



US 20150203121A1

(19) **United States**
(12) **Patent Application Publication**
Mori et al.

(10) **Pub. No.: US 2015/0203121 A1**
(43) **Pub. Date: Jul. 23, 2015**

(54) **DRIVER'S STATE ESTIMATION APPARATUS AND DRIVER'S STATE ESTIMATION METHOD**

A61B 5/021 (2006.01)
A61B 5/18 (2006.01)
G06F 19/00 (2006.01)
G01P 15/00 (2006.01)

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(52) **U.S. Cl.**

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CPC *B60W 40/08* (2013.01); *G06F 19/3431* (2013.01); *G01P 15/00* (2013.01); *A61B 5/021* (2013.01); *A61B 5/18* (2013.01); *A61B 5/7246* (2013.01); *B60W 2040/0872* (2013.01)

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(57) **ABSTRACT**

(21) Appl. No.: **14/415,063**

(22) PCT Filed: **Jun. 14, 2013**

(86) PCT No.: **PCT/JP2013/003747**

§ 371 (c)(1),

(2) Date: **Jan. 15, 2015**

(30) **Foreign Application Priority Data**

Jul. 26, 2012 (JP) 2012-166225

Publication Classification

(51) **Int. Cl.**

B60W 40/08 (2006.01)

A61B 5/00 (2006.01)

Heart rates of the driver are recorded at a deceleration start time when a vehicle in a travelling state starts to decelerate and stop. The heart rates within a predetermined period recorded before the deceleration start time by the biological information record unit are referred to, and a pre-deceleration heart rate which is a representative value of the referred heart rates is extracted. Furthermore, the heart rates within a predetermined period recorded after the deceleration start time by the biological information record unit are referred to and a post-deceleration heart rate which is a representative value of the referred heart rates is extracted. Then, the pre-deceleration biological information and the post-deceleration biological information extracted by the biological information extraction unit are compared with each other to estimate the steady state of the driver after deceleration.

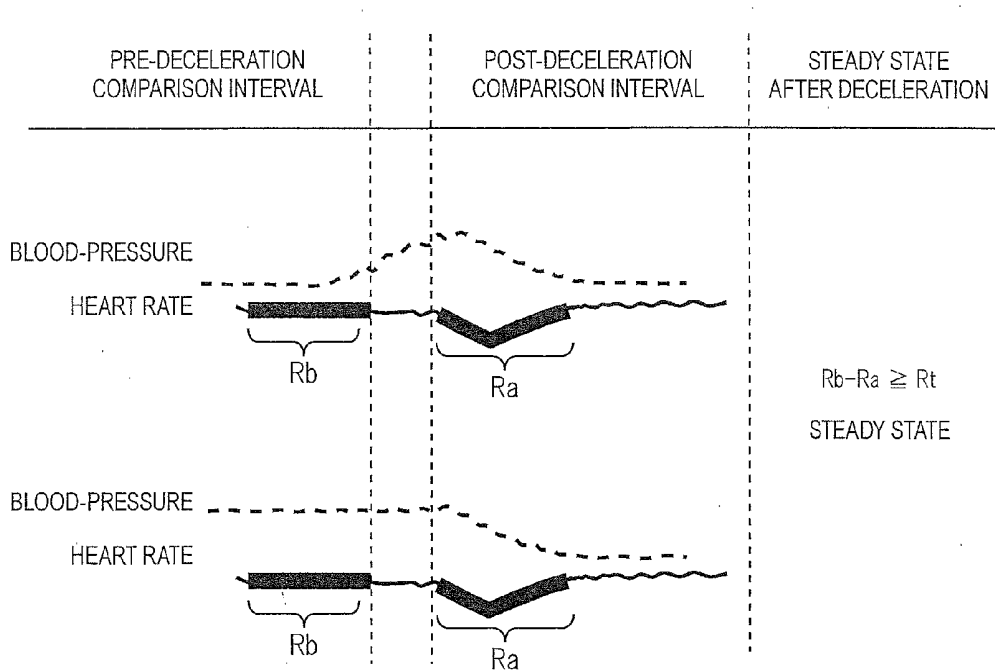


FIG. 1

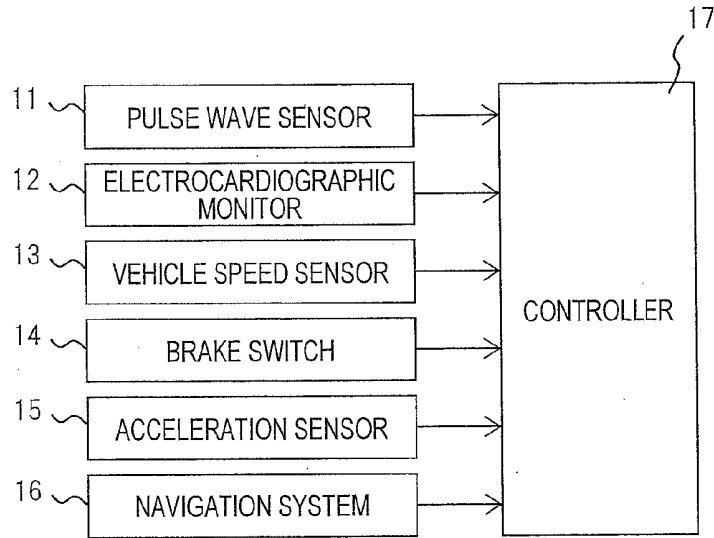


FIG. 2

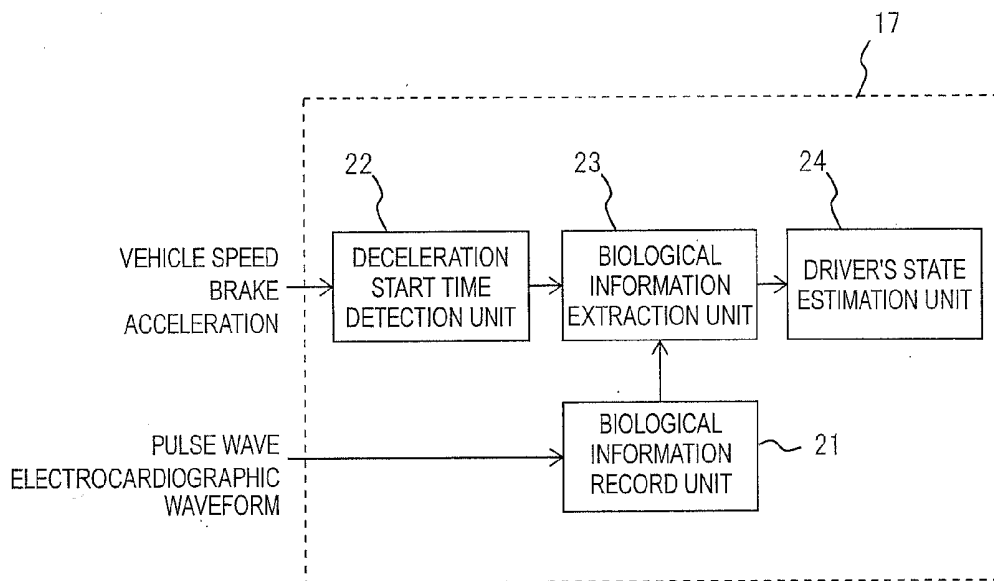
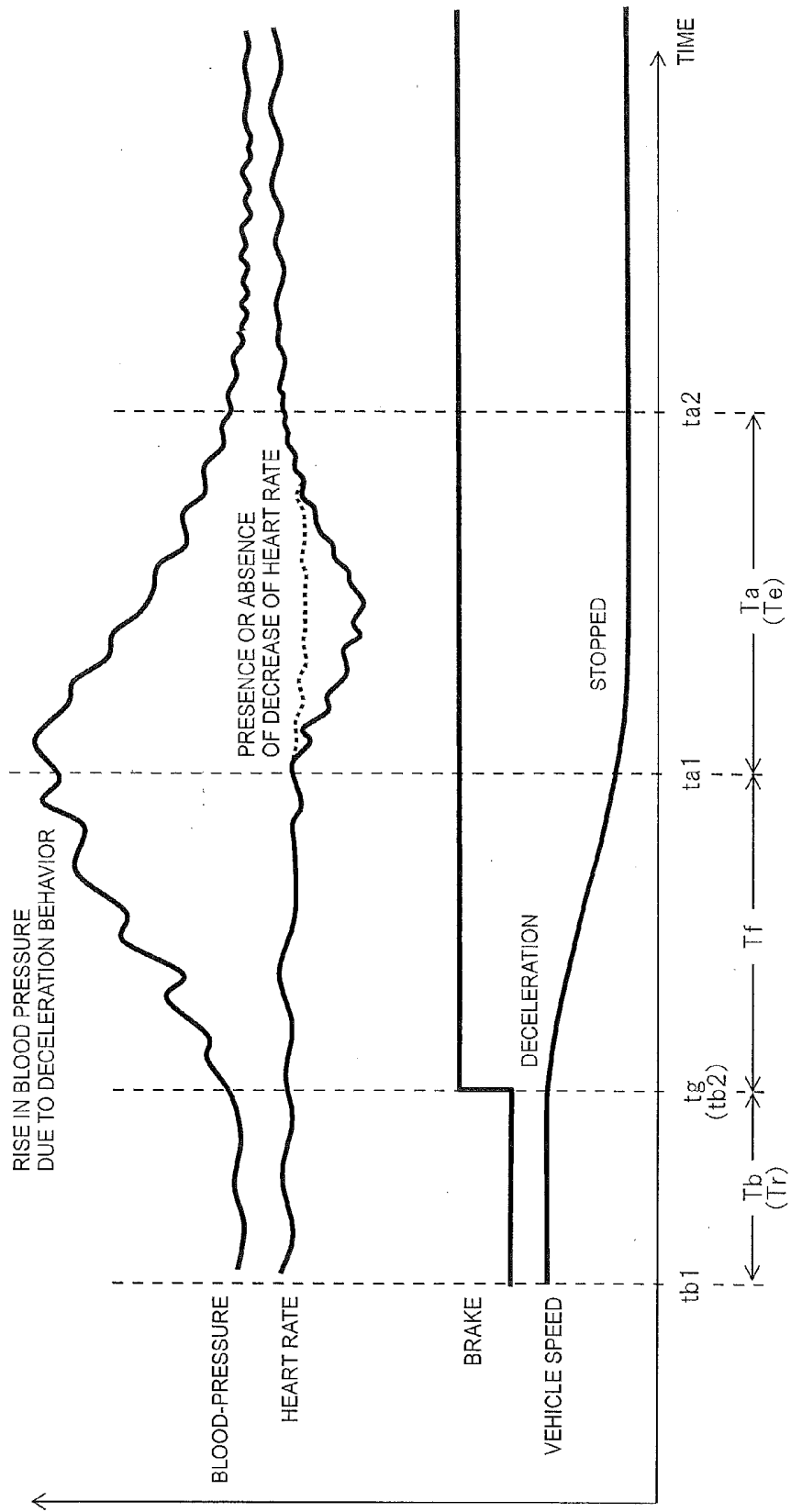


