depend on a road condition where the vehicle **10** is located, or the turning curvature radius r of the vehicle **10** itself. As long as the turning velocity of the vehicle **10** under the turning curvature radius r does not exceed the maximum anti-overturning velocity V_{max}, the vehicle **10** will not lose control (that is, controllable). For example, rollover will not occur. In addition, the maximum anti-overturn velocity calculation unit **123** could obtain the turning curvature radius r from a map data stored in the storage unit.

$$v_{max} = \sqrt{a_{ymax} \times r} \tag{4}$$

[0037] After obtaining the maximum anti-overturning velocity V_{max}, the control unit **127** could control a steering wheel, a brake and/or a throttle of the vehicle **10** so that the velocity of the vehicle **10** does not exceed the maximum anti-overturning velocity V_{max}, so as to avoid loss of control of the vehicle. Further examples are described below.

[0038] For example, the control unit **127** is electrically connected to the steering wheel control unit **124**, the brake control unit **125** and the throttle control unit **126**, and could control the steering wheel, the brake and/or the throttle of the vehicle **10** through these units.

[0039] The steering wheel control unit **124** is electrically connected to a driving mechanism of the steering wheel of the vehicle **10**. The steering wheel control unit **124** could control the driving mechanism to drive a rotation direction and/or a rotation amount of the steering wheel. The control unit **127** could control the steering wheel control unit **124** to control the turning direction and/or the turning amount of the steering wheel of the vehicle **10**, thereby controlling the turning curvature radius of the vehicle **10**, so as to prevent the velocity of the vehicle **10** from exceeding the maximum anti-overturning velocity V_{max}. For example, when the velocity of the vehicle **10** is close to (or approximates to) the maximum anti-overturning velocity V_{max}, the steering wheel control unit **124** could control the steering wheel of the vehicle **10** to reduce a turning angle, so as to reduce the turning curvature radius r and change a driving path and/or a driving trajectory.

[0040] The brake control unit **125** is electrically connected to the brake system (not shown) of the vehicle **10**. The control unit **127** could control the brake control unit **125** to drive the brake system to adjust the brake force of the brake system for controlling the velocity of the vehicle **10**. For example, the brake control unit **125** controls the brake force of the vehicle **10** according to the load m_W. The greater the load m_W is, the greater the brake force of the vehicle **10** is. When the brake force applied by driver is insufficient, the brake control unit **125** could assist in increasing the brake force of the vehicle **10**. In an embodiment, the brake control unit **125** could increase or decrease the brake force according to a navigation planning route. The aforementioned navigation planning route could be obtained by a navigation device (not shown).

[0041] The throttle control unit **126** is electrically connected to a throttle system (not shown) of the vehicle **10**. The control unit **127** could control the throttle control unit **126** to drive the throttle opening degree (not shown) of the vehicle **10** to control an output horsepower of the power system of the vehicle **10** for adjusting the velocity of the vehicle **10**.

[0042] The indication unit **128** is electrically connected to the maximum anti-overturn velocity calculation unit **123**. The indication unit **128** is configured to: when the velocity of the vehicle **10** is close to the maximum anti-overturning velocity V_{max}, generate an indication signal **S1** to warn the driver that the vehicle **10** may or will be out of control. In addition, the indication unit **128** is further configured to: when the acceleration of the vehicle **10** is close to the maximum anti-overturning lateral acceleration $a_{y,max}$, generate the indication signal **S1** to warn the driver that the vehicle **10** may or will be out of control.

[0043] Referring to FIGS. **5** to **6**, FIG. **5** shows a schematic diagram of a relationship between time and brake force which is achieved by the vehicle anti-runaway system **100** of FIG. **1**, and FIG. **6** shows a schematic diagram of a relationship between time and velocity which is achieved by the vehicle anti-runaway system **100** of FIG. **1**.

[0044] As shown in FIG. **5**, a curve **L11** represents a variation of the brake force of a conventional vehicle in the loaded state, a curve **L12** represents a variation of the brake force of the vehicle **10** in the loaded state, and a curve **L13** represents a variation of the brake force of the vehicle **10** in the empty state (no cargo). In general, when driving, the driver does not consider the impact of the load on the brake force. Therefore, when the load is high, it is difficult for the brake force curve to reach a target value (reason is that the driver does not have enough time to react). However, since the embodiment of the present disclosure could obtain the load m_W in advance, the brake force could be adjusted under consideration of the load m_W, and the brake force control of the high-load vehicle could be corrected in advance. Comparing the curves **L11** and **L12**, under the same brake force, the vehicle **10** of the present disclosed embodiment takes less time. Comparing the curves **L12** and **L13**, since the vehicle **10** in the embodiment of the present disclosure could obtain the load m_W in advance, the brake force could be increased in advance.

