(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
28 August 2003 (28.08.2003)

PCT

(10) International Publication Number
WO 03/070093 A1

(51) International Patent Classification[7]: A61B 5/00

(21) International Application Number: PCT/US03/04504

(22) International Filing Date: 19 February 2003 (19.02.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/357,135 19 February 2002 (19.02.2002) US
60/418,171 15 October 2002 (15.10.2002) US

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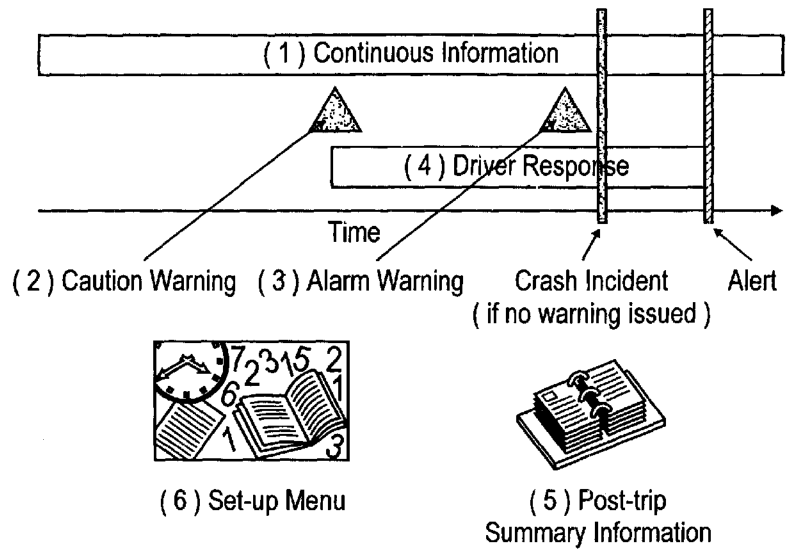
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

[Continued on next page]

(54) Title: SYSTEM AND METHOD FOR MONITORING AND MANAGING DRIVER ATTENTION LOADS



(57) Abstract: System and method for monitoring the physiological behaviour of a driver that includes measuring a physiological variable of a driver, assessing a driver's behavioural parameter on the basis of at least said measured physiological variable (1, 4), and informing the driver (2, 3) of the assessed driver's behavioural parameter (1, 4). The measurement of the physiological variable (1, 4) can include measuring a driver's eye movement, measuring a driver's eye-gaze direction, measuring a driver's eye-closure amount, measuring a driver's blinking movement, measuring a driver's head movement, measuring a driver's head position, measuring a driver's head orientation, measuring driver's movable facial features, and measuring a driver's facial temperature image.

WO 03/070093 A1

— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

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SYSTEM AND METHOD FOR MONITORING AND MANAGING DRIVER ATTENTION LOADS

TECHNICAL FIELD:

The present invention(s) relate to systems and methods that facilitate driver safety; and more particularly, to remedies against the effects of drowsiness, distraction and similar compromising conditions to a driver's driving capabilities.

BACKGROUND OF THE INVENTION(S):

Drivers of all types of vehicles are often unaware of the effects that drowsiness and distraction have on their own abilities for vehicle control. Humans in general, and particularly as drivers, are poor judges of their own performance capabilities. Typically, a driver's self-impression of his or her capabilities is better than actuality. Even persons who have basically good driving skills, will not perform uniformly at all times when behind the wheel of a vehicle. Furthermore, there are many times during driving trips that very little demand is placed on the driver with respect to execution of driving tasks. As a result, drivers are lulled into states of mind where little attention is being devoted to the driving task. Not surprisingly, driver inattention is a leading cause of vehicular collisions, and especially automotive collisions. According to a Nation Highway and Transportation Safety Administration (NHTSA) study of over two and one-half million tow-away crashes in a year's time, driver inattention is a primary cause of collisions that accounts for an estimated twenty-five to fifty-six percent of crashes. In that study, inattention was defined as having three components: visual distraction, mental distraction (looking without seeing) and drowsiness. Common crash types caused by inattention are: rear-end collisions, collisions at intersection, collisions while lane changing or merging, road departures, single vehicle crashes, and crashes that occur on low speed limit roadways.

Drowsy drivers are a well known phenomenon. At least one survey has indicated that fifty-seven percent of drivers polled had driven while drowsy in the previous year, and twenty-three percent had actually fallen asleep at the wheel. It is known that fatigue impairs driver performance, alertness and judgment. Collisions caused by drowsiness are a serious road safety problem, and fatigue has been estimated to be involved in as many as twenty-three percent of all crashes.

From a technological perspective, there is an ongoing and rapid increase of new information systems and functionalities that may be used within vehicles including mobile telephones, navigation aids, the internet, and other types of electronic services. The effect of mobile telephone use on drivers has been foremost in the public eye because of their widespread use, but sales of navigation aids and IT services are also growing fast. Mobile telephones alone have been estimated to have caused 300-1000 fatalities in one years time in the United States, and this is projected to reach 4000 fatalities per year in 2004. Distractions such as handheld telephone use, sign reading, eating food, interaction with other passengers, observing objects and manipulating devices in-the vehicle have the potential for capturing a driver's attention in an excessive way and thus also compromising safety. It is especially important that driving safety not be compromised as these new types of services and activities become more common place in the driving environment.

Driver workload increases based on utilization of these new functionalities and technologies. In this context, "workload" should be understood to refer to how busy a person is and the amount of effort they need to perform required tasks. When a driver has many things to do and is experiencing high workload, a high attention demand is being made on the driver in that there is much to be done at the same time. Drivers often attend to things that are not related to driver control of the vehicle and are therefore technically irrelevant to the driving situation. These things are often called secondary tasks and are potential distracters from driver attention to primary driving tasks. A secondary task becomes a distraction (including visual-, auditory-, cognitive-, and biomechanical distractions) when the driver's attention is captured thereby to a degree that insufficient attention is left for the primary control tasks of driving. As a result, driving performance such as lane keeping and speed control are compromised as ultimately is safety.

Driving tasks and secondary tasks overlap in the sense that some secondary tasks are driving related as diagrammatically shown in Fig. 1. Two difficulties arise from this relationship between the driving and secondary tasks. First, it can be difficult to delineate which secondary task information is "irrelevant to the driving situation" and which is not; and second, certain driving related secondary tasks, for instance, looking for a street sign or planning a driving route may also compromise safety as graphically depicted in Fig. 1.

It should also be appreciated that the driver is often unaware of the effects of distraction on the driving task. Also, drivers cannot reliably determine when they are impaired by fatigue to the point of having a serious vigilance lapse or uncontrolled sleep attacks. The attention management systems outlined herein are intended to increase safety by assisting the driver in drowsy, distractive, and/or high workload situations.

SUMMARY OF THE INVENTION:

The attention management systems and methods disclosed herein have as an objective to increase safety by assisting drivers in drowsy, distractive, and/or high workload situations. Functional specifications are provided for a number of attention management systems that can be characterized to include drowsiness managers, distraction managers, managers for distraction adaptation of forward collision and lane change warning systems, and workload managers that are at least in part controlled based on driving demand estimations observed or deduced from visual behavior of the driver. A hardware system that can be suitably employed to perform these driver attention management tasks is also described. A "platform" for development of the instant drowsiness and distraction manager based on Human Machine Interaction (HMI) is also disclosed, as is description of continuous and post-trip attention feedback systems. The HMI approach has as an objective thereof to counteract driver inattention by providing both imminent collision warnings, as well as attention-feedback to cause positive behavioral change.

BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1 is a diagrammatical representation of the inter-relationship of driver ** and driver secondary tasks;

Fig. 2 is a flowchart representing one embodiment of an attention management system that includes hardware and functional modules for sensing, computation, HMI, and electrical supply;

Fig. 3 is a diagrammatical representation of a platform upon which several drowsiness manager countermeasures may be exemplarily implemented;

Fig. 4 depicts exemplary representations of possible display warnings to a driver;

Fig. 5 depicts an exemplary, interactive, driver response panel;

Fig. 6 depicts an exemplary embodiment for driver gaze redirection;

Fig. 7 diagrammatically illustrates interaction of constituent components of driver inattentiveness;

Figs. 8(a)-(c) illustrate various "active" graphical displays for displaying real-time driver information according to the teachings of the present invention;

Fig. 9 provides an illustration of real-time driver feedback in a comparative format against an indication of an optimal level of attention;

Fig. 10 provides an illustration of an exemplarily formatted explanation of the basis for the detected increased workload/inattention level;

Fig. 11 provides an exemplary illustration of on-screen post-trip feedback;

Fig. 12 provides an exemplary illustration of a heads-up or screen display warning for forward collision situations;

Fig. 13 provides an exemplary illustration of a heads-up or screen display warning regarding lane-change collision situations;

Fig. 14 provides an exemplary flow chart for a system and method conducted according to the present invention in which a measure is made of a driver physiological characteristic such as head and/or eye movement. In another step, a behavior parameter is assessed such as level of driver distraction or attention load. In still another step, feedback regarding the assessment is made to the driver.

DETAILED DESCRIPTION OF THE INVENTION(S):

In at least one embodiment, the present invention provides a system and method that enables the implementation of attention management concepts in a vehicle, including exemplary hardware upon which the inventive functionalities can be accomplished. Several basic questions and goals are addressed herein, including: what visually derived support do drivers need and how should it be conceptualized to achieve acceptance; how can real-time recognition of driver visual behavior be applied to reduce driving errors and prevent accidents; what is the commercial feasibility of implementation. Functional descriptions are provided for exemplary drowsiness managers; distraction managers, distraction adaptation of forward collision and lane change warning systems; and workload managers. Systems and methods for implementing driving demand estimation from visual behavior are also included.

One or more of these systems and methods are individually, as well as collectively, described as making-up a so-called attention management system. One possible component of these systems, as well as a component of the several inventions described herein, is the attention support demonstrator that can be used to implement these systems and methods for demonstration and testing. Examples of driving demand estimation from visual behavior are also described herein.

In one embodiment, the attention management system includes hardware for (1) sensing, (2) computation, (3) HMI, and (4) electrical supply. The units or functional modules can be exemplarily configured (interrelated) as illustrated in Fig. 2, and are suitable for implementation in such vehicles as automobiles and trucks.

A visual behavior sensor is employed such as that which is available from the company, SeeingMachines, and which can be adapted to be installed in a vehicle. This type of system can include (1) a stereo camera head, (2) a personal computer (PC), and (3) appropriate driving software. A visual behavior sensor such as that produced and sold under the trade name SMARTEYE may also be optionally employed.

Vehicle performance signals can be acquired from the CAN bus. A steering wheel angle sensor can also utilized, as well as lane tracking hardware and software. An annotation box and video recording hardware is utilized. An onboard personal computer, or similarly capable computing device is utilized. Alternatively, and especially to facilitate testing and implementation, a laptop computer can be employed that exemplarily runs such software as "Director" and "Simulink." An xPC can also be installed and utilized. From a hardware perspective, LED controller hardware is employed. Audio HMI (warning sounds, recorded messages) are provided for via the computing device. A touch-screen for user input can also be utilized. It should be appreciated that some of these embodiments are suitable for product development and facilitate system testing, but when commercialized, the several components are integrated directly into the vehicle.

A seat vibration arrangement or similar driver alert can be included. In a preferred embodiment, a LED HUD (heads up display) is employed. A LED array (display), controlled by a LED controller can also be utilized. An electrical supply for the entire system can be tapped from the carrying vehicle.

A drowsiness manager can be implemented in two configurations. In a first example, it is entirely PC based; that is, no external hardware or external communication capabilities are required. This embodiment is scenario based; that is, tracking of a drowsiness episode based on real PERCLOS (analysis that considers scan patterns, number and length of fixations, saccade latency and the like) data rather than in real-time. The hardware functionality stimulates the driver via such stimuli as a visual display such as LED-based or HUD, or physical stimulation such as seat vibration. In another embodiment, HMI hardware and Simulink communication is implemented.

A "platform" upon which several drowsiness manager countermeasures may be implemented is desirable, and upon which tests may be conducted. An exemplary platform for such implementation is schematically illustrated in Fig. 3.

The illustration of Fig. 3 may be considered to depict a director program. Such an arrangement is easy to change with respect to different HMI components; for instance, to provide (1) continuous information streaming to the driver, to provide (2) cautionary warnings, (3) eminent danger warning alarms, (4) driver response tests, (5) post trip summary information, and (6) operator input set-up menu(s).

In one embodiment of the invention, a caution warning to the driver is provided. The driver is able to choose between warning versions, but is not able to completely disable the warning. Exemplarily, a beep followed by an optional voice message warning can be played to the driver such as "<automated insertion of drowsiness cause>, 'take a break.' " An icon can be alternatively displayed to the driver either individually, in conjunction with an audible warning, or together with a printed version of the warning.

Exemplary icon warnings are shown in Figs. 4(a)-(d) for (a) large eye closure detection, (b) inconsistent steering detection, (c) inconsistent lane-keeping detection, and (d) driver drowsiness detection. One or more of these icons can be simultaneously displayed depending upon detected driver conditions.

In another embodiment, a microphone is included so that the driver can record or supply his or her own warning much like in a telephone answering machine and other customizable audio play-back devices.

In still another embodiment, driver physical-stimulation warnings are applied. Preferably, the driver can choose between warning-types in the set-up menu, but in at least one embodiment the operator is prevented from completely disabling the physical warning. An example of such a physical stimulation would be seat vibration.

In another version, a flashing "HUD" LEDs may be used to sharply stimulate the driver; again, alone or in conjunction with the other types of warnings described herein. In a preferred embodiment, capabilities are provided to the driver for enabling up to three of the described warning types to be simultaneous presented when active.

A driver response functionality; that is, reaction-time to a signal, is also provided. With regard to this functionality, the driver is able to both enable and disable, as well as choose between warning versions in the set-up menu.

In a predetermined amount of time, for example five to eight seconds post-warning, a driver response function operates. Exemplarily, there will be a beep, with text "Press" under a button presented on a touch screen as illustrated in Fig. 5. If the driver does not react within the prescribed amount of time, or according to some other reaction time based algorithm, then an alarm warning will issue. This continues until the driver stops the vehicle, becomes alert and this fact is system-detected, or the driver turns the function off.

In order to provide customizing capabilities to the operator, exemplary options that may be selected via the HMI components are illustrated below:

HMI Component	**Option(s)**
(1) Continuous drowsiness feedback	Continuous feedback on/off Choice of one of several versions
(2) Caution Warning	Voice message on/off Default message on/off User supplied message on/off Use multiple icons or Use default icon
(3) Alarm/Stimulation Warning	Choice of following (at least one must be checked) Seat vibration on/off Sound on/off HUD visual warning on/off Fan (not implemented in iteration 1) Scent (not implemented in iteration 1) Cut gas (not implemented in iteration 1) Drive to roadside(not implemented in iteration 1) Use multiple icons or Use default icon
(4) Driver Response	Driver response on/off

A distraction manager can be exemplarily implemented in two embodiments. In a first embodiment, the distraction manager is entirely PC based with no external hardware or communication capabilities. It is scenario based; that is, a timeline of a distraction episode is given rather than in real-time. The hardware functionality is simulated. A second embodiment is based on a hardware implementation that includes the capability of real time communication.

Another aspect of the invention is safety threshold based distraction warnings. Warnings are provided that inform the driver of safety compromising distractive behavior. As appreciated hereinabove, drivers are often unaware of the effects of their distraction on their driving capabilities. Thus a goal of the safety based distraction warnings is to give the driver feedback about driving control task performance decrements. That is, if distraction is detected (i.e. glance behavior is over an appropriate safety threshold and/or vehicle performance deteriorates during glance behavior), the system provides one or more of the following alerts. A sound such as a simple beep or a performance-specific voice message referring to which performance decrements have been detected may be provided. For example, if glance behavior is above *glance safety threshold standards* (e.g. EU recommended 4 glances or 2 second single glance duration, US AAA recommended 10 second total glance duration), then the message "Visual Distraction Detected" or "Eyes off road extensively" can be issued. If steering is deviant during *secondary task glance behavior,* then the message "Inconsistent steering during visual distraction" can be issued. If lane keeping is deviant during *secondary task glance behavior,* then a message such as "Inconsistent lane-keeping during visual distraction" can be provided. If large_speed_reduction is detected during *secondary_task_glance_behavior*, then a message such as "Large speed reduction during visual distraction" can be issued. If multiple_causes are detected, then a generic message such as "Visual distraction detected" can be issued. If control task intrusion is detected during *secondary task glance behavior,* during *different road types* or *different demand levels,* then a corresponding warning is issued. The form(s) of the warnings can include a driver recorded or provided message, a seat vibration in a front part of seat or gaze redirection as described hereinbelow.