FIG. 3



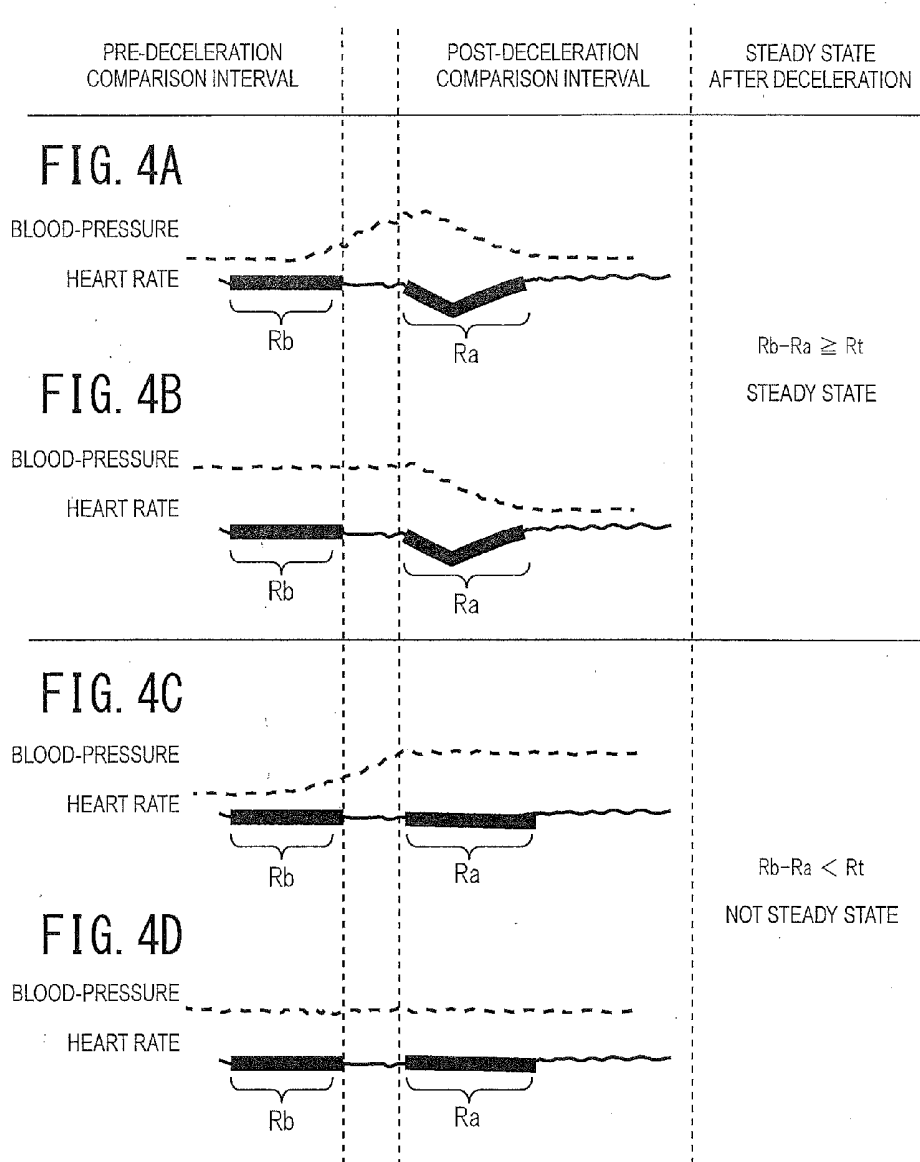


FIG. 5

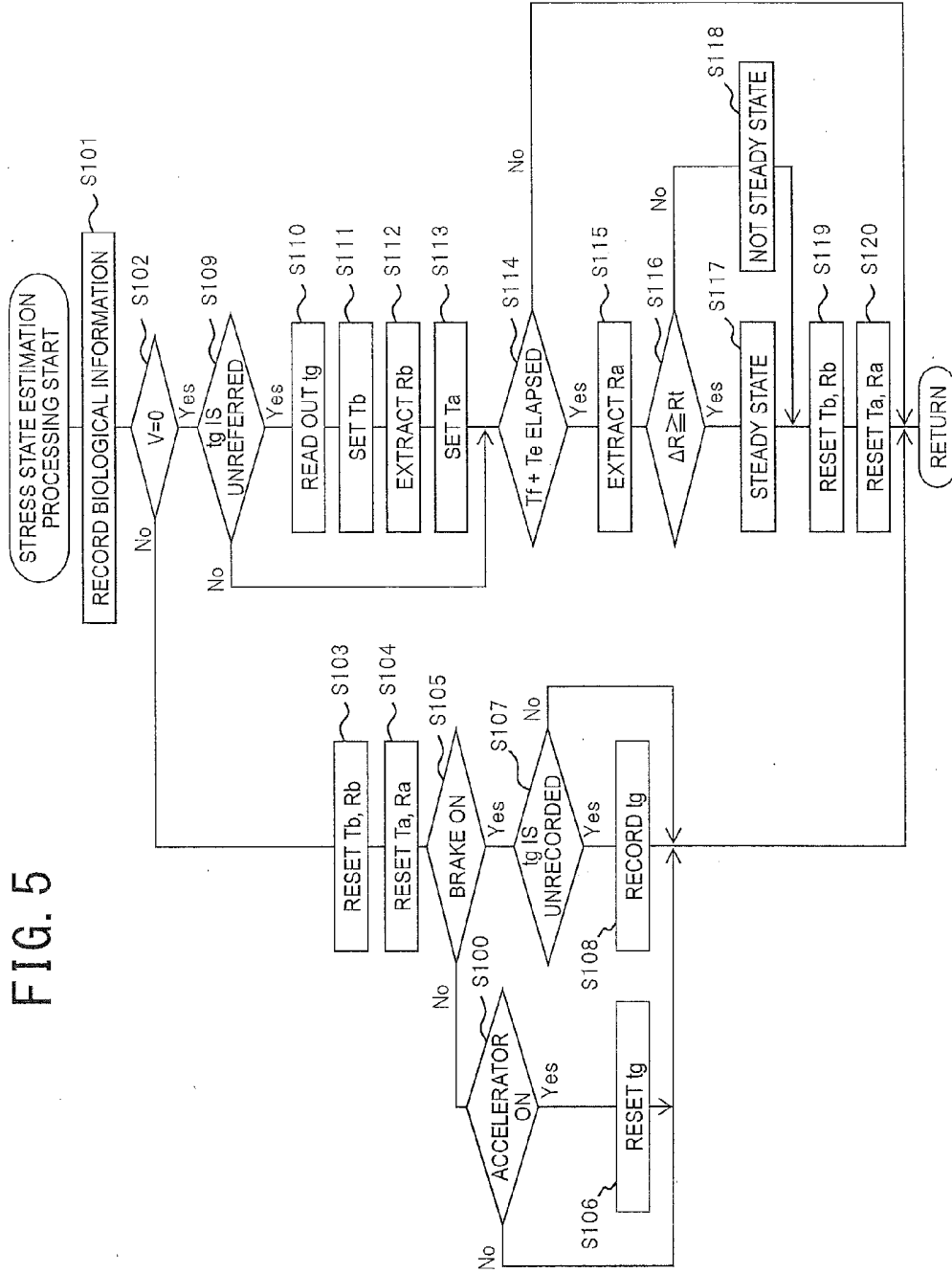


FIG. 6

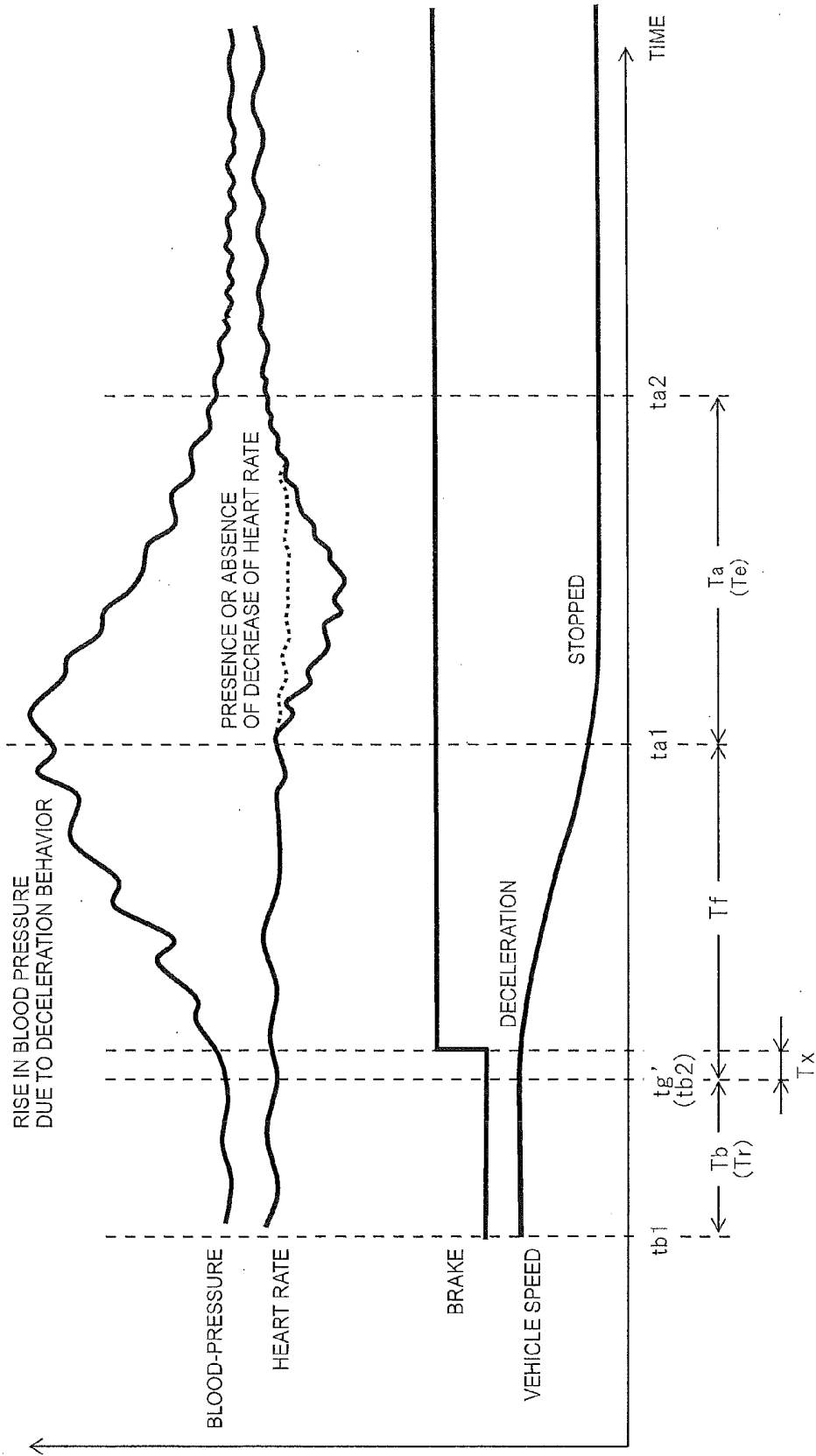


FIG. 7

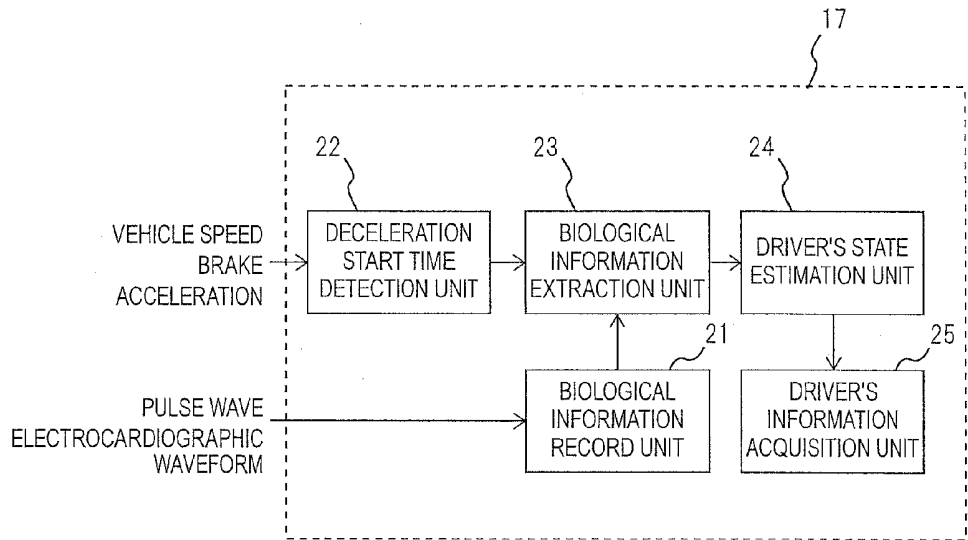


FIG. 8A

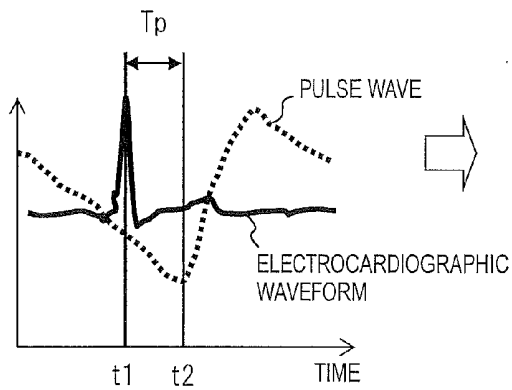