[0045] As shown in FIG. **6**, a curve **L21** represents a variation of the velocity of the conventional vehicle in the loaded state, a curve **L22** represents a variation of the velocity of the vehicle **10** in the loaded state, and a curve **L23** represents a variation of the velocity of the vehicle **10** in the empty state (no cargo). Comparing the curves **L21**, **L22** and **L23**, since the vehicle **10** of the embodiment of the present disclosure could obtain the load m_W in advance, the

time required for the vehicle **10** of the embodiment of the present disclosure is less under the same velocity drop.

[0046] As shown in FIGS. **5** and **6**, compared with the conventional vehicle, the vehicle **10** of the disclosed embodiment could achieve the same deceleration and brake force in a shorter time.

[0047] Referring to FIGS. **7**A and **7**B, FIGS. **7**A and **7**B show a flowchart of a vehicle anti-runaway method for the vehicle **10** according to an embodiment of the present disclosure.

[0048] In step **S110**, the vehicle **10** loads and unloads the cargo at a station.

[0049] In step **S120**, the load m_W and the load position P_W are obtained by using the aforementioned load calculation method. Step **S120** could include the following steps **S121** to **S123**.

[0050] In step **S121**, the inertial sensing unit **112** detects the tilt angle Ø, the tilt angular velocity $\dot{Ø}$, the tilt angular acceleration $\ddot{Ø}$ and the lateral acceleration a_y.

[0051] In step **S122**, the calculation unit **113** obtains the load mw corresponding to the engine performance according to the relationship **R1** between the engine performance and the load.

[0052] In step **S123**, the calculation unit **113** obtains the load position P_W according to the moment of inertia I_{XX}, the tilt angle Ø, the tilt angular velocity $\dot{Ø}$, the tilt angular acceleration $\ddot{Ø}$, the lateral acceleration a_y, the load m_W and the centroid distance h_{cr}.

[0053] In step **S130**, after obtaining the load m_W and the load position P_W, the maximum anti-overturning velocity V_{max} is obtained according to at least the load m_W and the load position P_W. Step **S130** could include the following steps **S131** to **S132**.

[0054] In step **S131**, the maximum anti-overturn lateral acceleration calculation unit **122** obtains the maximum anti-overturning lateral acceleration $a_{y,max}$ according to the load position $P_W(l_W, h_W)$, the load m_W, the centroid distance h_{cr}, the sprung mass m_S, the rotation center distance h_{fr}, and the wheelbase l_{wb}.

[0055] In step **S132**, the maximum anti-overturn velocity calculation unit **123** obtains the maximum anti-overturning velocity V_{max} corresponding to the maximum anti-overturning lateral acceleration $a_{y,max}$ according to the maximum anti-overturning lateral acceleration $a_{y,max}$ and a turning curvature radius r of the vehicle **10**.

[0056] In step **S140**, the control unit **127** determines whether a future driving route and/or a driving trajectory of the vehicle **10** exists a risk of loss of control. If so, the process proceeds to step **S150**; if not, the process proceeds to step **S160**.

[0057] In step **S150**, the control unit **127** could adjust the vehicle velocity, change the driving route and/or the driving trajectory, and control the steering wheel, the brake and/or the throttle of the vehicle **10** so that the vehicle velocity does not exceed the maximum anti-overturning velocity V_{max} for avoiding loss of control of the vehicle. The control unit **127** adjusts the velocity of the vehicle and changes the driving route and/or the driving trajectory as described above, and the similarities will not be repeated here. During the course between the two stations, the vehicle anti-runaway system **100** executes steps **S110** to **S150** at each time point, and obtains the load position P_W, the maximum anti-overturning lateral acceleration $a_{y,max}$ and the maximum anti-overturning velocity V_{max} by using the tilt angle Ø, the tilt angular velocity $\dot{Ø}$, the tilt angular acceleration $\ddot{Ø}$, the lateral acceleration a_y and engine performance.

[0058] In step **S160**, if the vehicle **10** still needs to load and unload the cargo at other station, the process returns to step **S110** and repeats the same steps above; if not, the process ends.

[0059] The other steps of the vehicle anti-runaway method in the embodiment of the present disclosure have been described above, and they will not be repeated here.

[0060] To sum up, the embodiment of this disclosure proposes a loading calculation module, a vehicle anti-runaway system, a vehicle using the same, a load calculation method using the same and a vehicle anti-runaway method using the same. The load calculation module is configured to calculate or obtain a height and a weight of the current cargo during the driving state, and accordingly adjusts a brake control and a brake distance estimation. The runaway prevention module is configured to calculate or obtain the maximum anti-overturning lateral acceleration and the maximum anti-overturning velocity which could be withstand in the future driving path and/or driving trajectory for adjusting the vehicle velocity and/or correcting the path, thereby ensuring that the vehicle could maintain a safe distance during driving, and applying the brakes smoothly to avoid overturning.