The present invention disclosure includes a new concept of "gaze redirection" that is illustrated in Fig.6. Therein, an interface directs the driver's eyes to the forward driving scene (i.e.; through the front windshield) if driver distraction is detected. Exemplarily, a wave of light following one or more of the three LED "lines" (left, center, or right) will be initiated depending on where the drivers' gaze detected. After a wave of light, a large circle may optionally light up and then the central line of LEDs will light up; each purposed to more clearly focus the driver's attention where needed. The exact placement and timing of the several LED lights is not critical, nor is the color. In fact, the timing may be subliminal; that is, so fast that they are not consciously perceived. Alternatively, the appropriate lights may be first slowly flashed and the driver evaluated by the system to determine if corrective behavior has taken place. If not, the flash timing, as well as light intensity may be increased.

The set-up menu for distraction feedback may have exemplary logic as shown below:

HMI Component	**Option(s)**
(1) Continuous distraction feedback	Continuous distraction feedback on/off
(2) Safety threshold based distraction warning	Voice message on/off Performance specific message on/off Default/multiple cause message on/off User supplied message on/off Seat vibration on/off Gaze redirection on/off

In another aspect, the present invention incorporates the concept of workload management with driving demand estimation derived from visual behavior of the driver. In general, the concept of a "workload manager" is a prioritization system that categorizes information and potentially delays presentation of the information to the driver until his or her workload is sufficiently low to avoid risk associated with the information's reception. The interfaces of integrated, in-vehicle information systems can be adapted to ensure that proper attention is being given to the driving task. The output from the distraction management algorithms referenced herein can be used as input to workload managers.

Workload managers of the type disclosed herein accurately measure driver workload using the *driving demand visual activity* measure of driving demand. This is a measure of how "visually active" a driver is; that is, head and eye movement (rotation) variability. This measure of head and eye movement is described in greater detail in United States Provisional Patent Application No. 60/418,171 filed 15 October 2002, the disclosure of which is expressly incorporated herein by reference, including the "visual activity" algorithm described therein. Furthermore, the *driving demand visual activity* measure also enables new functionality in the Workload Manager HMI, disclosed herein.

One aspect of the workload manager is to pause dialogue of audible conversation or information. As examples, this includes system-initiated or auto-initiated information (e.g. text-to-speech email and non-critical navigation system information) and randomly-initiated spoken dialogue (e.g. incoming and outgoing telephone conversations) can be paused during periods of high visual activity.

As an example, a series of emails can be being delivered to the driver, for example, ten new emails from memory that are being "read" out loud by a text-to-speech system. During the course of such audio transmission, a period of high driver visual activity is detected by the management system. In response, the system pauses the audio transmission to avoid increasing the driver's attention load beyond pre-selected levels; such levels exemplarily corresponding to attention loads beyond which driving capabilities are compromised. Optionally, the management system can include an audible indication to the driver of such interruption via a tone or the like which may also serve as notice to the driver of the high attention load condition. The audible transmission can be resumed based on driver initiation or system initiation that is dependent on the system's detection of a sufficient reduction in attention load to a pre-selected level exemplarily corresponding to safe conditions for driver receipt of such audible information.

In another aspect, continuous and/or post-trip attention load feedback is enabled via the disclosed management system. This aspect has been enabled pursuant to the fundamental human behavior characteristic commonly referred to as the feedback principle; such principle generally holding that feedback enhances performance. This is true for both task/skill learning (e.g. learning to drive safely) and for job motivation. As appreciated hereinabove, drivers are typically poor judges of their own performance. The degree to which direct, accurate, immediate, and continuous information on task/skill performance is available is a key element in enhanced driver performance and motivation. Attention feedback constitutes a form of intrinsic driving feedback that has heretofore been otherwise unavailable to the driver. The approach is one of positive behavioral adaptation and lifestyle change rather than imminent collision warning. For example, some researchers believe that the main mechanism for increased alertness is "decision influence." The concept of decision influence stipulates that information of this nature (driver attention load and state-of-alertness) will influence a driver's decision about whether to stop for rest, drink coffee, reduce alcohol consumption or change other such behaviors.

An objective of attention feedback is thus to encourage positive behavior change over one or more of a plurality (multiple) of time-frames, for instance: (1) immediate (e.g. short-term compensatory behaviors like changing posture or aborting a complicated task); (2) trip (e.g. stopping for a nap, turning off mobile phone); (3) day-to-day (sleeping more after a low attention day, removing video screen from front seat); (4) and long-term (adoption of a different sleep lifestyle or distraction attitude). This feedback increases driver self-awareness of inattentive behavior and enables better self-management.

Two main feedback types are considered. The first is continuous in-vehicle feedback that provides the driver with real-time attentive performance information, for example information presented while driving. This information is communicated in a way that, in itself, does not jeopardize safety. The concept is to provide a sort of attention-meter, alertness meter (alert-o-meter), or safe/unsafe driving performance meter. The second feedback type is post-trip feedback that provides the driver with more detailed attentive performance information once driving has stopped.

Saving post-trip feedback "to file" further allows fleet-based safety feedback to focus on source behaviors as opposed to outcome measures such as accident incidents. One option, perhaps contributing to driver acceptance, is the provision of a tiered system. In such a tiered system, drivers have continuous access to data, fleet managers have access to summarized data, and regulating agencies can be granted access to summary data. Therefore, in the instance of fleet drivers, the invention can be better enjoyed as a helpful tool, without necessarily having to induce driver apprehension about employer-reporting characteristics.

To be able to give attention feedback, the management system has to be operationalized. Inattention may be seen as being comprised of drowsiness/impairment, distraction, and high workload factors. Therefore, and as illustrated in Fig. 7, an integrated model considering each type of inattentiveness is preferred. Therein, one system model configured according to the present invention is shown that can selectively consider driver inattention, workload, and personal characteristics such as drowsiness and distraction.

In another aspect of the present invention, unique ways are provided for displaying various information or feedback to the driver. In the instance of continuous attention-feedback, Figs. 8(a)-(c) demonstrate various "active" graphical displays for displaying real-time driver information that has been sensed or generated by the management system. As an example, the display can be of a "generic" or synthesized attention feedback quantity such as the level of attention/inattention as a combined measure of drowsiness, distraction, and workload. In the instance of Fig. 8(a), a simple stack of lights with no trend information is exemplified. In the instance of Fig. 8(b), an "aircraft radar type" display is utilized in which a box is positioned around the current level and trend information in the form of "fading out" is enabled. Fig. 8(c) demonstrates a histogram in which instantaneous "real time" information is shown as an elongating/retracting bar (relatively wide) on the right, with aggregate statistical values (average, median, and the like) for periods of pre-selected duration represented by the more narrow bars on the left. In this manner, trend information is demonstrated. In the illustrative example of Fig. 8(c), five previous periods are represented. It should be appreciated that any previous periods may be displayed according to the control logic for the display and memory capacity.

In another aspect, the present invention also provides real-time driver feedback in a comparative format against an indication of an optimal level of attention. An exemplary embodiment of such a display is illustrated in Fig. 9 where a driver may observe his or her degree of distraction or overload relative to optimum attentiveness.

In still another aspect, the invention may be used to measure detected periods of driver inattention, with notification of the state provided. The driver may then "ask" (e.g. by touching a screen, for instance) what the problem was and receive an explanation of the basis for the detected increased workload/inattention level. Such feedback can exemplarily be provided in the form of verbal messages and/or graphically as shown in Fig. 10. Therein, three graphic representations of drowsiness, distraction, and workload are depicted on the right, and a combination of the effects is demonstrated on the left where relative driver attentiveness is indicated.

