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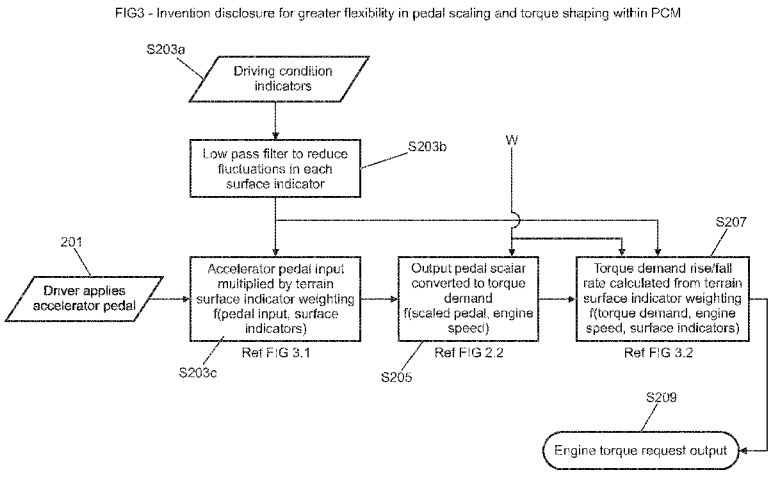


FIGURE 8

(57) Abstract: A vehicle control system for at least one vehicle subsystem of a vehicle, the vehicle control system comprising: a subsystem controller for initiating control of the at least one vehicle subsystem in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle, wherein for a given control mode at least one control parameter of the at least one vehicle subsystem is set by the controller to a predetermined state or value corresponding to that control mode; evaluation means configured to evaluate automatically at least one driving condition indicator determine the most appropriate state or value of at least one control parameter of at least one said at least one vehicle subsystem, the subsystem controller being configured to adjust the state or value of said at least one control parameter of at least one said at least one vehicle subsystem in dependence on the most appropriate state or value determined by the evaluation means.

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CONTROL SYSTEM FOR A VEHICLE AND METHOD

INCORPORATION BY REFERENCE

The content of co-pending UK patent applications GB2507622 and GB2499461 are hereby incorporated by reference. The content of US patent no US7349776 and co-pending international patent applications WO2013124321 and WO2014/139875 are incorporated herein by reference. The content of UK patent applications GB2492748, GB2492655 and GB2499279 and UK patent GB2508464 are also incorporated herein by reference.

TECHNICAL FIELD

The present disclosure relates to a vehicle control system and control method and particularly, but not exclusively, to a control system and a method for controlling operation of one or more vehicle systems or subsystems in a land-based vehicle capable of driving in a variety of different and extreme terrains and conditions. Aspects of the invention relate to a control system, a vehicle, a method, a non-transitory computer readable carrier medium carrying a computer readable code, a computer program product executable on a processor, a computer readable medium and a processor.

BACKGROUND

It is known to provide a control system for a motor vehicle for controlling one or more vehicle subsystems. US7349776 discloses a vehicle control system comprising a plurality of subsystem controllers including an engine management system, a transmission controller, a steering controller, a brakes controller and a suspension controller. The subsystem controllers are each operable in a plurality of subsystem function or configuration modes. The subsystem controllers are connected to a vehicle mode controller which controls the subsystem controllers to assume a required function mode so as to provide a number of driving modes for the vehicle. Each of the driving modes corresponds to a particular driving condition or set of driving conditions, and in each mode each of the sub-systems is set to the function mode most appropriate to those conditions. Such conditions are linked to types of terrain over which the vehicle may be driven such as grass/gravel/snow, mud and ruts, rock crawl, sand and a highway mode known as ‘special programs off’ (SPO). The vehicle mode controller may be referred to as a Terrain Response (TR) (RTM) System or controller. The driving modes may also be referred to as terrain modes, terrain response modes, or control modes.

As noted above, for each of the driving modes each of the sub-systems is set to the function mode most appropriate to those conditions, including an engine management system of the

vehicle. The engine management system is configured to control the response of the engine to an accelerator pedal of the vehicle according to the selected function mode.