[0061] It will be apparent to those skilled in the art that various modifications and variations could be made to the disclosed embodiments. It is intended that the specification and examples be considered as exemplary only, with a true scope of the disclosure being indicated by the following claims and their equivalents.

What is claimed is:

1. A load calculation module, comprising:

a first storage unit configured to store a relationship between an engine performance and a load, a sprung mass, a centroid distance between a sprung centroid and a rotation center;

an inertial sensing unit configured to detect a tilt angle, a tilt angular velocity, a tilt angular acceleration and a lateral acceleration; and

a calculation unit configured to:

obtain a load corresponding to the engine performance according to the relationship between the engine performance and the load; and

obtain a load position according to a moment of inertia, the tilt angle, the tilt angular velocity, the tilt angular acceleration, the lateral acceleration, the load and the centroid distance.

2. The load calculation module as claimed in claim **1**, wherein the calculation unit is further configured to obtain the load position (l_W, h_W) according to the following formulas (1)' to (1D);

$$A(l_w + h_w)^2 + Bl_w + Ch_w + D \cong 0; \quad (1)'$$

$$A = m_w\ddot{\phi}; \quad (1A)$$

$$B = m_w a_y \sin\phi - m_w g\cos\phi; \quad (1B)$$

$$C = -(m_w g\sin\phi + m_w a_y \cos\phi); \quad (1C)$$

-continued

$$D = I_{XX}\ddot{\phi} + C_R\dot{\phi} + K_R\phi - (m_s a_y h_{cr}\cos\phi + m_s g h_{cr}\sin\phi + m_w a_y h_{cr}\cos\phi + m_w g h_{cr}\sin\phi) \quad (1D)$$

wherein l_W is a first load distance between the load position and the sprung centroid along a first axis, h_W is a second load distance between the load position and the sprung centroid along a second axis, m_S is the sprung mass, a_y is the lateral acceleration, I_{XX} is the moment of inertia, g is a gravitational acceleration, Ø is the tilt angle, $\dot{Ø}$ is the tilt angular velocity, $\ddot{Ø}$ is the tilt angular acceleration, h_{cr} is the centroid distance, K_R is an elastic coefficient, and C_R is a damping coefficient.

3. The load calculation module as claimed in claim **2**, wherein the calculation unit is further configured to:

obtain a plurality of result values RV**1** of formula (1) by substituting a plurality of first trial-and-error values $(l_w)_e$ along the first axis and a plurality of second trial-and-error values $(h_w)_e$ along the second axis into formulas (1) to (1D);

select the result value less than a preset value from the result values RV**1**; and

use the first trial-and-error value and the second trial-and-error value corresponding to the result value less than the preset value as the first load distance l_W and the second load distance h_W;

$$A((l_w)_e + (h_w)_e)^2 + B(l_w)_e + C(h_w)_e + D = RV1. \quad (1)$$

4. The load calculation module as claimed in claim **3**, wherein the calculation unit is further configured to:

divide a container of the sprung system into a plurality of grids with a plurality of grid lines;

wherein an intersection point of the grid lines has a set of the first trial-and-error values $(l_w)_e$ and the second trial-and-error values $(h_w)_e$.

5. A vehicle anti-runaway system, comprising:

a load calculation module as claimed in in claim **1** configured to obtain the load and the load position; and

a runaway prevention module, comprising:

a second storage unit configured to store the centroid distance, the sprung mass, a rotation center distance and a wheelbase; and

a maximum anti-overturn lateral acceleration calculation unit configured to obtain a maximum anti-overturning lateral acceleration according to the load position, the load, the centroid distance, the sprung mass, the rotation center distance and the wheelbase.

6. The vehicle anti-runaway system as claimed in claim **5**, wherein the runaway prevention module further comprises:

a maximum anti-overturn velocity calculation unit configured to obtain a maximum anti-overturning velocity corresponding to the maximum anti-overturning lateral acceleration according to the maximum anti-overturning lateral acceleration and a turning curvature radius of a vehicle.

7. The vehicle anti-runaway system as claimed in claim **6**, wherein the vehicle anti-runaway system further comprises:

an indication unit electrically connected to the maximum anti-overturn velocity calculation unit and configure to:

generate an indication signal when a vehicle velocity is close to a maximum anti-overturning velocity.

8. The vehicle anti-runaway system as claimed in claim **6**, wherein the runaway prevention module further comprises:

a steering wheel control unit electrically connected to the maximum anti-overturn velocity calculation unit and configured to:

reduce a rotation angle of a steering wheel when a vehicle velocity is close to the maximum anti-overturning velocity.