As explained above, the aspect of trip-reporting can be highly advantageous for the driver's learning and behavior modification. Therefore, inventive ways to provide on-screen post-trip feedback are disclosed and exemplarily illustrated in Fig. 11. In this illustrative example, a menu choice from a display screen has been selected for post-trip feedback and the associated display of such measured characteristics as percent eye-closure, steering consistency and the like have been displayed in a historical format. Of course, this same information can advantageously be logged for later analysis and use.

The driver capabilities that have been discussed above can also be utilized for distraction adaptation of other vehicle systems such as forward-collision, rear-collision and lane-change collision warning (FCW, RCW and LCW) systems. Rear-end collisions account for approximately twenty-eight percent of automotive crashes. Because driver inattention is a contributing factor in more than sixty percent of these collisions, collision warning and avoidance systems are important tools for reducing crashes and saving lives. One objective of the present attention management systems is to detect the co-occurrence of inattention and safety critical events in the traffic environment; for example, sudden braking of a lead vehicle and driver eyes-off-road conditions. Two examples of this can be used as visual behavior information to adapt forward collision- and lane change- warnings.

Integration of detection of quantified secondary tasks (e.g. by detecting button presses or eye movements) greatly enhances the collision warning system by dynamically adjusting the collision warning threshold according to whether the driver is engaged with a potentially distracting device or other type task. For example, the collision warning system could generate a warning earlier if it is detected that the driver is involved in a cellular telephone conversation. An early collision warning helps the driver react more quickly and avoid more collisions compared to late warning, or no warning at all. If the driver is inattentive with respect to a certain aspect of the driving task, for example looking away from forward when a likelihood of forward collision is detected, or has not looked sideways when a possible lane change collision is detected, then warnings of such conditions are initiated earlier. Studies have shown that even a one second earlier warning when drivers are looking away is highly effective for avoiding collisions.

If it is detected that the driver is attentive, then the warnings can be delayed or even cancelled. A delay in warning presentation allows more time for the forward collision and lane change warning algorithms to more certainly ascertain that a warning is needed, thereby reducing false alarms. Still further, driver cancellation wherein the driver chooses not to have collision warnings active when looking at the road or side mirrors would also eliminate annoying false alarms.

As an implementation strategy, in a first stage, such warnings may be "soft," but increasing in intensity as conditions worsen and a crash becomes more imminent. In the instance of forward collision warning, a heads-up or screen display warning may first be called up, but later being joined by an audible warning sounded as crash conditions intensify. An example of such a warning and its control parameters (which may or may not be displayed to the driver) are depicted in Fig. 12 regarding forward collision situations and Fig. 13 regarding lane-change collision situations.

The detection features described hereinabove with regard to driver characteristics may be utilized in other environments and for other purposes than expressly described. The detection features may also be integrated for employment in other in-vehicle systems. For instance, as a passive safety feature, a "smart" airbag may be enabled that detects when the driver's/passenger's head is not in a proper position to receive a deployed airbag. Responsively, deployment of the airbag may be modified to accommodate the sensed head position.

In another capacity, sensed behavior could be used to identify the driver, or at least rule out that an authorized driver is behind the wheel thereby facilitating theft protection. The head and eye sensors could also be used to automatically configure mirrors, seat positions and the like. Mouth tracking can be used to enhance speech recognition accessories. Filters for oncoming headlights can be adapted, as can displays for the driver based on eye position and motion.

CLAIMS

1. A method for monitoring the physiological behaviour of a driver, comprising:

measuring a physiological variable of a driver;

assessing a driver's behavioural parameter on the basis of at least said measured physiological variable; and

informing the driver of the assessed driver's behavioural parameter.

2. The method for monitoring the physiological behaviour of a driver as recited in claim 1, wherein said step of measuring a physiological variable further comprises at least one step selected from a group consisting of: measuring a driver's eye movement; measuring a driver's eye-gaze direction; measuring a driver's eye-closure amount; measuring a driver's blinking movement; measuring a driver's head movement; measuring a driver's head position; measuring a driver's head orientation; measuring driver's movable facial features; measuring a driver's facial temperature image.

3. The method for monitoring the physiological behaviour of a driver as recited in claim 2, wherein said step of measuring a physiological variable further comprises at least one step selected from a group consisting of: measuring a grip force on a steering wheel; and measuring a movement of a steering column.

4. The method for monitoring the physiological behaviour of a driver as recited in claim 1, wherein said step of assessing a driver's behavioural parameter comprises one or more steps selected from a group consisting of:

assessing a time weighted parameter characterizing a driver's eye closure over a predetermined period of time;

assessing a time weighted parameter characterizing a driver's off-road eye-gaze over a predetermined period of time;

assessing a time weighted parameter characterizing a driver's blinking movement over a predetermined period of time;

assessing a time weighted parameter characterizing a driver's eye closure over a predetermined period of time;

assessing a time weighted parameter characterizing a driver's head position over a predetermined period of time; and

assessing a time weighted parameter characterizing a driver's head movement over a predetermined period of time.

5. The method for monitoring the physiological behaviour of a driver as recited in claim 1, wherein said step of informing the driver comprises at least one step selected from a group consisting of providing a real-time feedback to the driver and providing a post-trip feedback to the driver.

6. The method for monitoring the physiological behaviour of a driver as recited in claim 1, wherein said step of informing the driver comprises a step providing of a histogram of the parameter over a given period of time.

7. The method for monitoring the physiological behaviour of a driver as recited in claim 1, wherein said step of informing the driver comprises a step of providing a scaled comparison between the parameter and at least one normative value.

8. The method for monitoring the physiological behaviour of a driver as recited in claim 1, further comprising a step of providing the driver with a feedback message on how the driver's attitude should be changed, said message being dependent on said parameter.

9. The method for monitoring the physiological behaviour of a driver as recited in claim 1, further comprising the steps of deciding whether said parameter deteriorates and informing the driver when the assessed behaviour parameter deteriorates.

10. The method for monitoring the physiological behaviour of a driver as recited in claim 1, further comprising the steps of deciding whether said parameter is outside a safety range and informing the driver when the assessed behaviour parameter is outside said safety range.

11. The method for monitoring the physiological behaviour of a driver as recited in claim 10, further comprising a steps of assessing vehicle condition data provided by vehicle condition detection means positioned on the vehicle, assessing environment data provided by environment detection means positioned on the vehicle, and determining the safety range in function of at least one of the vehicle condition data and of the environment data.

12. The method for monitoring the physiological behaviour of a driver as recited in claim 11, wherein said vehicle condition detection means comprise detection means selected from a group consisting of: steering column detection means; vehicle speed detection means; gear shift detection means; brake detection means; throttle pedal detection means; clutch detection means; and wheel speed detection means.

13. The method for monitoring the physiological behaviour of a driver as recited in claim 11, wherein said environment detection means comprise detection means selected from a group consisting of: luminosity detection means; road condition detection means; vehicle positioning detection means; proximity detection means; and lane location detection means.

14. The method for monitoring the physiological behaviour of a driver as recited in claim 1, wherein said step of informing the driver comprises a step of outputting information data through a human-machine interface.

15. The method for monitoring the physiological behaviour of a driver as recited in claim 14, wherein said step of outputting information data comprises at least one step selected from a group consisting of outputting visual information data on a screen display; outputting visual information data on a head-up display; and outputting spoken information on an voice output.