FIG. 1 illustrates the manner in which the amount of torque generated by the engine as a function of accelerator pedal input is arranged to depend upon the selected function mode, which may be referred to as the terrain response (TR) mode or program, since the modes are implemented by means of computer program code in known vehicles.

At step S101 the driver depresses the accelerator pedal of the vehicle and an accelerator pedal position signal indicative of the extent of the depression is received by a vehicle controller. The controller also receives a signal indicative of the TR program that has been selected (step S103a). At step S103b the controller scales the accelerator pedal position signal according to the signal indicative of TR program, and generates a scaled pedal output signal.

The controller also receives a signal indicative of engine speed. At step S105 the scaled pedal output signal, in combination with the signal indicative of engine speed, is converted to an engine torque demand signal.

At step S107, the controller implements a function that controls the rate of rise or fall of the torque demand signal generated by the controller at step S105 in dependence on the signal indicative of TR program and the current engine speed.

At step S109 the controller outputs the signal generated at step S107 as an engine torque request output.

The present applicant has recognised that the particular configuration of a subsystem in a given driving mode may not be optimum for the actual prevailing conditions. By way of example, it is to be understood that the Sand driving mode may not provide optimum vehicle performance when driving on wet or damp sand, compared with dry sand.

It is against this background that the present invention has been conceived. Embodiments of the invention may provide a control system, a vehicle, a method, a non-transitory computer readable carrier medium carrying a computer readable code, a computer program product executable on a processor, a computer readable medium or a processor which address the above problem. Other aims and advantages of embodiments of the invention will become apparent from the following description, claims and drawings.

SUMMARY OF THE INVENTION

In one aspect of the invention for which protection is sought there is provided a vehicle control system for at least one vehicle subsystem of a vehicle, the vehicle control system comprising:

a subsystem controller for initiating control of the or each of the at least one vehicle subsystems in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle, and

means for receiving and/or generating at least one driving condition indicator,

wherein the control system is further configured to control a response of an engine of the vehicle to drive torque demand in dependence at least in part on the at least one driving condition indicator, and to adjust the engine response in dependence on changes in the at least one driving condition indicator, whilst the or each of the vehicle subsystems is operated in the selected one of the plurality of subsystem control modes.

Optionally, the system may comprise evaluation means for evaluating the at least one driving condition indicator to determine the extent to which each of the subsystem control modes is appropriate and for providing an output indicative of the subsystem control mode that is most appropriate.

In an aspect of the invention for which protection is sought there is provided a vehicle control system for at least one vehicle subsystem of a vehicle, the vehicle control system comprising:

a subsystem controller for initiating control of the at least one vehicle subsystem in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle, wherein in a given control mode at least one control parameter of at least one vehicle subsystem is set to a predetermined value or state corresponding to that control mode; and

means for receiving and/or generating at least one driving condition indicator,

wherein, when the subsystem is controlling the at least one vehicle subsystem in the selected control mode, the control system is configured to adjust the value or state of said at least one control parameter in dependence on changes in the at least one driving condition indicator, whilst the or each of the vehicle subsystems is operated in the selected one of the plurality of subsystem control modes.

In a further aspect of the invention for which protection is sought there is provided a vehicle control system for at least one vehicle subsystem of a vehicle, the vehicle control system comprising:

a subsystem controller for initiating control of the at least one vehicle subsystem in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle, wherein for a given control mode at least one control parameter of the at least one vehicle subsystem is set by the controller to a predetermined state or value corresponding to that control mode;

evaluation means configured to evaluate automatically at least one driving condition indicator to determine the most appropriate state or value of at least one control parameter of at least one said at least one vehicle subsystem,

the subsystem controller being configured to adjust the state or value of said at least one control parameter of at least one said at least one vehicle subsystem in dependence on the most appropriate state or value determined by the evaluation means.

The subsystem controller may be configured to adjust the state or value of said at least one control parameter of at least one said at least one vehicle subsystem in dependence on the most appropriate state or value determined by the evaluation means substantially in real time whilst the at least one vehicle subsystem is operated in the selected one of the plurality of subsystem control modes.