FIG. 8B

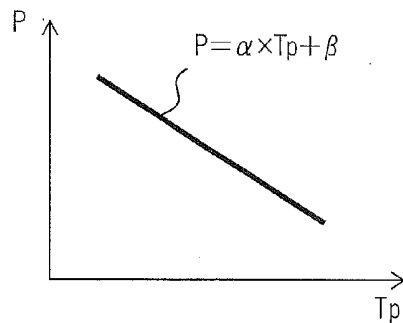


FIG. 9

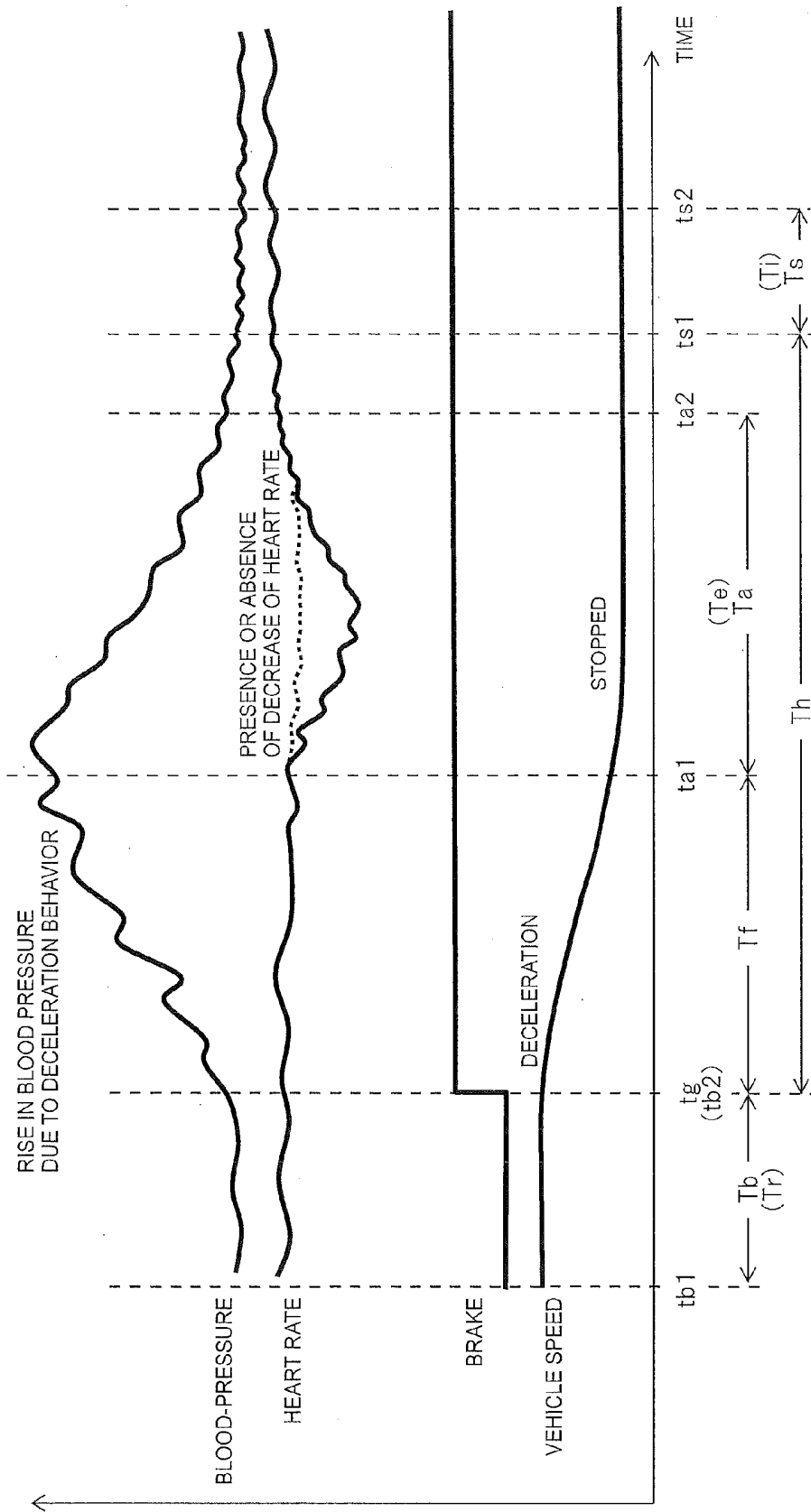


FIG. 10

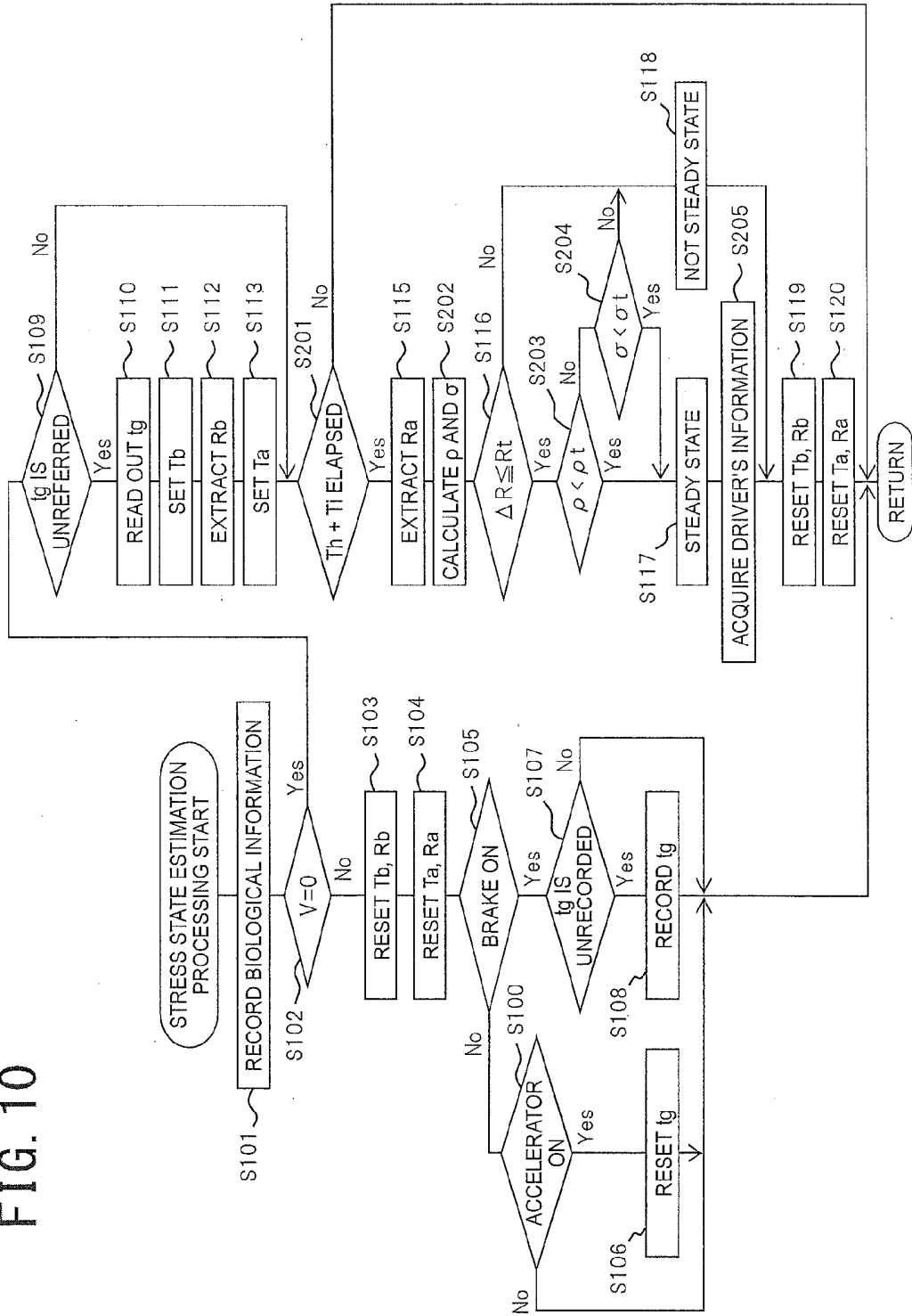


FIG. 11

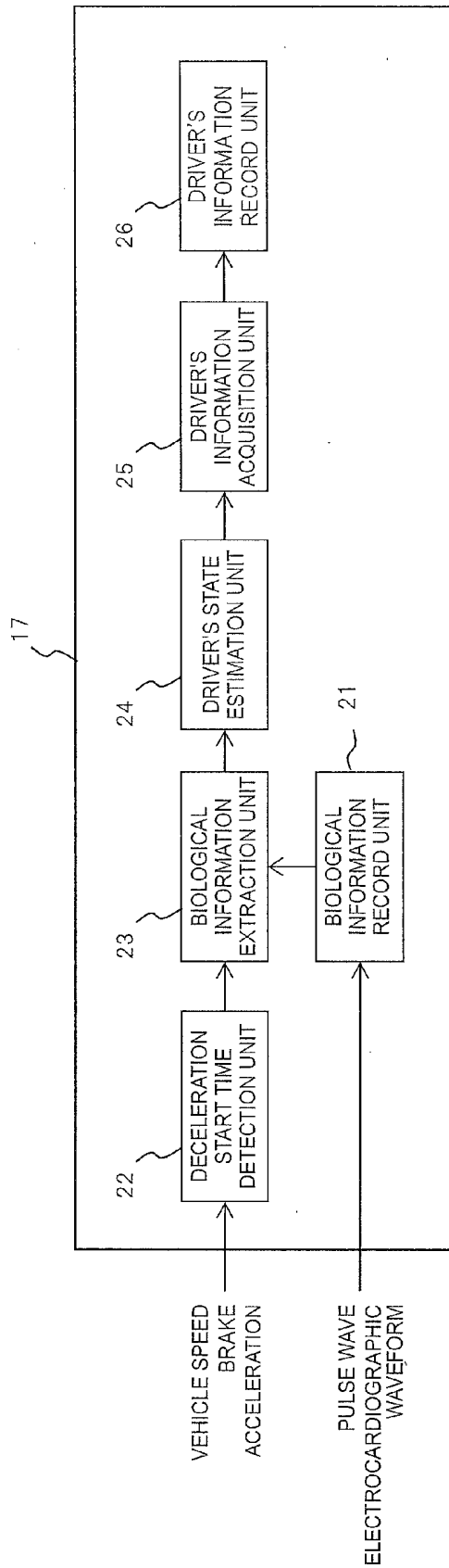
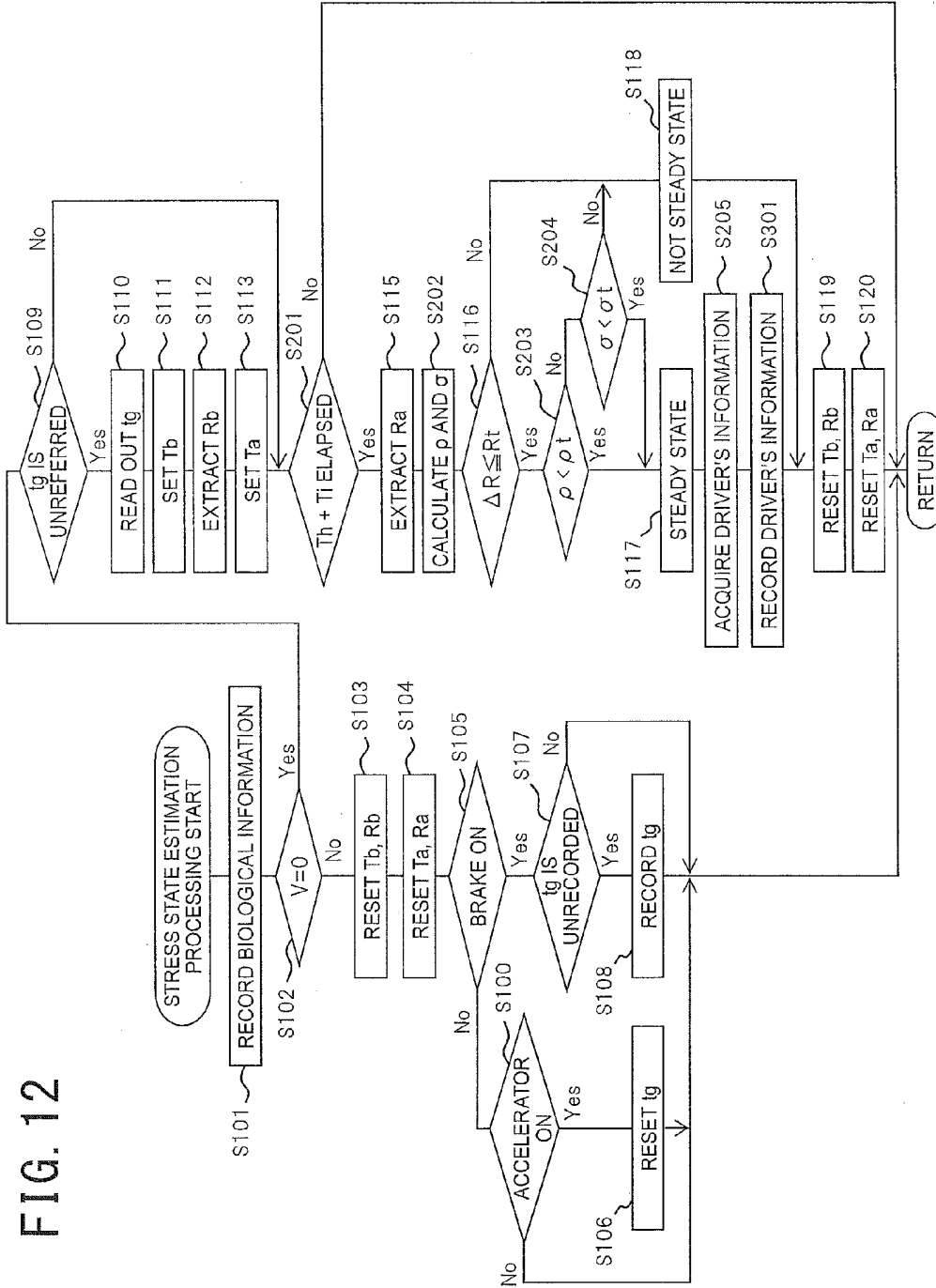