9. The vehicle runaway prevention system as claimed in claim **6**, wherein the runaway prevention module further comprises:

a brake control unit electrically connected to the maximum anti-overturn velocity calculation unit and configured to:

control a brake force according to the load.

10. The vehicle anti-runaway system as claimed in claim **9**, wherein the brake control unit is further configured to:

add the brake force according to a navigation planning route.

11. A vehicle comprising:

an unsprung system having a rotation center;

a sprung system disposed on the unsprung system and having a sprung centroid; and

a vehicle anti-runaway system as claimed in claim **5**, configured to obtain the maximum anti-overturning lateral acceleration of the vehicle.

12. A load calculation method, comprising:

detecting a tilt angle, a tilt angular velocity, a tilt angular acceleration and a lateral acceleration by an inertial sensing unit;

obtaining a load corresponding to an engine performance according to a relationship between an engine performance and a load by a calculation unit; and

obtaining a load position according to a moment of inertia, the tilt angle, the tilt angular velocity, the tilt angular acceleration, the lateral acceleration, the load and a centroid distance by the calculation unit.

13. The load calculation method claimed in claim **12** further comprising:

obtaining the load position (l_W, h_W) according to the following formulas (1)' to (1D);

$$A(l_w + h_w)^2 + Bl_w + Ch_w + D \cong 0; \quad (1)'$$

$$A = m_w\ddot{\phi}; \quad (1A)$$

$$B = m_w a_y \sin\phi - m_w g\cos\phi; \quad (1B)$$

$$C = -(m_w g\sin\phi + m_w a_y\cos\phi); \quad (1C)$$

$$D = I_{XX}\ddot{\phi} + C_R\dot{\phi} + K_R\phi - (m_s a_y h_{cr}\cos\phi + m_s g h_{cr}\sin\phi + m_w a_y h_{cr}\cos\phi + m_w g h_{cr}\sin\phi) \quad (1D)$$

wherein l_W is a first load distance between the load position and the sprung centroid along a first axis, h_W is a second load distance between the load position and the sprung centroid along a second axis, m_S is the sprung mass, a_y is the lateral acceleration, I_{XX} is the moment of inertia, g is a gravitational acceleration, Ø is the tilt angle, $\dot{Ø}$ is the tilt angular velocity, $\ddot{Ø}$ is the tilt angular acceleration, h_{cr} is the centroid distance, K_R is an elastic coefficient, and C_R is a damping coefficient.

14. The load calculation method claimed in claim **13** further comprising:

obtaining a plurality of result values RV**1** of formula (1) by substituting a plurality of first trial-and-error values $(l_w)_e$ along the first axis and a plurality of second trial-and-error values $(h_w)_e$ along the second axis into formulas (1) to (1D) by the calculation unit;

selecting the result value less than a preset value from the result values RV**1** by the calculation unit; and

using the first trial-and-error value and the second trial-and-error value corresponding to the result value less than the preset value as the first load distance l_W and the second load distance h_W by the calculation unit;

$$A((l_w)_e + (h_w)_e)^2 + B(l_w)_e + C(h_w)_e + D = RV1. \quad (1)$$

15. The load calculation method as claimed in claim **14** further comprising:

dividing a container of the sprung system into a plurality of grids with a plurality of grid lines;

wherein an intersection point of the grid lines has a set of the first trial-and-error values $(l_w)_e$ and the second trial-and-error values $(h_w)_e$.

16. A vehicle anti-runaway method, comprising:

using the load calculation method as claimed in claim **12** to obtain the load and the load position; and

obtaining a maximum anti-overturning lateral acceleration according to the load position, the load, the centroid distance, the sprung mass, a rotation center distance and a wheelbase.

17. The vehicle anti-runaway method as claimed in claim **16**, further comprising:

obtaining a maximum anti-overturning velocity corresponding to the maximum anti-overturning lateral acceleration according to the maximum anti-overturning lateral acceleration and a turning curvature radius of a vehicle by a maximum anti-overturn velocity calculation unit.

18. The vehicle anti-runaway method as claimed in claim **17**, further comprising:

generating an indication signal when a vehicle velocity is close to a maximum anti-overturning velocity.

19. The vehicle anti-runaway method as claimed in claim **17**, further comprising:

when a vehicle velocity is close to the maximum anti-overturning velocity, reducing a steering wheel rotation angle by a steering wheel control unit.

20. The vehicle anti-runaway method as claimed in claim **17**, further comprising:

controlling a brake force according to the load by a brake control unit.

21. The vehicle anti-runaway method as claimed in claim **20**, further comprising:

adding the brake force according to a navigation planning route by the brake control unit.

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