In an aspect of the invention for which protection is sought there is provided a vehicle control system for at least one vehicle subsystem of a vehicle, the vehicle control system comprising:

a subsystem controller for initiating control of one or more of the at least one vehicle subsystems in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle, and

evaluation means for evaluating at least one driving condition indicator to determine the extent to which each of the subsystem control modes is appropriate and for providing an output indicative of the subsystem control mode that is most appropriate,

wherein the control system is further configured to control a response of an engine of the vehicle to drive torque demand in dependence at least in part on the at least one driving condition indicator, and to adjust the engine response in dependence on changes in the at least one driving condition indicator, whilst one or more of the at least one vehicle subsystems are operated in the selected one of the plurality of subsystem control modes.

Optionally, the subsystem controller may be configured to adjust the state or value of said at least one control parameter of at least one vehicle subsystem in dependence on the most appropriate state or value determined by the evaluation means comprises the subsystem controller being configured to control a response of an engine of the vehicle to drive torque demand in dependence at least in part on the at least one driving condition indicator, and to adjust the engine response in response to changes in the at least one driving condition indicator, whilst one or more of the at least one vehicle subsystems are operated in the selected one of the plurality of subsystem control modes.

The subsystem controller may be configured to control the response of the engine of the vehicle to drive torque demand in dependence at least in part on the at least one driving condition indicator, and to adjust the engine response in dependence on changes in the at least one driving condition indicator, substantially in real time whilst one or more of the at least one vehicle subsystems are operated in the selected one of the plurality of subsystem control modes.

Some embodiments of the present invention have the advantage that a substantial enhancement in vehicle operation may be enjoyed when one or more vehicle subsystem is operating in the selected subsystem control mode. This is at least in part because the response of the engine to changes in one or more driving condition indicators may be adjusted even whilst the control system is causing one or more vehicle subsystem to operate in the selected subsystem control mode. Accordingly, the engine may be controlled in a manner that is further optimised for the driving conditions prevailing at a given moment in time.

It is to be understood that, in known control systems where a subsystem controller initiates control of one or more subsystems in a given control mode, the response of the engine to drive torque demand is predetermined for that control mode. For example, in a control system where the control modes include a mode optimised for travel over grass, gravel and snow (GGS), a fixed, predetermined engine response to drive torque demand is employed when the vehicle is operated in the GGS mode. The present applicant has recognised that this response may be unsuitable for certain grass, gravel or snow terrain. Embodiments of the present invention allow the response of the engine to be optimised according to the prevailing one or more driving condition indicators at a given moment in time, whilst the subsystems are operated in a given subsystem control mode such as the GGS mode.

The control system may be configured to control a response of the engine of the vehicle to drive torque demand at least in part in dependence on a raw drive demand signal indicative of drive torque demand from at least one of a user-operable drive demand control and an automatic speed control system.

The control system may be configured to control the response of the engine to drive torque demand in dependence at least in part on a raw drive torque demand signal generated in dependence at least in part on the position of a user-movable element of a user-operable drive demand control relative to a range of allowable positions thereof, and engine speed.

Optionally, the user-operable drive demand control comprises a pedal.

The control system may be configured to generate a scaled drive demand signal in dependence on the raw drive demand signal according to a predetermined relationship between scaled drive demand signal and raw drive demand signal, the scaled drive demand signal being employed to determine an instant value of drive torque to be developed by the engine.

Optionally, the scaled drive demand signal is applied to a drivability reference filter, an output of the drivability reference filter being employed to generate an output corresponding to the instant value of drive torque to be developed by the engine.

Optionally, the raw drive demand signal is applied to a drivability reference filter, an output of the drivability reference filter being employed to generate an output corresponding to the instant value of drive torque to be developed by the engine.

The control system may be configured to control a response of the engine to drive torque demand in dependence at least in part on the at least one driving condition indicator by controlling a rate of increase of the output of the drivability reference filter as a function of rate of increase of the drive torque demand signal applied to the input thereof, in dependence at least in part on the at least one driving condition indicator.