FIG. 12



DRIVER'S STATE ESTIMATION APPARATUS AND DRIVER'S STATE ESTIMATION METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application is a national phase application of PCT Application No. PCT/JP2013/003747 filed Jun. 14, 2013, and claims priority to Japanese Patent Application No. 2012-166225, filed on Jul. 26, 2012, the entire content of which is hereby incorporated by reference as a part of this application.

BACKGROUND

[0002] 1. Technical Field

[0003] This disclosure relates to a driver's state estimation apparatus and a driver's state estimation method.

[0004] 2. Related Art

[0005] PTL 1 discloses a navigation apparatus which searches a facility around the current location and provides information thereof. The navigation apparatus measures biological information of a passenger, such as a blood-pressure, a pulse rate, a body temperature, or the like, and provides facility information depending on a health condition of the passenger.

CITATION LIST

Patent Literature

[0006] PTL1: JP 2007-47196

SUMMARY

[0007] With regard to the blood-pressure as one example of the biological information, a normal value can be obtained only when a measuring object person is in a steady state. For example, the blood-pressure generally becomes higher after exercise, after meals, on smoking, at a cold time, or the like. The blood-pressure also generally becomes higher when the person is in an excited state due to emotional ups and downs, or in a nervous state. Therefore, in order to obtain the normal value of the blood-pressure, it is firstly necessary to know whether or not the measuring object person is in the physically and mentally steady state. However, it is difficult to estimate that the measuring object person is in the steady state. Especially, the blood-pressure of the driver fluctuates largely during travelling, and the driver is not always in the steady state even when a vehicle is stopped.

[0008] One or more embodiments of the present invention improves an estimate accuracy in estimating the driver's steady state.

[0009] According to one embodiment of the present invention, there is provided a driver's state estimation apparatus in which biological information of a driver is recorded and a deceleration start time is detected when a vehicle in travelling state starts to decelerate and stops. Then, the biological information within a predetermined period recorded before the deceleration start time is referred to and pre-deceleration biological information which is a representative value of the referred biological information is extracted, and the biological information within a predetermined period recorded after the deceleration start time is referred to and post-deceleration biological information which is a representative value of the referred biological information is extracted. Then, the

extracted pre-deceleration biological information and the extracted post-deceleration biological information are compared with each other to estimate whether or not the driver after deceleration is in a steady state.

BRIEF DESCRIPTION OF DRAWINGS

[0010] FIG. 1 is a schematic configuration of a driver's state estimation apparatus;

[0011] FIG. 2 is a block diagram illustrating a driver's state estimation processing;

[0012] FIG. 3 is a time chart illustrating a pre-deceleration comparison period T_b and a post-deceleration comparison period T_a ;

[0013] FIG. 4A to FIG. 4D are views illustrating an estimation of a steady state;

[0014] FIG. 5 is a flowchart illustrating a driver's state estimation processing;

[0015] FIG. 6 is a time chart illustrating a reaction time T_x and a deceleration start time t_g ;

[0016] FIG. 7 is a block diagram illustrating a driver's state estimation processing of a second embodiment;

[0017] FIG. 8A and FIG. 8B are views illustrating a calculation method of a blood-pressure value P ;

[0018] FIG. 9 is a time chart illustrating a post-deceleration stability period T_s ;

[0019] FIG. 10 is a flowchart illustrating a driver's state estimation processing of the second embodiment;

[0020] FIG. 11 is a block diagram illustrating a driver's state estimation processing of a third embodiment; and

[0021] FIG. 12 is a flowchart illustrating a driver's state estimation processing of the third embodiment.

DETAILED DESCRIPTION

[0022] Hereinafter, embodiments of the present invention will be described with reference to the drawings. In embodiments of the invention, numerous specific details are set forth in order to provide a more thorough understanding of the invention. However, it will be apparent to one of ordinary skill in the art that the invention may be practiced without these specific details. In other instances, well-known features have not been described in detail to avoid obscuring the invention.

First Embodiment

[0023] (Configuration)

[0024] The present embodiment estimates a steady state of a driver.

[0025] FIG. 1 is a schematic configuration of a driver's state estimation apparatus.

[0026] The driver's state estimation apparatus is installed in a vehicle and includes a pulse wave sensor 11, an electrocardiographic monitor 12, a vehicle speed sensor 13, a brake switch 14, an acceleration sensor 15, a navigation system 16, and a controller 17.

[0027] The pulse wave sensor 11 is configured to detect a pulse wave (volume pulse wave) of the driver. The pulse wave is biological information representing a change of a volume of the peripheral arterial vessel associated with the pulsation of the heart. The pulse wave sensor 11 may be formed by using a photoelectric sensor having a combination of a light emitting element and a light receiving element of the infrared light to utilize a characteristic of the near-infrared wavelength light passing through a living body and being absorbed into hemoglobin in blood. Specifically, the pulse wave sensor 11

may be provided on a grip portion of a steering wheel, for example, and configured to irradiate the infrared light to a palm or a fingertip of the driver and input a voltage signal depending on a light intensity of a scattered light reflecting thereon to the controller 17. The controller 17 configured to determine the pulse wave on the basis of the input voltage signal.

[0028] The electrocardiographic monitor 12 is configured to detect an electrocardiographic waveform of the driver. The electrocardiographic monitor 12 may include, for example, plural electrodes provided on a seating face or a surface of a backrest of a seat, or the like. The electrocardiographic monitor 12 may be configured to input to the controller 17 a potential difference signal which occurs between the respective electrodes due to a depolarization produced with a conduction of impulse which occurs when the heart muscle of the driver expands and contracts. The electrocardiographic monitor 12 is configured to determine the electrocardiographic waveform on the basis of the input potential difference. It is noted that clothes or a cloth intervenes between a skin of the driver and the electrodes, therefore, the Laplacian electrode arrangement may be employed or a capacitive measurement circuit may have a high input impedance.

[0029] The driver's state estimation apparatus of the present embodiment may be supposed to be installed in the vehicle, and the biological information may be continuously acquired without binding the driver. Therefore, the pulse wave sensor 11 and the electrocardiographic monitor 12 may be provided on the grip portion of the steering wheel or on the seating face or the surface of the backrest of the seat. The pulse wave sensor 11 and the electrocardiographic monitor 12 may be provided at a part which the driver operates within the reach of a portion of the body or a part supporting the body of the driver, as long as the biological information of the driver can be acquired.

[0030] The vehicle speed sensor 13 is configured to detect a speed of a vehicle body (hereinafter, referred to as "vehicle speed") V. The vehicle speed sensor 13 may be provided on a driven gear on an output side of a transmission, for example, and be configured to detect magnetic field lines of a sensor rotor by a detection circuit to convert the change of the magnetic field due to a rotation of the sensor rotor into a pulse signal and input it to the controller 17. The controller 17 is configured to determine the vehicle speed V on the basis of the input pulse signal.

[0031] The brake switch 14 is configured to detect ON/OFF of a brake. The brake switch 14 is configured to input a voltage signal depending on the ON/OFF of the brake to the controller 17, for example, by the use of a detection circuit including a normally-closed contact. The controller 17 is configured to determine the ON/OFF of the brake on the basis of the input voltage signal.

[0032] The acceleration sensor 15 is configured to detect an acceleration/deceleration G in a front-rear direction of the vehicle. The acceleration sensor 15 is configured to detect a displacement of a movable electrode with respect to a fixed electrode as a change of an electrostatic capacity, for example, and to convert it into a voltage signal proportional to the acceleration/deceleration and the direction to input the voltage signal to the controller 17. The controller 17 is configured to determine the acceleration/deceleration G on the basis of the input voltage signal.

[0033] The navigation system 16 is configured to recognize a current location of the vehicle and road map information at

the current location. The navigation system 16 includes a GPS receiver and is configured to recognize the location (latitude, longitude, altitude) and the travelling direction of the vehicle on the basis of time differences between radio waves arriving from three or more GPS satellites. Then, the navigation system 16 is configured to refer to the road map information including road types, road shapes, widths of lanes, passing directions of vehicles, and the like, which are stored in a DVD-ROM drive or a hard disk drive, and to recognize the road map information at the current location of the vehicle to input it to the controller 17. It is noted that the Dedicated Short Range Communication (DSRC) may be used to receive various data from an infrastructure as the Driving Safety Support Systems (DSSS).

[0034] It is noted that the controller 17 is configured to directly receive the various detection signals from the sensors or the like, but is not limited thereto. The controller 17 may be connected to another control unit to receive the various data, for example, via Controller Area Network (CAN) using a multiplex communication of a CSMA/CA system.

[0035] The controller 17 may include a micro computer for example, and be configured to perform a driver's state estimation processing every predetermined period (10 msec, for example).

[0036] FIG. 2 is a block diagram illustrating the driver's state estimation processing.

[0037] The driver's state estimation processing performed by the controller 17 includes a biological information record unit 21, a deceleration start time detection unit 22, a biological information extraction unit 23, and a driver's state estimation unit 24.

[0038] The biological information record unit 21 is configured to record a vital sign of the circulatory system of the driver, which is influenced by the autonomic nerve, as the biological information. The heart rate R is the number of the pulsation of the heart within a certain period, and generally indicates the number of the pulsation per minute. Specifically, the heart rate R is calculated on the basis of the pulse wave detected by the pulse wave sensor 11 and the electrocardiographic waveform detected by the electrocardiographic monitor 12, and the heart rate R is recorded as the biological information. The biological information record unit 21 is configured to accumulate the heart rates R with time information in a nonvolatile memory and manage them.

[0039] Herein, the calculation of the heart rate R will be described.

[0040] In the present embodiment, a period of the pulsation propagating from the pumping of the heart to the periphery is measured. For example, the heart rate (sec) is calculated by dividing a unit time (60 sec, for example) by a period from a peak value to a next peak value in the pulse wave or the electrocardiographic waveform (a period of one pulsation).

[0041] What is described above is the record processing of the heart rate R by the biological information record unit 21.

[0042] The deceleration start time detection unit 22 is configured to detect a deceleration start time t_g when the vehicle in a travelling state starts to decelerate and stops. Specifically, the deceleration start time detection unit 22 is configured to read the vehicle speed V detected by the vehicle speed sensor 13, the ON/OFF state and the like detected by the brake switch 14. Then, the deceleration start time detection unit 22 is configured to detect the time when the deceleration operation of the driver switches to ON as the deceleration start time t_g , when the break including an engine brake switches from

OFF to ON in a state where the vehicle speed V is faster than zero, and then the vehicle speed V decreases to zero. The deceleration start time t_g substantially corresponds to the time when the driver recognizes that the vehicle needs to stop.