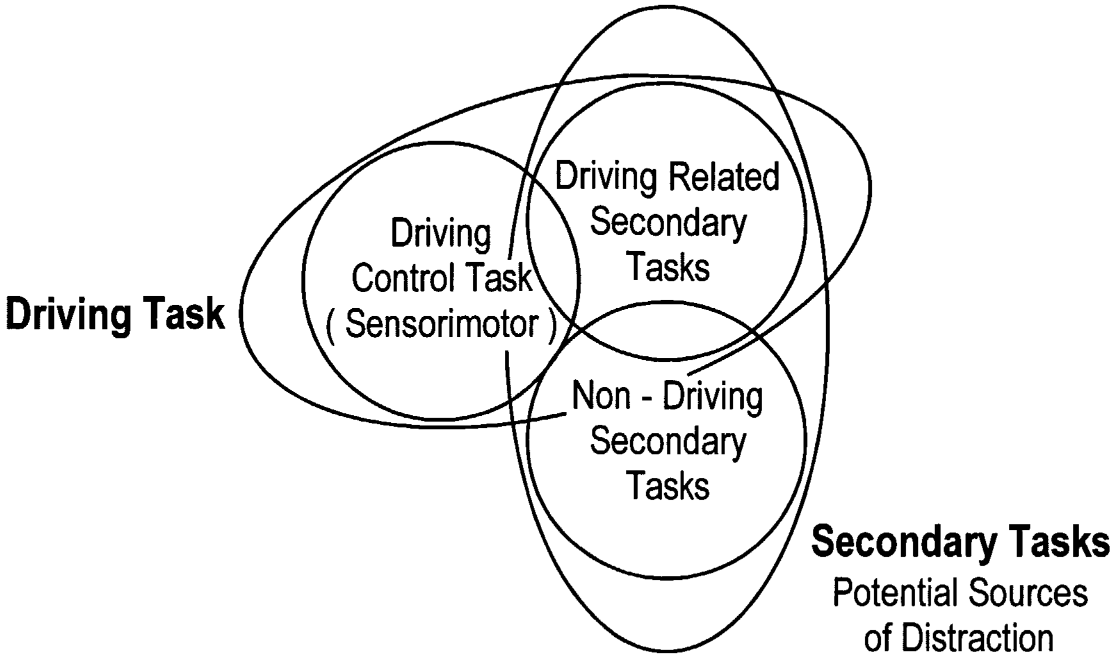
Driving Task
Driving Control Task (Sensorimotor)
Driving Related Secondary Tasks
Non - Driving Secondary Tasks
Secondary Tasks
Potential Sources of Distraction

FIG. 1

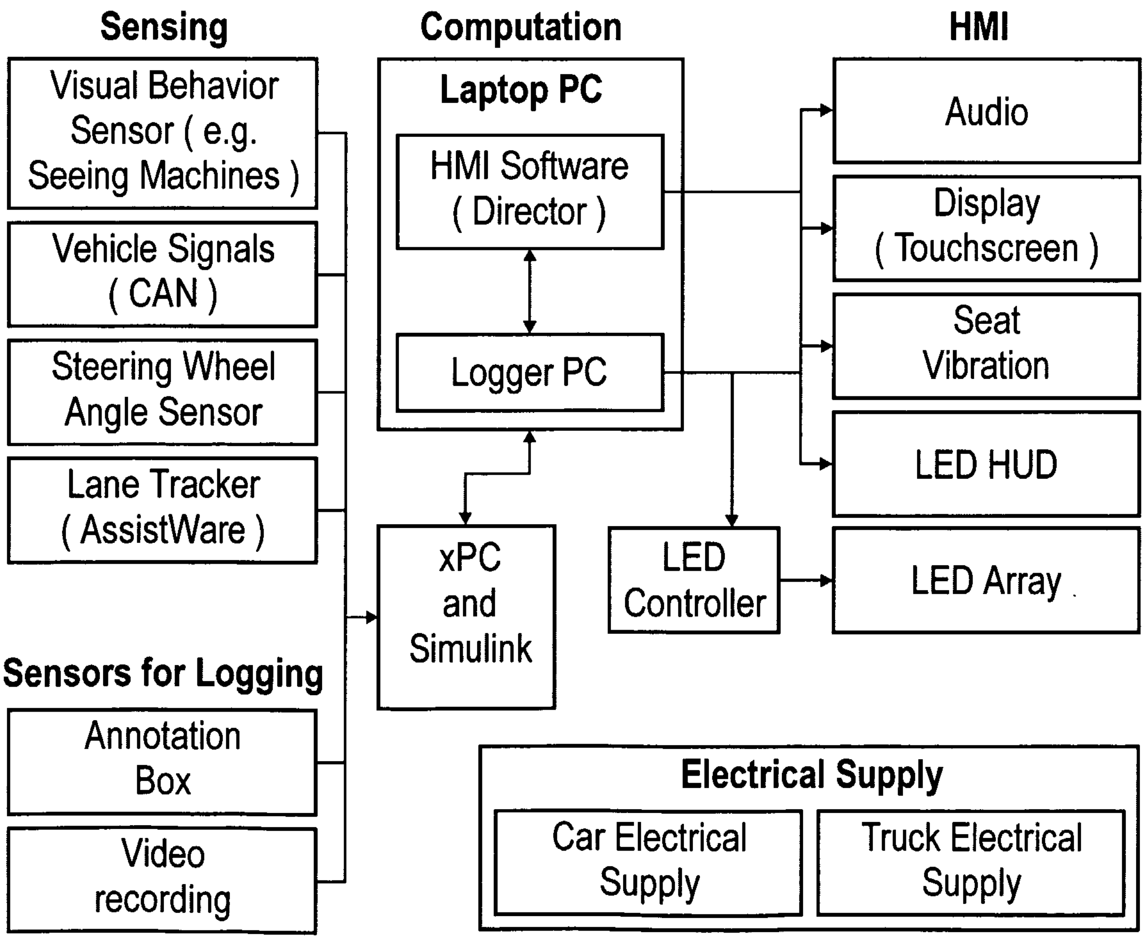
Sensing
Visual Behavior Sensor (e.g. Seeing Machines)
Vehicle Signals (CAN)
Steering Wheel Angle Sensor
Lane Tracker (AssistWare)
Sensors for Logging
Annotation Box
Video recording
Computation
Laptop PC
HMI Software (Director)
Logger PC
xPC and Simulink
LED Controller
HMI
Audio
Display (Touchscreen)
Seat Vibration
LED HUD
LED Array
Electrical Supply
Car Electrical Supply
Truck Electrical Supply