The control system may be configured to control a response of the engine to drive torque demand in dependence at least in part on the at least one driving condition indicator by controlling a rate of decrease of the output of the drivability reference filter as a function of rate of decrease of the drive torque demand signal applied to the input thereof, in dependence at least in part on the at least one driving condition indicator.

Optionally, the evaluation means is further configured to evaluate at least one driving condition indicator to determine the extent to which each of the subsystem control modes is appropriate and provide an output indicative of the subsystem control mode that is most appropriate, the subsystem controller being configured to initiate automatically control of the or each of the vehicle subsystems in the subsystem control mode that is most appropriate.

Thus the selected control mode may be the subsystem control mode that is determined by the evaluation means to be the most appropriate

Optionally, the control modes comprise at least one control mode adapted for driving on a driving surface of relatively low surface coefficient of friction.

It is to be understood that the control modes may be referred to as driving modes since they correspond to different driving conditions. Each of a plurality of subsystems may each have a control mode adapted for driving under a given driving condition, such as over a particular terrain type. For example, each of a plurality of subsystems may have a mode adapted for driving over grass, gravel or snow, a mode adapted for driving over mud/ruts, a mode adapted for driving over sand, and a mode adapted for driving slowly over rocks, such as a 'rock crawl' mode.

Optionally, the control modes comprise at least one driving mode adapted for driving on at least one of a snowy surface, an icy surface, grass, gravel, snow, mud and sand.

Optionally, the subsystems include at least one of a powertrain subsystem, a brakes subsystem, a power assisted steering (PAS) subsystem and a suspension subsystem.

The control system may comprise an electronic processor having an electrical input for receiving a signal indicative of at least one driving condition indicator, and an electronic memory device electrically coupled to the electronic processor and having instructions stored therein,

wherein the processor is configured to access the memory device and execute the instructions stored therein such that it is operable to evaluate automatically at least one driving condition indicator, determine which of the subsystem control sub-modes of the at least one control mode is most appropriate, control a response of the engine of the vehicle to drive torque demand in dependence at least in part on the at least one driving condition indicator, and to adjust the response of the engine to drive torque demand in dependence at

least in part on changes in the at least one driving condition indicator, whilst the or each of the vehicle subsystems is operated in the selected one of the plurality of subsystem control modes

Thus it is to be understood that the evaluation means may be implemented by the electronic processor executing the instructions stored in the memory device.

In an aspect of the invention for which protection is sought there is provided a vehicle comprising a control system according to a preceding aspect.

In one aspect of the invention for which protection is sought there is provided a method of controlling at least one vehicle subsystem of a vehicle by means of a control system, the method comprising:

initiating control of the or each of the vehicle subsystems in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle, and

evaluating at least one driving condition indicator to determine the extent to which each of the subsystem control modes is appropriate and for providing an output indicative of the subsystem control mode that is most appropriate,

the method further comprising controlling a response of an engine of the vehicle to drive torque demand in dependence at least in part on the at least one driving condition indicator, and adjusting the engine response in dependence on changes in the at least one driving condition indicator, whilst the or each of the vehicle subsystems is operated in the selected one of the plurality of subsystem control modes.

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In a further aspect of the invention for which protection is sought there is provided a method of controlling at least one vehicle subsystem of a vehicle by means of a control system, the method comprising:

initiating control of the at least one vehicle subsystem in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle, whereby for a given control mode at least one control parameter of the at least one vehicle subsystem is set to a predetermined state or value corresponding to that control mode; and

evaluating automatically at least one driving condition indicator to determine the most appropriate state or value of at least one control parameter of at least one said at least one vehicle subsystem,

the method comprising adjusting the state or value of said at least one control parameter of at least one said at least one vehicle subsystem in dependence on the most appropriate state or value determined by the evaluation means.

The method may comprise controlling a response of the engine of the vehicle to drive torque demand at least in part in dependence on a raw drive demand signal indicative of drive torque demand from at least one of a user-operable drive demand control and an automatic speed control system.

The method may comprise controlling the response of the engine to drive torque demand in dependence at least in part on a raw drive torque demand signal generated in dependence at least in part on the position of a user-movable element of a user-operable drive demand control relative to a range of allowable positions thereof, and engine speed.