[0043] The biological information extraction unit **23** is configured to refer to the heart rates R within a predetermined pre-deceleration comparison period T_b recorded by the biological information record unit **21** before the deceleration start time t_g with reference to the deceleration start time t_g detected by the deceleration start time detection unit **22** to extract a pre-deceleration heart rate R_b , which is a representative value of the referred heart rates R . Furthermore, the biological information extraction unit **23** is configured to refer to the heart rates R within a predetermined post-deceleration comparison period T_a recorded by the biological information record unit **21** after the deceleration start time t_g to extract a post-deceleration heart rate R_a , which is a representative value of the referred heart rates R .

[0044] FIG. 3 is a time chart illustrating the pre-deceleration comparison period T_b and the post-deceleration comparison period T_a .

[0045] First, the time ($t_g - T_r = t_{b1}$) prior to the deceleration start time t_g by a predetermined time T_r is set as a pre-deceleration reference start time t_{b1} and the deceleration start time t_g is set as a pre-deceleration reference end time t_{b2} ($t_g = t_{b2}$). Then, a period from the pre-deceleration reference start time t_{b1} to the pre-deceleration reference end time t_{b2} is set as the pre-deceleration comparison period T_b ($t_{b2} - t_{b1} = T_b = T_r$).

[0046] Furthermore, the time ($t_g + T_f = t_{a1}$) when a predetermined time T_f elapses from the deceleration start time t_g is set as a post-deceleration reference start time t_{a1} and the time ($t_{a1} + T_e = t_{a2}$) when a predetermined time T_e elapses from the post-deceleration reference start time t_{a1} is set as a post-deceleration reference end time t_{a2} . Herein, T_f corresponds to a time from the start of the deceleration to the start of decrease of the heart rate R . T_e corresponds to a time from the start of decrease of the heart rate R until the heart rate R returns to the same status as before the start of the deceleration. Then, the period ($t_{a2} - t_{a1} = T_a = T_e$) from the post-deceleration reference start time t_{a1} to the post-deceleration reference end time t_{a2} is set as the post-deceleration comparison period T_a .

[0047] Then, a data group of the heart rates R recorded within the pre-deceleration comparison period T_b is referred to and an average value of the heart rates R is extracted as the pre-deceleration heart rate R_b , as follows.

$$R_b = \sum R(i)/N, \text{ where } i=R_1, R_2, \dots, R_N$$

[0048] Furthermore, a data group of the heart rates R recorded within the post-deceleration comparison period T_a is referred to and an average value of the heart rates R is extracted as the post-deceleration heart rate R_a , as follows.

$$R_a = \sum R(i)/N, \text{ where } i=R_1, R_2, \dots, R_N$$

[0049] It is noted that the data group of the heart rates R is referred to and the average value is utilized as the representative value of the referred heart rates R in the present embodiment, but the present disclosure is not limited thereto. In other embodiments, an intermediate value or a maximum value may be used as the representative value.

[0050] What is described above is the extraction processing of the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a by the biological information extraction unit **23**.

[0051] The driver's state estimation unit **24** is configured to compare the pre-deceleration heart rate R_b and the post-

deceleration heart rate R_a extracted by the biological information extraction unit **23** to estimate the steady state of the driver after the deceleration.

[0052] FIG. 4A to FIG. 4D are views the estimation of the steady state.

[0053] First, as illustrated in FIG. 4A and FIG. 4B, the driver's state estimation unit **24** is configured to estimate that the driver after the deceleration is in the steady state when the difference $\Delta R (=R_b - R_a)$ between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a is equal to or larger than a predetermined threshold value R_t . Herein, FIG. 4A illustrates a case where the blood pressure which has risen due to the deceleration behavior decreases after the deceleration. FIG. 4B illustrates a case where the blood pressure which has risen before the deceleration behavior decreases after the deceleration.

[0054] On the other hand, as illustrated in FIG. 4C and FIG. 4D, the driver's state estimation unit **24** is configured to estimate that the driver after the deceleration is not in the steady state when the difference $\Delta R (=R_b - R_a)$ between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a is less than the predetermined threshold value R_t . Herein, FIG. 4C illustrates a case where the blood pressure which has risen due to the deceleration behavior is kept after the deceleration. FIG. 4D illustrates a case where the blood pressure does not change before the deceleration behavior and after the deceleration.

[0055] It is noted that the one threshold value R_t is set in the above description, and two phases in which the driver after the deceleration is in the steady state or not is estimated depending on whether or not the difference ΔR between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a is larger than the threshold value R_t , the present discloser is not limited thereto. That is, three or more phases of the steady state of the driver after the deceleration, for example, "steady state", "a bit steady state", "not steady state", and the like, may be estimated by setting plural threshold values and depending on the range where the difference ΔR falls into.

[0056] What is described above is the descriptions of the driver's state estimation processing based on the block diagram in FIG. 2.

[0057] Next, the driver's state estimation processing will be described based on a flowchart.

[0058] FIG. 5 is the flowchart illustrating the driver's state estimation processing.

[0059] First, in the step **S101** corresponding to a processing in the biological information record unit **21**, the heart rate R is calculated on the basis of the pulse wave detected by the pulse wave sensor **11** and the electrocardiographic waveform detected by the electrocardiographic monitor **12** and the heart rate R is recorded as the biological information.

[0060] In the step **S102**, it is determined whether or not the vehicle speed V is zero. Now, when the vehicle speed V is faster than zero, it is determined that the vehicle is in the travelling state, and the processing proceeds to the step **S103**. On the other hand, when the vehicle speed V is zero, it is determined that the vehicle is in a stopped state, and the processing proceeds to the step **S109**.

[0061] In the step **S103**, the pre-deceleration comparison period T_b and the pre-deceleration heart rate R_b which are set by the biological information extraction unit **23** are reset.

[0062] In the following step S104, the post-deceleration comparison period T_a and the post-deceleration heart rate R_a which are set by the biological information extraction unit 23 are reset.

[0063] In the following step S105, it is determined whether or not the break including the engine brake is ON. Now, when the break is OFF, it is determined that the deceleration operation is not performed and the processing proceeds to the step S100. On the other hand, when the brake is ON, it is determined that the deceleration operation is performed and the processing proceeds to the step S107. It is noted that the driver may continuously switch the braking operation between ON and OFF, such as in a case of the intermittent brake operation or the like. Thus, when the brake switch 14 switches from OFF to ON, the brake switch 14 may be considered as being remaining in the ON state until a predetermined time elapses.

[0064] In the step S100, it is determined whether or not the accelerator is ON. Now, when the accelerator is ON, it is determined that the acceleration operation is performed and the processing proceeds to the step S106. On the other hand, the accelerator is OFF, it is determined that the acceleration operation is not performed and the processing returns to a predetermined main program.

[0065] In the step S106 corresponding to a processing in the deceleration start time detection unit 22, the deceleration start time t_g is reset and the processing returns to the predetermined main program.

[0066] In step S107, it is determined whether or not the deceleration start time t_g is unrecorded. Now, when the deceleration start time t_g is unrecorded, it is determined that it is just after starting the brake operation, and the processing proceeds to the step S108. On the other hand, when the deceleration start time t_g is recorded, it is determined that it is not just after starting the brake operation, and the processing returns to the predetermined main program.

[0067] In the step S108, the deceleration start time t_g when the vehicle in the travelling state starts to decelerate is recorded, and then the processing returns to the predetermined main program.

[0068] In the step S109, it is determined whether or not the deceleration start time t_g is unreferring to. Now, when the deceleration start time t_g is unreferring to, it is determined that it is just after the vehicle stops, the processing proceeds to the step S110. On the other hand, when the deceleration start time t_g is referring to, it is determined that it is not just after the vehicle stops, the processing proceeds to the step S114.

[0069] In the step S110 corresponding to a processing in the deceleration start time detection unit 22, the deceleration start time t_g when the vehicle in the travelling state starts to decelerate is read out (referred to).

[0070] In the following step S111 corresponding to a processing in the biological information extraction unit 23 and the pre-deceleration comparison period T_b is set. That is, the pre-deceleration reference start time $tb1$ prior to the the deceleration start time t_g by the predetermined time T_r is set is set and the deceleration start time t_g is set as the pre-deceleration reference end time $tb2$. And the period from the pre-deceleration reference start time $tb1$ to the pre-deceleration reference end time $tb2$ is set as the pre-deceleration comparison period T_b .

[0071] In the following step S112 corresponding to the processing in the biological information extraction unit 23, the data group of the heart rates R recorded within the pre-deceleration comparison period T_b is referred to, and the

average of the heart rates R is extracted as the pre-deceleration heart rate R_b . In the following step S113 corresponding to the processing in the biological information extraction unit 23, the post-deceleration comparison period T_a is set. That is, the required time T_f from the deceleration start time t_g until the biological information of the driver becomes stable is set, and the post-deceleration reference start time $ta1$ when the predetermined time T_f elapses from the deceleration start time t_g is set. And the post-deceleration reference end time $ta2$ when the predetermined time T_e elapses from the post-deceleration reference start time $ta1$ is set. Then, the post-deceleration comparison period T_a from the post-deceleration reference start time $ta1$ to the post-deceleration reference end time $ta2$ is set.

[0072] In the following step S114, it is determined that whether or not the time (T_f+T_e) has elapsed from the deceleration start time t_g . The time (T_f+T_e) corresponds to the time from when the deceleration starts and the heart rate R decreases until the heart rate R returns to the same status as before the start of deceleration. Herein, when the time (T_f+T_e) has not elapsed, it is determined that the post-deceleration comparison period T_a has not elapsed, and thus the post-deceleration heart rate R_a can not be extracted. And the processing returns to the predetermined main program. On the other hand, when the time (T_f+T_e) has elapsed, it is determined that the post-deceleration comparison period T_a has elapsed, and thus the post-deceleration heart rate R_a can be extracted. And the processing proceeds to the step S115.

[0073] In the step S115 corresponding to a processing in the biological information extraction unit 23, the data group of the heart rates R recorded within the post-deceleration comparison period T_a is referred to and the average of the heart rates R is extracted as the post-deceleration heart rate R_a .

[0074] In the following step S116 corresponding to a processing in the driver's state estimation unit 24, it is determined whether or not the difference ΔR between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a is equal to or larger than the predetermined threshold value R_t . Now, when the difference ΔR is equal to or larger than the predetermined threshold value R_t , it is estimated that the driver after the deceleration is in the steady state, and the processing proceeds to the step S117. On the other hand, when the difference ΔR is smaller than the predetermined threshold value R_t , it is estimated that the driver after the deceleration is not in the steady state, and the processing proceeds to the step S118.

[0075] In the step S117 corresponding to the processing in the driver's state estimation unit 24, the estimation result that the driver after the deceleration is in the steady state is recorded as a history, for example in a predetermined drive recorder, and then the processing proceeds to the step S119.

[0076] In the step S118 corresponding to the processing in the driver's state estimation unit 24, the estimation result that the driver after the deceleration is not in the steady state is recorded as a history, for example in the predetermined drive recorder, and then the processing proceeds to the step S119.

[0077] In the step S119, the pre-deceleration comparison period T_b and the pre-deceleration heart rate R_b which are set by the biological information extraction unit 23 are reset, and then the processing returns to the predetermined main program.

[0078] The following step S120, the post-deceleration comparison period T_a and the post-deceleration heart rate R_a

which are set by the biological information extraction unit 23 are reset, and then the processing returns to the predetermined main program.

[0079] What is described above is the descriptions of the driver's state estimation processing based on the flowchart in FIG. 6.

[0080] (Operation)

[0081] Next, the operation of the first embodiment will be described.

[0082] With regard to the blood-pressure as one example of the biological information, a normal value can be obtained only when a measuring object person is in the steady state. For example, it is known that the blood-pressure becomes higher due to exercise, meals, an excited state, a nervous state, smoking, a coldness, or the like, and contrarily, the blood-pressure becomes lower due to a warmness, a steady state, relaxed state, or the like. Among these factors, the factors other than the mental factors can be self-controlled. However, the mental factors may not be sufficiently self-controlled.

[0083] Furthermore, some people experience a rise in blood pressure only by wearing a sphygmomanometer cuff. Thus, multiple measurements may be needed for measuring a blood-pressure value in the real steady state. Therefore, a user has to reduce the various fluctuating factor by taking a break for a few minutes before measuring the blood-pressure to secure the accuracy of the measured values. And the user also has to consider that the various fluctuating factor may be affected by the physical exercise or the emotional ups and downs of the user. Thus, in measuring the biological information, the measurement of the biological information in the steady state with high accuracy is difficult and an important problem.

[0084] Therefore, in the present embodiment, focusing on the tendency of the heart rate R of the driver to be stabilized uniformity after the change of the heart rate R of the driver due to the deceleration of the vehicle, it is estimated whether or not the driver after the deceleration is in the steady state by comparing the pre-deceleration heart rate Rb and the post-deceleration heart rate Ra.