FIG. 2

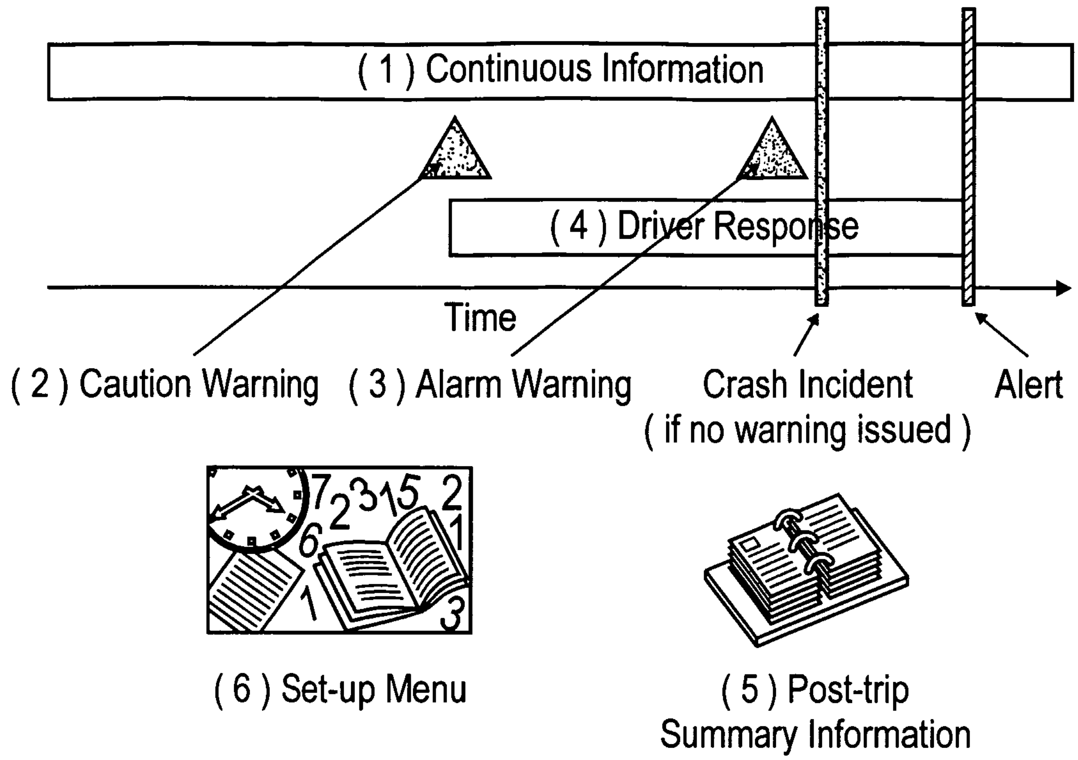

FIG. 3

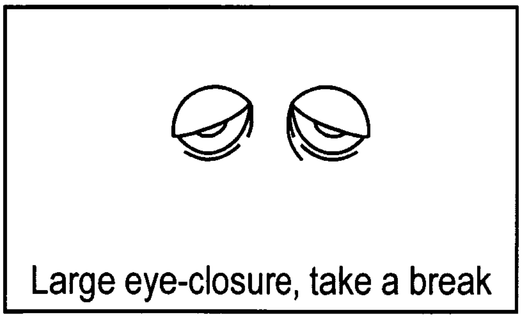

FIG. 4a

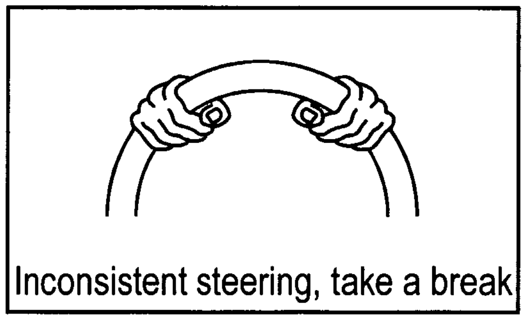

FIG. 4b

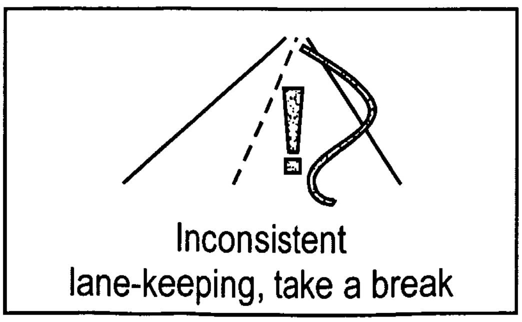

FIG. 4c

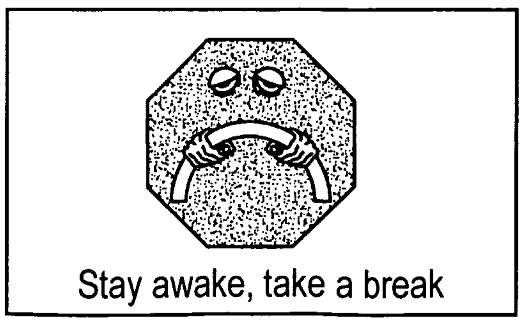

FIG. 4d

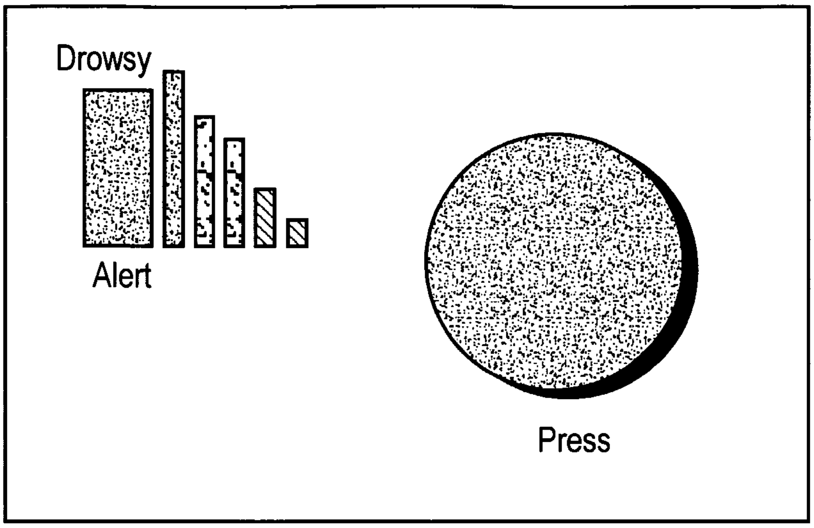

FIG. 5

Gaze Redirection

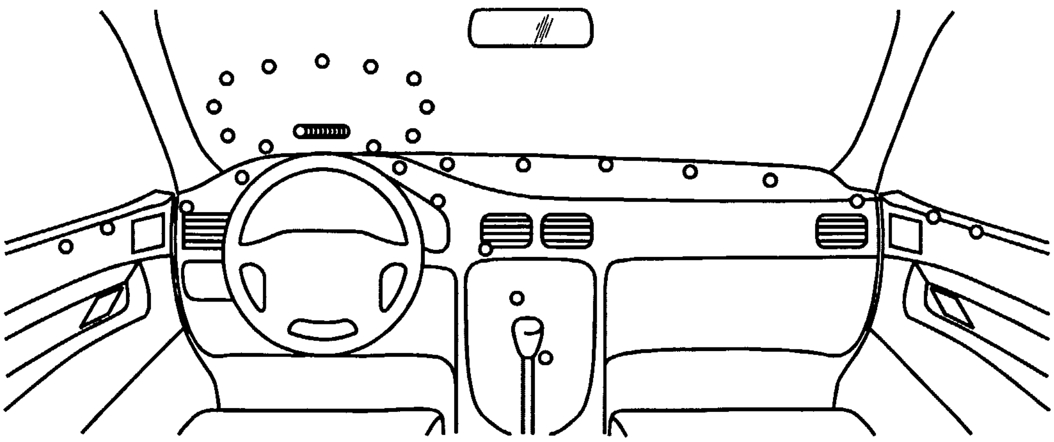

FIG. 6

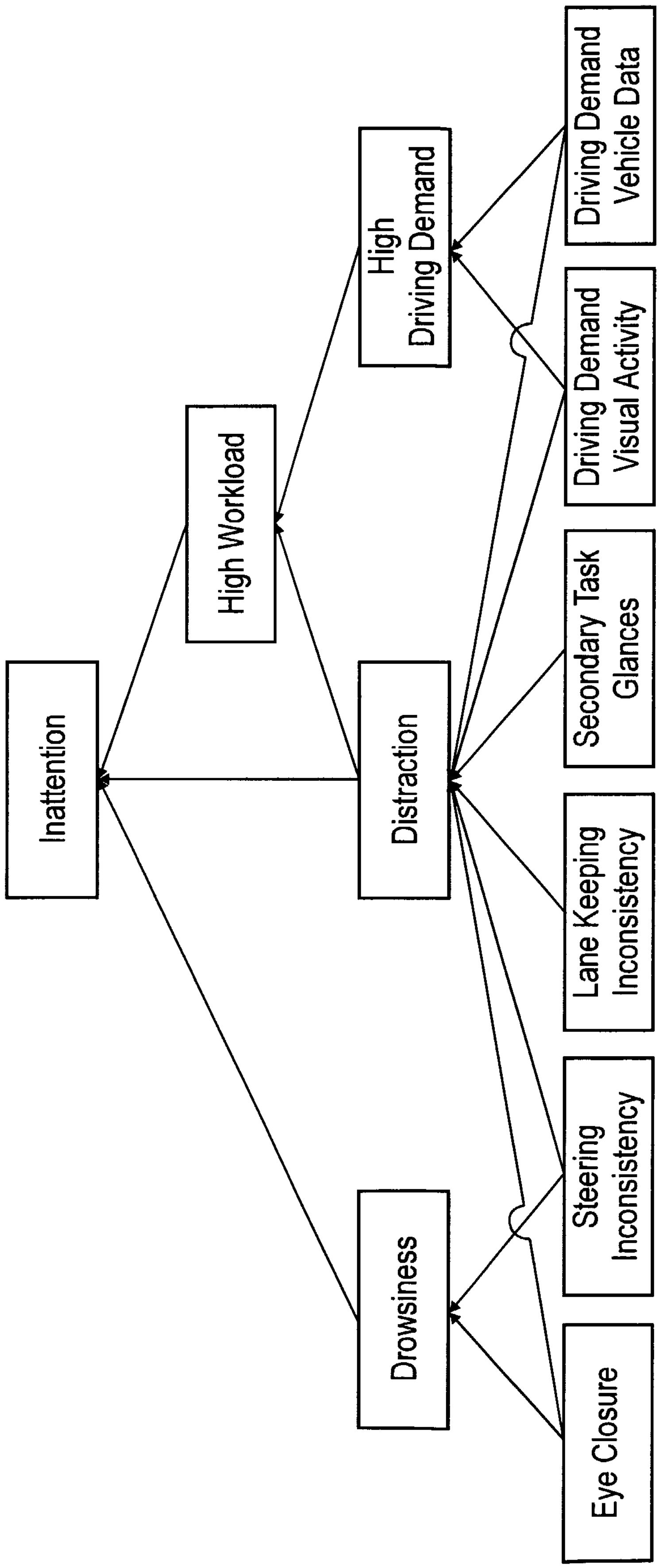
Inattention
High Workload
High Driving Demand
Distraction
Drowsiness
Eye Closure
Steering Inconsistency
Lane Keeping Inconsistency
Secondary Task Glances
Driving Demand Visual Activity
Driving Demand Vehicle Data