Optionally, the user-operable drive demand control comprises a pedal.

The method may comprise generating a scaled drive demand signal in dependence on the raw drive demand signal according to a predetermined relationship between scaled drive demand signal and raw drive demand signal, and determining an instant value of drive torque to be developed by the engine based on the scaled drive demand signal.

The method may comprise applying the scaled drive demand signal to a drivability reference filter, and causing the engine to develop an amount of torque corresponding to the output of the drivability reference filter.

The method may comprise applying the raw drive demand signal to a drivability reference filter, and causing the engine to develop an amount of torque corresponding to the output of the drivability reference filter.

In an aspect of the invention for which protection is sought there is provided a vehicle control system for at least one vehicle subsystem of a vehicle, the vehicle control system comprising:

a subsystem controller for initiating control of one or more of the at least one vehicle subsystems in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle, and

evaluation means for evaluating at least one driving condition indicator to determine the extent to which each of the subsystem control modes is appropriate and for providing an output indicative of the subsystem control mode that is most appropriate,

wherein the control system is further configured to control a response of an engine of the vehicle to drive torque demand in dependence at least in part on the at least one driving condition indicator, and to adjust the engine response in dependence on changes in the at least one driving condition indicator, whilst one or more of the at least one vehicle subsystems are operated in the selected one of the plurality of subsystem control modes.

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Optionally, adjusting the state or value of said at least one control parameter of at least one vehicle subsystem in dependence on the most appropriate state or value determined by the evaluation means comprises controlling a response of an engine of the vehicle to drive torque demand in dependence at least in part on the at least one driving condition indicator, and adjusting the engine response in response to changes in the at least one driving condition indicator, whilst one or more of the at least one vehicle subsystems are operated in the selected one of the plurality of subsystem control modes.

In one aspect of the invention for which protection is sought there is provided a vehicle control system for at least one vehicle subsystem of a vehicle, the vehicle control system comprising:

a subsystem controller for initiating control of the at least one vehicle subsystem in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle, wherein for a given control mode at least one control parameter of the at least one vehicle subsystem is set by the controller to a predetermined state or value corresponding to that control mode;

evaluation means configured to evaluate automatically at least one driving condition indicator and determine the most appropriate state or value of at least one control parameter of at least one said at least one vehicle subsystem,

the subsystem controller being configured to adjust the state or value of said at least one control parameter of at least one said at least one vehicle subsystem in dependence on the most appropriate state or value determined by the evaluation means, whilst the at least one vehicle subsystem is operated in the selected one of the plurality of subsystem control modes.

In an aspect of the invention for which protection is sought there is provided a non-transitory computer readable carrier medium carrying a computer readable code for controlling a vehicle to carry out the method of another aspect.

In an aspect of the invention for which protection is sought there is provided a computer program product executable on a processor so as to implement the method of another aspect.

In an aspect of the invention for which protection is sought there is provided a computer readable medium loaded with the computer program product of another aspect.

In an aspect of the invention for which protection is sought there is provided a processor arranged to implement the method of another aspect, or the computer program product of another aspect.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIGURE 1 is a schematic illustration of the manner in which an accelerator control input signal is converted to an engine torque request signal in a known vehicle;

FIGURE 2 is a schematic illustration of a vehicle according to an embodiment of the present invention;

FIGURE 3 is a block diagram to illustrate a vehicle control system in accordance with an embodiment of the invention, including various vehicle subsystems under the control of the vehicle control system;

FIGURE 4 is a table showing which vehicle subsystem configuration mode is selected in each respective vehicle operating mode;

FIGURE 5 is an example of a calculation of a scaled pedal position signal in a control system according to an embodiment of the present invention;

FIGURE 6 is a schematic illustration of a portion of an engine management system in a control system according to an embodiment of the present invention;

FIGURE 7 is an example of a calculation of a scaled pedal position signal in a control system according to an embodiment of the present invention; and

FIGURE 8 is a schematic illustration of the manner in which an accelerator control input signal is converted to an engine torque request signal in a vehicle according to an embodiment of the present invention.