[0085] First, the heart rate R as the vital sign of the circulatory system of the driver is calculated on the basis of the pulse wave and the electrocardiographic waveform of the driver and recorded with the time information (the step S101). In the present embodiment, focusing on the tendency of the heart rate R of the driver to be stabilized uniformity after the change of the heart rate R of the driver due to the deceleration of the vehicle, by observing how the heart rate R of the driver changes before and after the deceleration start time tg before the vehicle stops, the steady state of the driver after the deceleration is estimated.

[0086] First, the time when the brake switches from OFF to ON ("Yes" in the determination in the step S105) in the state where the vehicle speed V is faster than zero ("No" in the determination in the step S102) is recorded as the deceleration start time tg (the step S108). Then, the recorded deceleration start time tg is read out (the step S110) at a vehicle stop time is when the vehicle is stopped by the deceleration operation ("Yes" in the determination in the step S102).

[0087] Then, as illustrated in FIG. 3, the pre-deceleration reference start time tb1 and the pre-deceleration reference end time tb2 are set in accordance with the deceleration start time tg and the predetermined time Tr, and the period from the pre-deceleration reference start time tb1 to the pre-deceleration reference end time tb2 is set as the pre-deceleration

comparison period Tb (the step S111). Then, the heart rates R within the pre-deceleration comparison period Tb are referred to and the average of the data group of the heart rates R is extracted as the pre-deceleration heart rate Rb (the step S112). In the pre-deceleration comparison period Tb, both of the blood-pressure value and the heart rate are in stable state.

[0088] Furthermore, as illustrated in FIG. 3, the post-deceleration reference start time ta1 and the post-deceleration reference end time ta2 are set in accordance with the deceleration start time tg, the predetermined time Tf and the predetermined time te, and the period from the post-deceleration reference start time ta1 to the post-deceleration reference end time ta2 is set as the post-deceleration comparison period Ta (the step S113). In this case, in the period from the deceleration start time tg to the vehicle stop time ts, the heart rate does not change significantly generally, however the blood-pressure has a tendency to rise due to the deceleration operation. Then, when the vehicle is stopped completely, the blood-pressure starts to drop from the state where the blood-pressure has risen, and returns to the stable state. On the other hand, the heart rate R also drops temporarily, and starts to rise again, and then returns to the stable state.

[0089] Then, the processing waits from the deceleration start time tg until the time (Tf+Te) elapses ("No" in the determination of the step S114), that is, until the data collection of the heart rates R within the post-deceleration comparison period Ta is completed. Then, when the time (Tf+Te) elapses ("Yes" in the determination of the step S114), the heart rates R within the post-deceleration comparison period Ta are referred to, and the average of the data group of the heart rates R is extracted as the post-deceleration heart rate Ra (the step S115).

[0090] Then, as illustrated in FIG. 4A and FIG. 4B, it is estimated that the driver after the deceleration is in the steady state (the step S117) when the difference ΔR between the pre-deceleration heart rate Rb and the post-deceleration heart rate Ra is equal to or larger than the predetermined threshold value Rt ("Yes" in the determination in the step S116). On the other hand, as illustrated in FIG. 4C and FIG. 4D, it is estimated that the driver after the deceleration is not in the steady state (the step S118) when the difference ΔR is smaller than the predetermined threshold value Rt. In this way, by comparing the pre-deceleration heart rate Rb and the post-deceleration heart rate Ra, it is possible to estimate whether or not the driver after the deceleration is in the steady state with high accuracy. Furthermore, since it is estimated whether or not the driver is in the steady state by using the magnitude of the difference ΔR between the pre-deceleration heart rate Rb and the post-deceleration heart rate Ra, it is easy to estimate whether or not the driver is in the steady state.

[0091] Furthermore, by setting the pre-deceleration comparison period Tb on the basis of the deceleration start time tg and the predetermined time Tr, and referring to the data group of the heart rates R recorded within the pre-deceleration comparison period Tb, it is possible to easily extract the pre-deceleration heart rate Rb with high reliability, which can be considered as the heart rate in the steady state before the deceleration. Furthermore, by extracting the average value of the data group of the heart rates R recorded within the pre-deceleration comparison period Tb as the pre-deceleration heart rate Rb, it is possible to easily extract the statistically representative value averaging the dispersion in the data observed within the pre-deceleration comparison period Tb.

[0092] Furthermore, by setting the post-deceleration comparison period T_a depending on the deceleration start time t_g , the predetermined time T_f and the predetermined time T_e , and referring to the data group of the heart rates R recorded within the post-deceleration comparison period T_a , it is possible to easily extract the post-deceleration heart rate R_a with high reliability, which generally drops after the deceleration. Furthermore, by extracting the average value of the data group of the heart rates R recorded within the post-deceleration comparison period T_a as the post-deceleration heart rate R_a , it is possible to easily extract the statistically representative value averaging the dispersion in the data observed within the post-deceleration comparison period T_a .

Application Example 1

[0093] In the present embodiment, the time when the brake is switched to ON by the driver as the deceleration start time t_g , the deceleration start time t_g' may be detected by adding the reaction time T_x from the time when the driver recognizes that the vehicle needs to stop until a time when the driver starts the deceleration operation.

[0094] First, the reaction time T_x from the time when the driver recognizes that the vehicle needs to stop until the time when the driver starts the deceleration operation is preset. The reaction time is obtained by summing a reflex time from recognizing that the vehicle needs to stop until the foot moves (0.4 to 0.5 sec, for example), and a rereading time from the accelerator pedal to the brake pedal (0.2 sec, for example), and a pedaling time from start of pedaling the brake pedal until the brake switch 14 switches to OFF (0.1 to 0.3 sec, for example). Thus, T_x is about 0.7 to 1.0 sec.

[0095] FIG. 6 is a time chart illustrating the reaction time T_x and the deceleration start time t_g .

[0096] The deceleration start time detection unit 22 is configured to detect the time prior to the time t_g when the brake switch 14 switches to ON by the reaction time T_x as the deceleration start time t_g' ($t_g - T_x = t_g'$).

[0097] The biological information extraction unit 23 is configured to set the time prior to the deceleration start time t_g' by the predetermined time T_r is set as the pre-deceleration reference start time t_{b1} ($t_g' - T_r = t_{b1}$). Furthermore, the time when a predetermined time T_f elapses from the deceleration start time t_g' is set as the post-deceleration reference start time t_{a1} ($t_g' + T_f = t_{a1}$).

[0098] Next, the operation of the above-mentioned application example will be described.

[0099] There is a slight time difference (loss of time) associated with recognition, determination and action between the time when the driver recognizes that the vehicle needs to stop and the time when the brake switch 14 switches to ON. Therefore, when the post-deceleration comparison period T_a is set on the basis of the predetermined times T_f and T_e with reference to the deceleration start time t_g when the brake switch 14 switches to ON, the heart rate R just before the post-deceleration reference start time t_{a1} may have already started to drop. In this case, the post-deceleration heart rate R_a is extracted in a state where the heart rate R has already drops outside the post-deceleration comparison period T_a , the estimate accuracy of the steady state may be subject to the influence.

[0100] Therefore, in order to improve the estimate accuracy of the steady state, it is necessary to correctly set the pre-deceleration comparison period T_b and the post-deceleration

comparison period T_a , and thus it is needed to accurately detect the deceleration start time t_g' .

[0101] Therefore, in this application example, the reaction time T_x from the time when the driver recognizes that the vehicle needs to stop until the time when the driver starts the deceleration operation is set, the time prior to the time t_g when the brake switch 14 switches to ON by the reaction time T_x is detected as the deceleration start time t_g' . In this way, the deceleration start time t_g' approximates the time when the driver recognizes that the vehicle needs to stop. Therefore, it is possible to correctly set the pre-deceleration comparison period T_b and the post-deceleration comparison period T_a , and thus it is possible to improve the estimate accuracy of the steady state.

[0102] In the above description, the processing in the step S101 in the biological information record unit 21 corresponds to the "biological information record unit", and the processing in the steps S108 and S110 in the deceleration start time detection unit 22 corresponds to the "deceleration start time detection unit". Furthermore, the processing in the steps S110 to S115 in the biological information extraction unit 23 corresponds to the "biological information extraction unit", and the processing in the steps S116 to S118 in the driver's state estimation unit 24 corresponds to the "driver's state estimation unit".

[0103] (Effects)

[0104] Next, effects of the main part of the first embodiment will be described.

[0105] (1) In the driver's state estimation apparatus according to the present embodiment, the biological information of the driver is recorded by the processing in the biological information record unit 21, and the deceleration start time t_g when the vehicle in the travelling state starts to decelerate and stops is detected by the processing in the deceleration start time detection unit 22. Furthermore, the heart rates R within the predetermined period recorded before the deceleration start time t_g by the biological information record unit 21 are referred to, and the pre-deceleration heart rate R_b which is the representative value of the referred heart rates R is extracted by the processing of the biological information extraction unit 23. Furthermore, the heart rates R within the predetermined period recorded after the deceleration start time t_g by the biological information record unit 21 are referred to, and the post-deceleration heart rate R_a which is the representative value of the referred heart rates R is extracted. Then, the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a extracted by the biological information extraction unit 23 are compared with each other to estimate whether or not the driver after the deceleration is in the steady state by the processing in the driver's state estimation unit 24.

[0106] In this way, the pre-deceleration heart rate R_b in the stable state before the deceleration start time t_g and the post-deceleration heart rate R_a which may change after the deceleration start time t_g are compared with each other to estimate the steady state of the driver, and thus it is possible to improve the estimate accuracy. That is, focusing on the tendency of the heart rate R of the driver to be stabilized uniformly after the heart rate R of the driver drops due to the deceleration of the vehicle, the pre-deceleration heart rate R_b which can be considered as a heart rate in the stable state and the post-deceleration heart rate R_a which may change are compared with each other. Thus, it is possible to estimate with high accuracy whether or not the driver after the deceleration is in the steady state.

[0107] (2) In the driver's state estimation apparatus according to the present embodiment, when the difference ΔR between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a is equal to or larger than the predetermined threshold value R_t , it is estimated that the driver after the deceleration is in the steady state by the processing in the driver's state estimation unit **24**.

[0108] In this way, it is estimated whether or not the driver after the deceleration is in the steady state by using the magnitude of the difference ΔR between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a , thus it is easy to estimate whether or not the driver is in the steady state.

[0109] (3) In the driver's state estimation apparatus according to the present embodiment, the time prior to the deceleration start time t_g by the predetermined time T_r is set as the pre-deceleration reference start time $tb1$ and the deceleration start time t_g is set as the pre-deceleration reference end time $tb2$, by the processing in the biological information extraction unit **23**. Then, the heart rates R from the pre-deceleration reference start time $tb1$ to the pre-deceleration reference end time $tb2$ from the heart rates R recorded by the biological information record unit **21** are referred to, and the pre-deceleration heart rate R_b which is the presentative value of the referred heart rates R is extracted.

[0110] In this way, the data group of the heart rates R recorded within the pre-deceleration comparison period T_b is referred to. Thus, it is possible to easily extract the pre-deceleration heart rate R_b with high reliability, which can be considered as the heart rate in the steady state before the deceleration.

[0111] (4) In the driver's state estimation apparatus according to the present embodiment, the time when the predetermined time T_f elapses from the deceleration start time t_g is set as the post-deceleration reference start time $ta1$ and the time when the predetermined time T_e elapses from the post-deceleration reference start time $ta1$ is set as the post-deceleration reference end time $ta2$, by the processing in the biological information extraction unit **23**. Then, the heart rates R from the post-deceleration reference start time $ta1$ to the post-deceleration reference end time $ta2$ from the heart rates R recorded by the biological information record unit **21** are referred to, and the post-deceleration heart rate R_a which is the presentative value of the referred heart rates R is extracted.

[0112] In this way, the data group of the heart rates R recorded within the post-deceleration comparison period T_a is referred to. Thus, it is possible to easily extract the post-deceleration heart rate R_a with high reliability, which can be considered as the heart rate in the steady state after the vehicle stops.

[0113] (5) In the driver's state estimation apparatus according to the present embodiment, the heart rates R within the predetermined period recorded before the deceleration start time t_g by the biological information record unit **21** are referred to, and the average value of the referred heart rates R is extracted as the pre-deceleration heart rate R_b , by the processing of the biological information extraction unit **23**. Furthermore, the heart rates R within the predetermined period recorded after the deceleration start time t_g by the biological information record unit **21** are referred to, and the average value of the referred heart rates R is extracted as the post-deceleration heart rate R_a .