FIG. 7

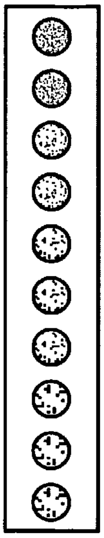

FIG. 8a

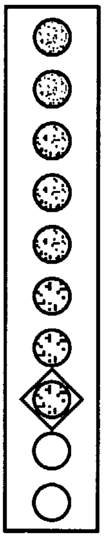

FIG. 8b

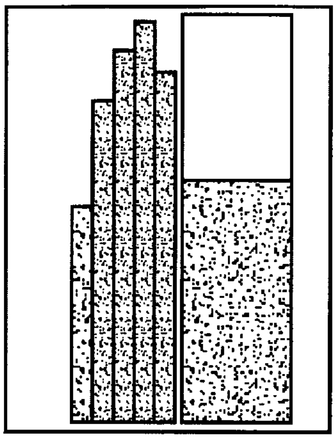

FIG. 8c

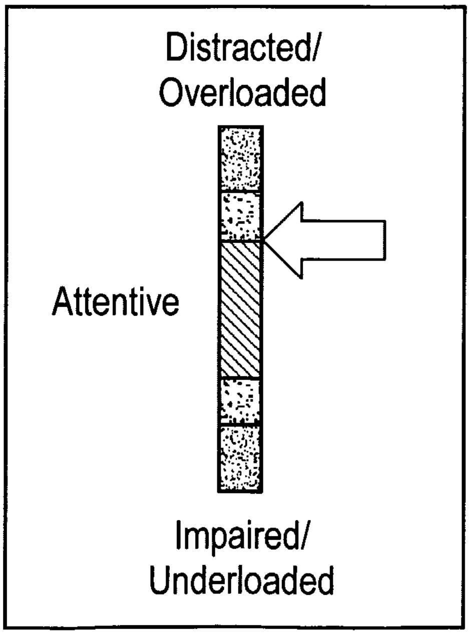

FIG. 9

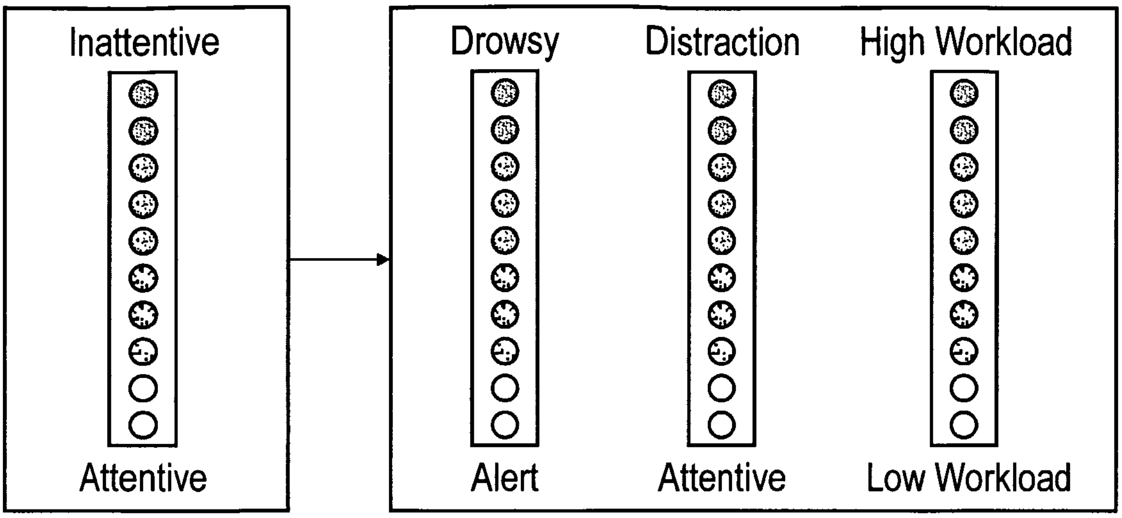
Inattentive
Attentive
Drowsy
Alert
Distraction
Attentive
High Workload
Low Workload

FIG. 10

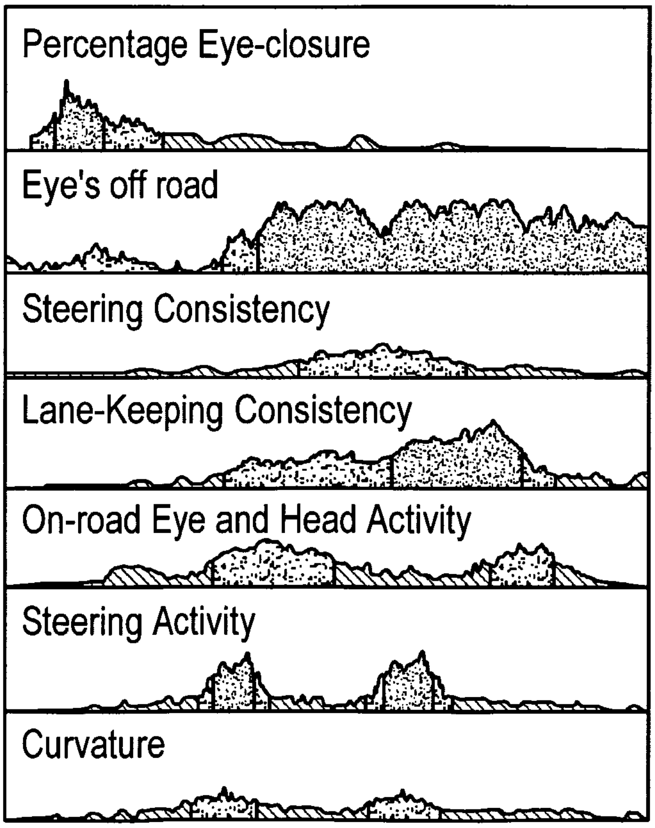
Percentage Eye-closure
Eye's off road
Steering Consistency
Lane-Keeping Consistency
On-road Eye and Head Activity
Steering Activity
Curvature

FIG. 11

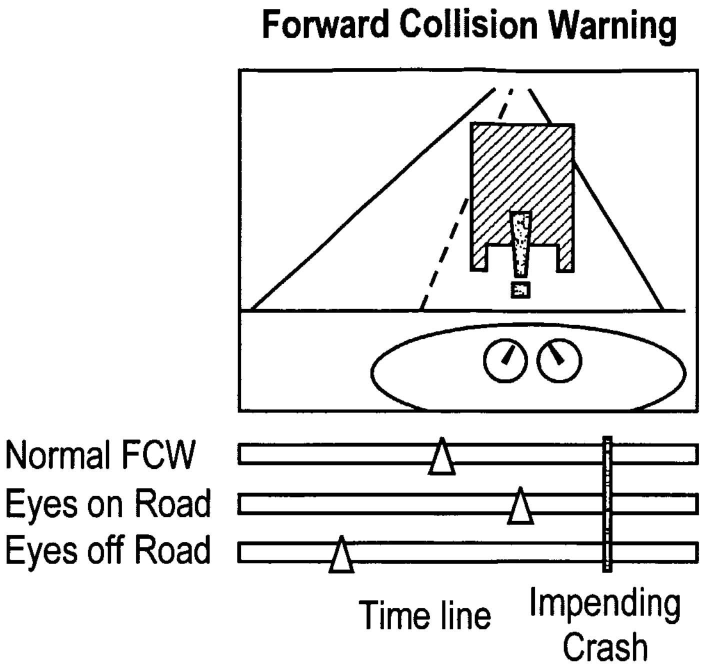
Forward Collision Warning
Normal FCW
Eyes on Road
Eyes off Road
Time line
Impending Crash