DETAILED DESCRIPTION

FIG. 2 shows a vehicle 100 according to an embodiment of the invention intended to be suitable for off-road use, that is for use on terrains other than regular tarmac road, as well as on-road. The vehicle 100 has a powertrain 129 that includes an engine 121 that is connected to a driveline 130 having an automatic transmission 124. The transmission 124 has a transmission mode selector dial 124L permitting a driver to select the required transmission operating mode selected from park (P), forward drive (D), neutral (N) and reverse drive (R).

The driveline 130 is arranged to drive a pair of front vehicle wheels 111,112 by means of a front differential 135F and a pair of front drive shafts 118. The driveline 130 also comprises an auxiliary driveline portion 131 arranged to drive a pair of rear wheels 114, 115 by means of an auxiliary driveshaft or prop-shaft 132, a rear differential 135 and a pair of rear driveshafts 139. It is to be understood that embodiments of the present invention are suitable for use with vehicles in which the transmission 124 is arranged to drive only a pair of front wheels or only a pair of rear wheels (i.e. front wheel drive vehicles or rear wheel drive vehicles) or selectable two wheel drive/four wheel drive vehicles, or permanent four wheel drive vehicles. In the embodiment of FIG. 2 the transmission 124 is releasably connectable to the auxiliary driveline portion 131 by means of a power transfer unit (PTU) 137, allowing selectable two wheel drive or four wheel drive operation. It is to be understood that embodiments of the invention may be suitable for vehicles having more than four wheels or less than four wheels.

The PTU 137 is operable in a 'high ratio' or a 'low ratio' configuration, in which a gear ratio between an input shaft and an output shaft thereof is selected to be a high or low ratio. The high ratio configuration is suitable for general on-road or 'on-highway' operations whilst the low ratio configuration is more suitable for negotiating certain off-road terrain conditions and other low speed applications such as towing.

The vehicle 100 has an accelerator pedal 161, a brake pedal 163 and a steering wheel 181. The steering wheel 181 has a cruise control selector button 181C mounted thereto for activating an on-highway cruise control system 10CC that is implemented in software by a vehicle central controller, referred to as a vehicle control unit (VCU) 10 described in more detail below. The steering wheel 181 is also provided with a low speed progress control system selector button 181LSP for selecting operation of a low speed progress (LSP) control system 10LSP which may also be referred to as an off-road speed control system or off-road cruise control system. The LSP control system 10LSP is also implemented in software by the VCU 10. In addition to the cruise control system 10CC and LSP control system 10LSP the VCU 10 is configured to implement a hill descent control (HDC) system 10HDC that limits maximum vehicle speed when descending an incline by automatic application of a brakes system 12d described in more detail below. The HDC system 10HDC may be activated via human machine interface (HMI) module 32.

The VCU 10 receives and outputs a plurality of signals to and from various sensors and subsystems 12 provided on the vehicle 100. The signals may be received via one or more intermediate devices such as controllers with which the sensors and subsystems are in communication.

FIG. 3 is a schematic diagram illustrating operation of the VCU 10 in more detail. The VCU 10 controls a plurality of vehicle subsystems 12 including, but not limited to, an engine management system 12a, a transmission system 12b, an electronic power assisted steering unit 12c (ePAS unit), the brakes system 12d and a suspension system 12e. These vehicle sub-systems can be considered to form a first group of subsystems. Although five subsystems are illustrated as being under the control of the VCU 10, in practice a greater number of vehicle subsystems may be included on the vehicle and may be under the control of the VCU 10. The VCU 10 includes a subsystem control module 14 which provides control signals via line 13 to each of the vehicle subsystems 12 to initiate control of the subsystems in a manner appropriate to the driving condition, such as the terrain, in which the vehicle is travelling (referred to as the terrain condition). The subsystems 12 also communicate with

the subsystems control module 14 via signal line 13 to feedback information on subsystem status. In some embodiments, instead of an ePAS unit 12c, a hydraulically operated power steering unit may be provided.