[0114] In this way, the average value of the data group of the heart rates R recorded within the pre-deceleration comparison period T_b is extracted as the pre-deceleration heart rate

R_b . Thus, it is possible to easily extract the statistically representative value averaging the dispersion in the data observed within the pre-deceleration comparison period T_b . Furthermore, the average value of the data group of the heart rates R recorded within the post-deceleration comparison period T_a is extracted as the post-deceleration heart rate R_a . Thus, it is possible to easily extract the statistically representative value averaging the dispersion in the data observed within the post-deceleration comparison period T_a .

[0115] (6) In the driver's state estimation apparatus according to the present embodiment, the heart rate R of the driver is recorded as the biological information, by the processing in the biological information record unit **21**.

[0116] In this way, the heart rate R which is affected by the autonomic nerve is recorded. Thus, it is possible to estimate with high accuracy whether or not the driver after the deceleration is in the steady state.

[0117] (7) In the driver's state estimation apparatus according to the present embodiment, the reaction time T_x from the time when the driver recognizes that the vehicle needs to stop until the time when the driver starts the deceleration operation is preset by the processing of the deceleration start time detection unit **22**. Then, the time prior to the time t_g when the driver starts the deceleration operation by the reaction time T_x is detected as the deceleration start time t_g' .

[0118] In this way, the deceleration start time t_g' is detected by adding the reaction time T_x from the time when the driver recognizes that the vehicle needs to stop until the time when the driver starts the deceleration operation. Therefore, it is possible to correctly set the post-deceleration comparison period T_a , and thus it is possible to improve the estimate accuracy of the steady state.

[0119] (8) In the driver's state estimation method according to the present embodiment, the heart rate R is recorded, and the deceleration start time t_g when the vehicle in the travelling state starts to decelerate and stops is detected. Then, the heart rates R within the predetermined period recorded before the deceleration start time t_g are referred to, and the pre-deceleration heart rate R_b which is the representative value of the referred heart rates R is extracted. And, the heart rates R within the predetermined period recorded after the deceleration start time t_g are referred to, and the post-deceleration heart rate R_a which is the representative value of the referred heart rates R is extracted. Then, the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a are compared with each other to estimate whether or not the driver after the deceleration is in the steady state.

[0120] In this way, the pre-deceleration heart rate R_b in the stable state before the deceleration start time t_g and the post-deceleration heart rate R_a which may change after the deceleration start time t_g are compared with each other to estimate the steady state of the driver, and thus it is possible to improve the estimate accuracy. That is, focusing on the tendency of the heart rate R of the driver to be stabilized uniformly after the heart rate R of the driver drops due to the deceleration of the vehicle, the pre-deceleration heart rate R_b which can be considered as a heart rate in the stable state and the post-deceleration heart rate R_a which may change are compared with each other. Thus, it is possible to estimate with high accuracy whether or not the driver after the deceleration is in the steady state.

Second Embodiment

[0121] (Configuration)

[0122] The present embodiment estimates whether or not the driver after the deceleration is in the steady state with high

accuracy, and acquires driver's information when the driver is in the steady state.

[0123] Herein, only the differences from the above-mentioned first embodiment will be described, and descriptions on the identical elements are omitted.

[0124] Hereinafter, the driver's state estimation processing performed by the controller 17 will be described.

[0125] First, the driver's state estimation processing of the second embodiment will be described based on a block diagram.

[0126] FIG. 7 is the block diagram illustrating the driver's state estimation processing of the second embodiment.

[0127] In the second embodiment, the above-mentioned processing in the biological information record unit 21, the biological information extraction unit 23, and the driver's state estimation unit 24 are modified, and a driver's information acquisition unit 25 is added. With regard to the other processing, the second embodiment is the same as the above-mentioned first embodiment, thus, descriptions thereof are omitted.

[0128] The biological information record unit 21 is configured to calculate the blood-pressure value P in addition to the heart rate R, and to record the blood-pressure value P as the biological information, too. The biological information record unit 21 is configured to accumulate the blood-pressure values P with time information in a nonvolatile memory and manage them.

[0129] In the present embodiment, the blood-pressure value P is calculated based on a pulse transmission time Tp, by utilizing a negative correlation between the blood-pressure value P and the pulse transmission time Tp which is a time from the pumping of the heart until the pulse arrives at the periphery.

[0130] FIG. 8A and FIG. 8B are views illustrating a calculation method of the blood-pressure value P.

[0131] FIG. 8A illustrates the pulse transmission time Tp depending on the pulse wave and the electrocardiographic waveform. FIG. 8B illustrates the blood-pressure value P depending on the pulse transmission time Tp. Furthermore, in FIG. 8A, the time t1 when a peak value of electrocardiographic waveform appears is the time of the pumping of the heart. The time t2 when a peak value of the pulse wave appears is the time when the pulse arrives at the periphery. The difference (t2-t1) between the peak time t2 of the pulse wave and the peak time t1 of the electrocardiographic waveform is the pulse transmission time Tp. Furthermore, as illustrated in FIG. 8B, the pulse transmission time Tp and blood-pressure value P have a relationship of $P = \alpha \cdot T_p + \beta$. The blood-pressure value P is calculated on the basis of the pulse transmission time Tp in accordance with the relationship expression.

[0132] What is described above is the record processing of the blood-pressure value P by the biological information record unit 21.

[0133] The biological information extraction unit 23 is configured to refer the blood-pressure values P within a predetermined post-deceleration stability period Ts recorded after the deceleration start time tg by the biological information record unit 21, and extract an average change rate ρ and a standard deviation σ of the referred pressure values P.

[0134] FIG. 9 is a time chart illustrating the post-deceleration stability period Ts.

[0135] A time when a predetermined time Th elapses from the deceleration start time tg is set as a stability period refer-

ence start time ts1 ($tg + Th = ts1$), and a time when the predetermined time Ti elapses from the stability period reference start time ts1 is set as a stability period reference end time ts2 ($ts1 + Ti = ts2$). Herein, the time Th corresponds to a time from the start of the deceleration until the heart rate R which has changed starts to stabilize again. Then, a period from the stability period reference start time ts1 to the stability period reference end time ts2 is set as the post-deceleration stability period Ts ($ts2 - ts1 = Ts = Ti$).

[0136] Then, the data group of the pressure values P recorded within the post-deceleration stability period Ts is referred to, and the average change rate ρ and the standard deviation σ of the pressure values P are extracted.

[0137] What is described above is the extraction processing of the average change rate ρ and the standard deviation σ by the biological information extraction unit 23.

[0138] The driver's state estimation unit 24 is configured to estimate that the driver after the deceleration is in the steady state when the difference ΔR between the pre-deceleration heart rate Rb and the post-deceleration heart rate Ra is equal to or larger than the predetermined threshold Rt and when the average change rate ρ is smaller than the predetermined threshold value ρt . Or, the driver's state estimation unit 24 is configured to estimate that the driver after the deceleration is in the steady state when the difference ΔR between the pre-deceleration heart rate Rb and the post-deceleration heart rate Ra is equal to or larger than the predetermined threshold Rt and when the standard deviation σ is smaller than the predetermined threshold value σt .

[0139] The driver's information acquisition unit 25 is configured to acquire at least one of blood-pressure information, electrocardiogram information, heart rate information, respiratory information, pulse wave information, electrodermal activity information, body temperature information, facial expression information, and utterance information of the driver as the driver's information when it is estimated by the driver's state estimation unit 24 that the driver after the deceleration is in the steady state.

[0140] What is described above is the descriptions of the driver's state estimation processing based on the block diagram in FIG. 7.

[0141] Next, the driver's state estimation processing of the second embodiment will be described based on a flowchart.

[0142] FIG. 10 is the flowchart illustrating the driver's state estimation processing of the second embodiment.

[0143] Herein, the processing of the above-mentioned step S114 is changed to new processing of the step S201, and new processing of the steps S202 to S205 is added. With respect to the processing of the other steps S101 to S120, and S100, the second embodiment is the same as the above-mentioned first embodiment, thus, descriptions thereof are omitted.

[0144] In the step S201, it is determined whether or not the time (Th+Ti) has elapsed from the deceleration start time tg. The time Th corresponds to a time from the start of the deceleration until the heart rate R which has changed starts to stabilize again. Now, when the time (Th+Ti) has not elapsed yet, it is determined that the post-deceleration stability period Ts has not elapsed, and thus it is not possible to extract the average change rate ρ and the standard deviation σ of the pressure values P. Then, the processing returns to the predetermined main program. On the other hand, when the time (Th+Ti) has elapsed, it is determined that it is possible to

extract the average change rate ρ and the standard deviation σ of the pressure values P . Then, the processing proceeds to the step S115.

[0145] In the step S202 corresponding to the processing of the biological information extraction unit 23, the blood-pressure values P within the predetermined post-deceleration stability period T_s recorded after the deceleration start time t_g by the biological information record unit 21 are referred to, and the average change rate ρ and the standard deviation σ of the referred pressure values P are extracted. Then, the processing proceeds to the step S116.

[0146] In the step S203 corresponding to the processing of the driver's state estimation unit 24, it is determined whether or not the average change rate ρ of the pressure values P is smaller than the predetermined threshold ρ_t . Now, when the average change rate ρ of the pressure values P is smaller than the predetermined threshold ρ_t , it is estimated that the driver after the deceleration is in the steady state, and then the processing proceeds to the step S117. On the other hand, when the average change rate ρ of the pressure values P is equal to or larger than the predetermined threshold ρ_t , it is estimated that the driver after the deceleration may not be in the steady state, and then the processing proceeds to the step S204.

[0147] In the step S204 corresponding to the processing of the driver's state estimation unit 24, it is determined whether or not the standard deviation σ of the pressure values P is smaller than the predetermined threshold σ_t . Now, when the standard deviation σ of the pressure values P is smaller than the predetermined threshold σ_t , it is estimated that the driver after the deceleration is in the steady state, and then the processing proceeds to the step S117. On the other hand, when the standard deviation σ of the pressure values P is equal to or larger than the predetermined threshold σ_t , it is estimated that the driver after the deceleration may not be in the steady state, and then the processing proceeds to the step S118.

[0148] In the step S205 corresponding to the processing of the driver's information acquisition unit 25, at least one of the blood-pressure information, the electrocardiogram information, the heart rate information, the respiratory information, the pulse wave information, the electrodermal activity information, the body temperature information, the facial expression information, and the utterance information of the driver is acquired as the driver's information, and then the processing proceeds to the step S119.

[0149] What is described above is the descriptions of the driver's state estimation processing based on the flowchart in FIG. 10.

[0150] (Operation)

[0151] Next, the operation of the second embodiment will be described.

[0152] In the present embodiment, it is estimated whether or not the driver after the deceleration is in the steady state on the basis of not only the difference ΔR between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a but also the average change rate ρ and the standard deviation σ of the pressure values P . That is, when the time $(T_h + T_i)$ has elapsed from the deceleration start time t_g ("Yes" in the determination in the step S201), the average change rate ρ and the standard deviation σ of the pressure values P are extracted.

[0153] Then, it is estimated that the driver after the deceleration is surely in the steady state when the difference ΔR between the pre-deceleration heart rate R_b and the post-de-

celeration heart rate R_a is equal to or larger than the predetermined threshold R_t ("Yes" in the determination in the step S116) and when the average change rate ρ of the pressure values P is smaller than the predetermined threshold value ρ_t ("Yes" in the determination in the step S203). In this situation, even when the average change rate ρ of the pressure values P is equal to or larger than the predetermined threshold value ρ_t ("No" in the determination in the step S203), when the standard deviation σ of the pressure values P is smaller than the predetermined threshold value σ_t ("Yes" in the determination in the step S204), it is estimated that the driver after the deceleration is surely in the steady state.

[0154] By considering not only the difference ΔR between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a but also the average change rate ρ and the standard deviation σ of the pressure values P in this way, it is possible to estimate more accurately whether or not the driver after the deceleration is in the steady state.

[0155] As described above, when it is estimated that the driver after the deceleration is surely in the steady state, it means that the driver is relaxed and is in normal state. Therefore, the information on the driver at the time should be acquired. For example, the information on the driver to be acquired may be the blood-pressure information, the electrocardiogram information, the heart rate information, the respiratory information, the pulse wave information, the electrodermal activity information, the body temperature information, the facial expression information, and the utterance information of the driver. By acquiring this information, it is possible to know the normal state where the drive is relaxed.