FIG. 12

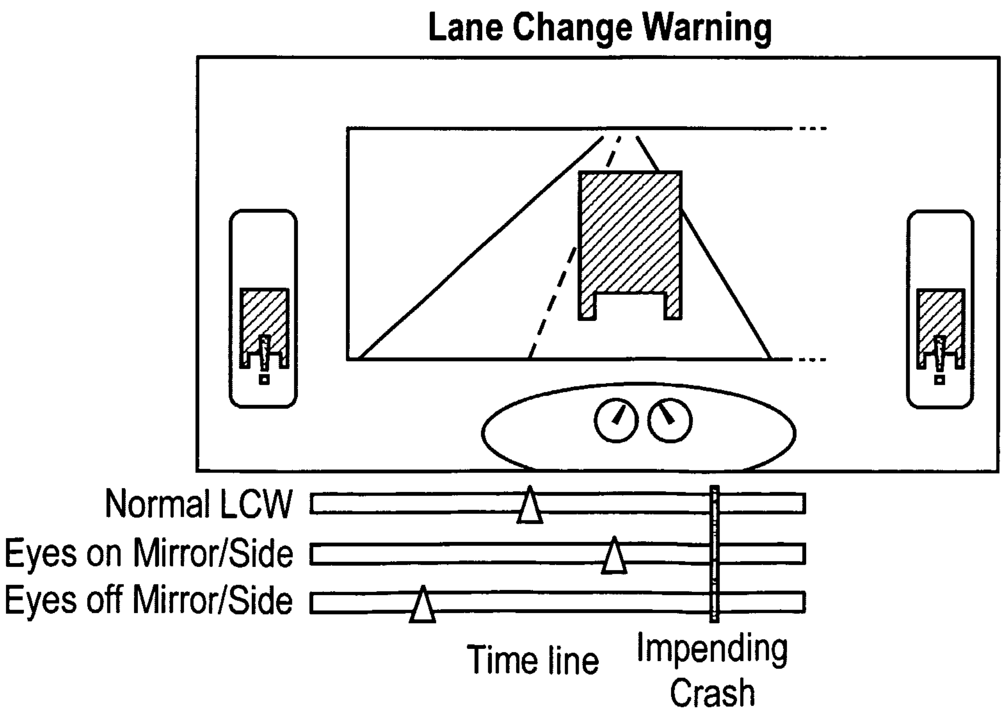
Lane Change Warning
Normal LCW
Eyes on Mirror/Side
Eyes off Mirror/Side
Time line
Impending Crash

FIG. 13

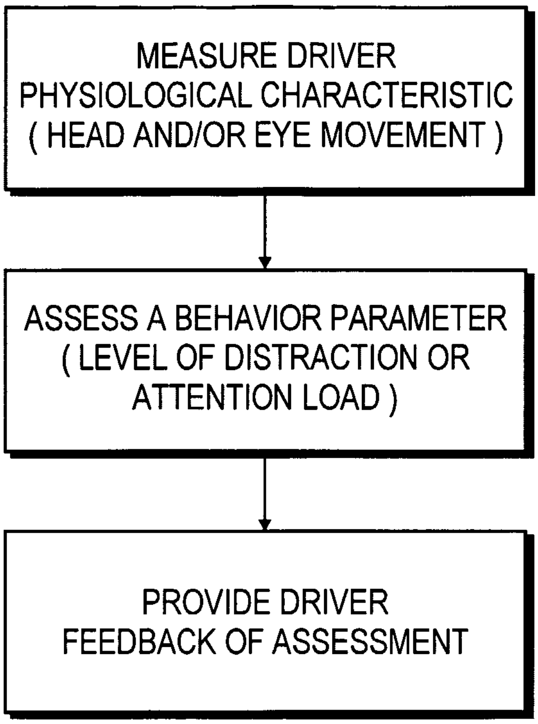
MEASURE DRIVER
PHYSIOLOGICAL CHARACTERISTIC
(HEAD AND/OR EYE MOVEMENT)
ASSESS A BEHAVIOR PARAMETER
(LEVEL OF DISTRACTION OR
ATTENTION LOAD)
PROVIDE DRIVER
FEEDBACK OF ASSESSMENT

FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/04504

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : A61B 5/00
US CL : 600/300

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : Please See Continuation Sheet

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WEST 2.1

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 5,585,785 A (GWIN et al.) 17 December 1996, See abstract, column 1, lines 45-67, column 2, lines 1-23, column 3, lines 13-19, and column 4, lines 3-12	1, 5-10, and 14-15 ---------- 3
X	US 5,786,765 A (KUMAKURA et al.) 28 July 1998, See abstract, figures 1-2, column 3, lines 32-65, column 4, lines 37-65, column 5, lines 15-47, and column 7, lines 38-65	1-2, 4-10, 14-15
Y	US 5,900,819 A (KYRTSOS) 04 May 1999, See abstract, figures 1-2, column 1, lines 57-67 and column 2, lines 1-19	11-12
X	US 6,130,617 A (YEO) 10 October 2000, See abstract, figures 1-3, column 1, lines 9-29, and column 2, lines 1-54	1-2, 4, 7-10, 14-15

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
05 May 2003 (05.05.2003)

Date of mailing of the international search report
31 JUL 2003

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Alexandria, Virginia 22313-1450
Facsimile No. (703)305-3230

Authorized officer
Michael C. Astorino Diane Smith
Telephone No. (703) 306-9067

Continuation of B. FIELDS SEARCHED Item 1:

600/26-28, 300-301, 558, 587, 595; 128/897-898, 920, 922-923; 340/438, 439, 573.1, 575-576, 669, 679; 180/271-272, 282; 701/70; 704/270.1, 274; 351/205, 209-210; 382/115-118 patsnap

专利名称(译)	用于监视和管理驾驶员注意力负载的系统和方法		
公开(公告)号	EP1478268A1	公开(公告)日	2004-11-24
申请号	EP2003742752	申请日	2003-02-19
[标]申请(专利权)人(译)	沃尔沃技术公司		
申请(专利权)人(译)	VOLVO科技股份有限公司		
当前申请(专利权)人(译)	VOLVO科技股份有限公司		
[标]发明人	VICTOR TRENT		
发明人	VICTOR, TRENT		
IPC分类号	A61B3/113 A61B5/11 A61B5/18 G08B21/06 A61B5/00		
CPC分类号	A61B3/113 A61B5/015 A61B5/11 A61B5/1103 A61B5/1114 A61B5/163 A61B5/18 B60K35/00 B60K2370/191 B60K2370/338 B60T2201/022 B60T2201/08 B60T2201/086 B60W40/09 B60W50/14 B60W2040/0827 B60W2540/22 G06K9/00845 G08B21/06		
优先权	60/357135 2002-02-19 US 60/418171 2002-10-15 US		
其他公开文献	EP1478268A4 EP1478268B1		
外部链接	Espacenet		

摘要(译)

用于监测驾驶员的生理行为的系统和方法，包括测量驾驶员的生理变量，至少基于所述测量的生理变量（1,4）评估驾驶员的行为参数，并通知驾驶员（2,3））评估的驾驶员的行为参数（1,4）。生理变量（1,4）的测量可以包括测量驾驶员的眼睛运动，测量驾驶员的眼睛注视方向，测量驾驶员的闭眼量，测量驾驶员的眨眼运动，测量驾驶员的头部运动，测量驾驶员的头部位置，测量驾驶员的头部方向，测量驾驶员的可移动面部特征，以及测量驾驶员的面部温度图像。