The VCU 10 receives a plurality of signals, represented generally at 16 and 17, from a plurality of vehicle sensors that are representative of a variety of different parameters associated with vehicle motion and status. As described in further detail below, the signals 16, 17 provide, or are used to calculate, a plurality of driving condition indicators which are indicative of the nature of the condition in which the vehicle is travelling. One advantageous feature of some embodiments of the present invention is that the VCU 10 determines the most appropriate control mode for the various subsystems on the basis of the driving condition indicators, and automatically controls the subsystems accordingly. That is, the VCU 10 determines the most appropriate control mode on the basis of the driving condition indicators and automatically causes each of the subsystems 12 to operate in the respective subsystem configuration mode corresponding to that control mode.

The sensors (not shown) on the vehicle include, but are not limited to, sensors which provide continuous sensor outputs 16 to the VCU 10, including wheel speed sensors, an ambient temperature sensor, an atmospheric pressure sensor, tyre pressure sensors, yaw sensors to detect yaw, roll and pitch of the vehicle, a vehicle speed sensor, a longitudinal acceleration sensor, an engine torque sensor (or engine torque estimator), a steering angle sensor, a steering wheel speed sensor, a gradient sensor (or gradient estimator), a lateral acceleration sensor (part of a stability control system (SCS)), a brake pedal position sensor, an accelerator pedal position sensor and longitudinal, lateral and vertical motion sensors. In some other embodiments, only a selection of the aforementioned sensors may be used.

The VCU 10 also receives a signal from the electronic power assisted steering unit (ePAS unit 12c) of the vehicle 100 to indicate the steering force that is applied to the wheels (steering force applied by the driver combined with steering force applied by the ePAS unit 12c).

The vehicle 100 is also provided with a plurality of sensors which provide discrete sensor output signals 17 to the VCU 10, including a cruise control status signal (ON/OFF), a transfer box or PTU 137 status signal (whether the gear ratio is set to the high (HI) range or low (LO) range), a Hill Descent Control (HDC) status signal (ON/OFF), a trailer connect status signal (ON/OFF), a signal to indicate that the Stability Control System (SCS) has been activated

(ON/OFF), a windscreen wiper signal (ON/OFF), an air suspension ride-height status signal (HI/LO), and a Dynamic Stability Control (DSC) signal (ON/OFF).

The VCU 10 includes an evaluation means in the form of an estimator module or processor 18 and a calculation and selection means in the form of a selector module or processor 20. Initially the continuous outputs 16 from the sensors are provided to the estimator module 18 whereas the discrete signals 17 are provided to the selector module 20.

Within a first stage of the estimator module 18, various ones of the sensor outputs 16 are used to derive a number of driving condition indicators. In a first stage of the estimator module 18, a vehicle speed is derived from the wheel speed sensors, wheel acceleration is derived from the wheel speed sensors, the longitudinal force on the wheels is derived from the vehicle longitudinal acceleration sensor, and the torque at which wheel slip occurs (if wheel slip occurs) is derived at least in part from a knowledge of instantaneous engine torque. Other calculations performed within the first stage of the estimator module 18 include the wheel inertia torque (the torque associated with accelerating or decelerating the rotating wheels), “continuity of progress” (the assessment of whether the vehicle is starting and stopping, for example as may be the case when the vehicle is travelling over rocky terrain), aerodynamic drag, yaw rate, and lateral vehicle acceleration.

The estimator module 18 also includes a second stage in which the following driving condition indicators are calculated: surface rolling resistance (based on the wheel inertia torque, the longitudinal force on the vehicle, aerodynamic drag, and the longitudinal force on the wheels), the steering force on the steering wheel 181 (based on the lateral acceleration and the output from the steering wheel sensor), the wheel longitudinal slip (based on the longitudinal force on the wheels, the wheel acceleration, SCS activity and a signal indicative of whether wheel slip has occurred), lateral friction (calculated from the measured lateral acceleration and the yaw versus the predicted lateral acceleration and yaw), and corrugation detection (high frequency, low amplitude wheel height excitement indicative of a washboard type surface). A longitudinal surface coefficient of friction or ‘surface mu’ (that is, surface coefficient of friction in a longitudinal direction with respect to the vehicle) may also be calculated by the estimator module 18. In some alternative embodiments the value of surface mu may be received by the estimator module 18 and not calculated by the estimator module 18.