[0156] In the above description, the processing in the steps S203 and S204 is included in the "driver's state estimation unit", and the processing in the step S205 in the driver's information acquisition unit 25 corresponds to the "driver's information acquisition unit".

[0157] (Effect)

[0158] Next, effects of the main part of the second embodiment will be described.

[0159] (1) In the driver's state estimation apparatus according to the present embodiment, it is estimated that the driver after the deceleration is in the steady state by the processing in the 24, when the difference ΔR between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a is larger than the predetermined threshold R_t , and the average change rate ρ of the blood-pressure values P from the stability period reference start time t_{s1} to the stability period reference end time t_{s2} referred from the blood-pressure values P recorded by the biological information record unit 21 is smaller than the threshold value ρ_t .

[0160] By considering not only the difference ΔR between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a but also the average change rate ρ of the pressure values P in this way, it is possible to estimate more accurately whether or not the driver after the deceleration is in the steady state.

[0161] (2) In the driver's state estimation apparatus according to the present embodiment, it is estimated that the driver after the deceleration is in the steady state by the processing in the driver's state estimation unit 24, when the difference ΔR between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a is larger than the predetermined threshold R_t and the standard deviation σ of the blood-pressure values P from the stability period reference start time t_{s1}

to the stability period reference end time ts_2 referred from the blood-pressure values P recorded by the biological information record unit **21** is smaller than the threshold value σ .

[0162] By considering not only the difference ΔR between the pre-deceleration heart rate R_b and the post-deceleration heart rate R_a but also the standard deviation σ of the pressure values P in this way, it is possible to estimate more accurately whether or not the driver after the deceleration is in the steady state.

[0163] (3) In the driver's state estimation apparatus according to the present embodiment, at least one of the blood-pressure information, the electrocardiogram information, the heart rate information, the respiratory information, the pulse wave information, the electrodermal activity information, the body temperature information, the facial expression information, and the utterance information of the driver is acquired as the driver's information, by the processing in the driver's information acquisition unit **25**, when it is estimated by the driver's state estimation unit **24** that the driver after the deceleration is in the steady state.

[0164] By acquiring the driver's information when it is estimated that the driver after the deceleration is in the steady state, it is possible to know the normal state where the drive is relaxed.

Third Embodiment

[0165] (Configuration)

[0166] The present embodiment records and utilizes the driver's information acquired when it is estimated that the driver after the deceleration is in the steady state.

[0167] Herein, only the differences from the above-mentioned second embodiment will be described, and descriptions on the identical elements are omitted.

[0168] Hereinafter, the driver's state estimation processing performed by the controller **17** will be described.

[0169] First, the driver's state estimation processing of the third embodiment will be described based on a block diagram.

[0170] FIG. **11** is the block diagram illustrating the driver's state estimation processing of the third embodiment.

[0171] In the third embodiment, a driver's information record unit **26** is added. With regard to the other processing, the third embodiment is the same as the above-mentioned second embodiment, thus, descriptions thereof are omitted.

[0172] The driver's information record unit **26** is configured to record the driver's information acquired by the driver's information acquisition unit **25** in association with date-time information and current location information of the vehicle. Recording of this information is not limited to recording in an in-vehicle recording device, such as, the DVD-ROM drive, the hard disk drive, a flash memory drive, or the like. This information may be recorded in a personal digital assistance, a portable audio device, or the like, having a communication function

[0173] The driver's information record unit **26** is configured to further classify the driver's information on the basis of the date-time information and the current location information and to refer to the driver's information recorded in the past time, and to extract the driver's information under the same condition of date, time, traveling path, or the like, and to extract transition of the driver's information in the steady state. Furthermore, the driver's information record unit **26** is configured to extract the driver's information under the same

condition of date, time, traveling path, or the like, to estimate the state of the driver in the future.

[0174] What is described above is the descriptions of the driver's state estimation processing based on the block diagram in FIG. **11**.

[0175] Next, the driver's state estimation processing of the third embodiment will be described based on a flowchart.

[0176] FIG. **12** is the flowchart illustrating the driver's state estimation processing of the third embodiment.

[0177] Herein, a new processing of the step **S301** is added after the above-mentioned step **S205**. With respect to the processing of the steps **S101** to **S120**, **S100**, and **S201** to **S205**, the third embodiment is the same as the above-mentioned second embodiment, thus, descriptions thereof are omitted.

[0178] In the step **301** corresponding to the driver's information record unit **26**, the driver's information acquired by the driver's information acquisition unit **25** is recorded in association with the date-time information and the current location information of the vehicle, then the processing proceeds to the step **S119**.

[0179] What is described above is the descriptions of the driver's state estimation processing based on the flowchart in FIG. **12**.

[0180] (Operation)

[0181] Next, the operation of the third embodiment will be described.

[0182] Since when it is estimated that the driver after the deceleration is surely in the steady state, the driver is relaxed and is in normal state. Therefore, the information on the driver at the time is acquired and recorded in association with the date-time information and the current location information (the step **S301**).

[0183] This makes it possible to analyze the transition of the driver's state or to estimate how the driver's state will change in the future, when extracting the driver's information in the past on the basis of the date-time information and the current location information.

[0184] In the above description, the processing in the step **S301** in the driver's information record unit **26** corresponds to the "driver's information record unit".

[0185] (Effect)

[0186] Next, an effect of the main part of the third embodiment will be described.

[0187] (1) In the driver's state estimation apparatus according to the present embodiment, the driver's information acquired by the driver's information acquisition unit **25** is recorded in association with the date-time information and the current location information of the vehicle, by the processing in the driver's information record unit **26**.

[0188] By recording the driver's information when it is estimated that the driver is surely in the steady state in this way, it is possible to analyze the transition of the driver's state or to estimate how the driver's state will change in the future, when extracting the driver's information in the past on the basis of the date-time information and the current location information.

[0189] While the present invention has been described with reference to the definite number of embodiments, the scope of the present invention is not limited thereto and improvements and modifications of the embodiments based on the above disclosure are obvious to those skilled in the art. Those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from

the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims.

REFERENCE SIGNS LIST

- [0190] 11 pulse wave sensor
- [0191] 12 electrocardiographic monitor
- [0192] 13 vehicle speed sensor
- [0193] 14 brake switch
- [0194] 15 acceleration sensor
- [0195] 16 navigation system
- [0196] 17 controller
- [0197] 21 biological information record unit
- [0198] 22 deceleration start time detection unit
- [0199] 23 biological information extraction unit
- [0200] 24 driver's state estimation unit
- [0201] 25 driver's information acquisition unit
- [0202] 26 driver's information record unit

1. A driver's state estimation apparatus comprising:

a biological information record unit configured to record biological information of a driver;

a deceleration start time detection unit configured to detect a deceleration start time when a vehicle in a travelling state starts to decelerate and stops;

a biological information extraction unit configured to refer to the biological information within a predetermined period recorded by the biological information record unit before the deceleration start time detected by the deceleration start time detection unit to extract pre-deceleration biological information which is a representative value of the referred biological information, and to refer to the biological information within a predetermined period recorded by the biological information record unit after the deceleration start time to extract post-deceleration biological information which is a representative value of the referred biological information; and

a driver's state estimation unit configured to compare the pre-deceleration biological information and the post-deceleration biological information extracted by the biological information extraction unit to estimate whether or not the driver after deceleration is in a steady state.

2. The driver's state estimation apparatus according to claim 1, wherein the driver's state estimation unit is configured to estimate that the driver after the deceleration is in the steady state when a difference between the pre-deceleration biological information and the post-deceleration biological information is larger than a predetermined difference threshold.

3. The driver's state estimation apparatus according to claim 1, wherein the biological information extraction unit is configured:

to set a time prior to the deceleration start time by a predetermined time as a pre-deceleration reference start time;

to set the deceleration start time as a pre-deceleration reference end time; and

to refer the biological information from the pre-deceleration reference start time to the pre-deceleration reference end time from the biological information recorded by the biological information record unit to extract the pre-deceleration biological information which is the presentative value of the referred biological information.

4. The driver's state estimation apparatus according to claim 1, wherein the biological information extraction unit is configured:

to set a time when a predetermined time elapses from the deceleration start time as a post-deceleration reference start time;

to set a time when a predetermined time elapses from the post-deceleration reference start time as a post-deceleration reference end time; and

to refer the biological information from the post-deceleration reference start time to the post-deceleration reference end time from the biological information recorded by the biological information record unit to extract the post-deceleration biological information which is the presentative value of the referred biological information.

5. The driver's state estimation apparatus according to claim 1, wherein the driver's state estimation unit is configured:

to set a time when a predetermined time elapses from the deceleration start time as a stability period reference start time;

to set a time when a predetermined time elapses from the stability period reference start time as a stability period reference end time;

to estimate that the driver after the deceleration is in the steady state when the difference between the pre-deceleration biological information and the post-deceleration biological information is larger than the predetermined difference threshold, and when an average change rate of the biological information from the stability period reference start time to the stability period reference end time referred from the biological information recorded by the biological information record unit is smaller than an average change ratio threshold.

6. The driver's state estimation apparatus according to claim 1, wherein the driver's state estimation unit is configured:

to set a time when a predetermined time elapses from the deceleration start time as a stability period reference start time;

to set a time when a predetermined time elapses from the stability period reference start time as a stability period reference end time;

to estimate that the driver after the deceleration is in the steady state when the difference between the pre-deceleration biological information and the post-deceleration biological information is larger than the predetermined difference threshold, and when a standard deviation of the biological information from the stability period reference start time to the stability period reference end time referred from the biological information recorded by the biological information record unit is smaller than the standard deviation threshold.

7. The driver's state estimation apparatus according to claim 1, wherein the biological information extraction unit is configured to refer the biological information within the predetermined period recorded before the deceleration start time by the biological information record unit to extract an average value of the referred biological information as the pre-deceleration biological information, and to refer the biological information within the predetermined period recorded after the deceleration start time by the biological information

record unit to extract an average value of the referred biological information as the post-deceleration biological information.

8. The driver's state estimation apparatus according to claim 1, wherein the biological information record unit is configured to record a heart rate of the driver as the biological information.

9. The driver's state estimation apparatus according to claim 1, wherein further comprising a driver's information acquisition unit configured to acquire at least one of blood-pressure information, electrocardiogram information, heart rate information, respiratory information, pulse wave information, electrodermal activity information, body temperature information, facial expression information, and utterance information of the driver as driver's information, when it is estimated that the driver after the deceleration is in the steady state by the driver's state estimation unit.

10. The driver's state estimation apparatus according to claim 9, wherein further comprising a driver's information record unit configured to record the driver's information acquired by the driver's information acquisition unit in association with date-time information and current location information of the vehicle.

11. The driver's state estimation apparatus according to claim 1, wherein the deceleration start time detection unit is configured to preset a reaction time from a time when the driver recognizes that the vehicle needs to stop until a time when the driver starts a deceleration operation, and to detect a time prior to the time when the driver starts the deceleration operation by the reaction time is detected as the deceleration start time.

12. (canceled)

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专利名称(译)	驾驶员的状态估计装置和驾驶员的状态估计方法		
公开(公告)号	US20150203121A1	公开(公告)日	2015-07-23
申请号	US14/415063	申请日	2013-06-14
申请(专利权)人(译)	日产汽车公司., LTD.		
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IPC分类号	B60W40/08 A61B5/00 A61B5/021 A61B5/18 G06F19/00 G01P15/00		
CPC分类号	B60W40/08 G06F19/3431 G01P15/00 B60W2040/0872 A61B5/18 A61B5/7246 A61B5/021 A61B5/02255 A61B5/0245 A61B5/0261 A61B5/6893 A61B2503/22 B60K28/06 B60T7/14 B60T7/18 B60W2040/0827 B60W2520/105 B60W2540/22 F04C2270/041 G08B21/06 G16H50/30		
优先权	2012166225 2012-07-26 JP		
外部链接	Espacenet USPTO		

摘要(译)

当行驶状态的车辆开始减速和停止时，在减速开始时记录驾驶员的心率。参考生物信息记录单元在减速开始时间之前记录的预定时段内的心率，并且提取作为参考心率的代表值的减速前心率。此外，参考生物信息记录单元在减速开始时间之后记录的预定时段内的心率，并且提取作为参考心率的代表值的减速后心率。然后，将生物信息提取单元提取的减速前生物信息和减速后生物信息相互比较，以估计减速后驾驶员的稳态。