The SCS activity signal is derived from several outputs from an SCS ECU (not shown), which contains the DSC (Dynamic Stability Control) function, the TC (Traction Control)

function, ABS (Anti-Lock Braking System) and HDC algorithms, indicating DSC activity, TC activity, ABS activity, brake interventions on individual wheels, and engine torque reduction requests from the SCS ECU to the engine 121. All these indicate a slip event has occurred and the SCS ECU has taken action to control it. The estimator module 18 also uses the outputs from the wheel speed sensors to determine a wheel speed variation and corrugation detection signal.

On the basis of the windscreen wiper signal (ON/OFF), the estimator module 18 also calculates how long the windscreen wipers have been in an ON state (i.e. a rain duration signal).

The VCU 10 also includes a road roughness module 24 for calculating the terrain roughness based on the air suspension sensors (the ride height sensors) and the wheel accelerometers. A driving condition indicator signal in the form of a roughness output signal 26 is output from the road roughness module 24.

The estimates for the wheel longitudinal slip and the lateral friction estimation are compared with one another within the estimator module 18 as a plausibility check.

Calculations for wheel speed variation and corrugation output, the surface rolling resistance estimation, the wheel longitudinal slip and the corrugation detection, together with the friction plausibility check, are output from the estimator module 18 and provide driving condition indicator output signals 22, indicative of the nature of the terrain in which the vehicle is travelling, for further processing within the VCU 10.

The driving condition indicator signals 22 from the estimator module 18 are provided to the selector module 20 for determining which of a plurality of vehicle subsystem control modes (and therefore corresponding subsystem configuration modes) is most appropriate based on the indicators of the type of terrain in which the vehicle is travelling. The most appropriate control mode is determined by analysing the probability that each of the different control modes is appropriate on the basis of the driving condition indicator signals 22, 26 from the estimator module 18 and the road roughness module 24.

If an “automatic mode” or “automatic condition” of operation of the VCU 10 is selected, the vehicle subsystems 12 may be controlled automatically to operate in a given subsystem control mode in response to a control output signal 30 from the selector module 20 and without the need for driver input. In the present embodiment, if the VCU 10 is in the

automatic mode of operation the vehicle subsystems 12 are caused automatically to assume the subsystem control mode corresponding to the control output signal 30 from the selector module 20.

Alternatively, the vehicle subsystems 12 may be operated in a given subsystem control mode according to a manual user input (in a “manual mode” or “manual condition” of operation of the VCU 10) via the HMI module 32. In the manual mode of operation the user determines in which subsystem control mode the subsystems will be operated by selection of a required system control mode (operating mode). The HMI module 32 comprises a display screen (not shown) and a user operable switchpack 170. The user may select between the manual and automatic modes (or conditions) of operation of the VCU 10 via the switchpack 170. When the VCU 10 is operating in the manual mode or condition, the switchpack 170 also allows the user to select the desired subsystem control mode.

As described in more detail below, the engine management system 12a receives inputs from drive torque control module 60 in addition to subsystem controller 14.

It is to be understood that in some embodiments subsystem controller 14 may control the vehicle subsystems 12a-12e directly via the signal line 13, or alternatively each subsystem may be provided with its own associated intermediate controller (not shown in Figure 1) for providing control of the relevant subsystem 12a-12e. In the latter case the subsystem controller 14 may only control the selection of the most appropriate subsystem control mode for the subsystems 12a-12e, rather than implementing the actual control steps for the subsystems. The or each intermediate controller may in practice form an integral part of the main subsystem controller 14.

When operating in the automatic mode, the selection of the most appropriate subsystem control mode may be achieved by means of a three phase process:

(1) for each type of control mode, a calculation is performed of the probability that the control mode is suitable for the terrain over which the vehicle is travelling, based on the driving condition indicators;

(2) the integration of “positive differences” between the probability for the current control mode and the other control modes; and

(3) the program request to the control module 14 when the integration value exceeds a pre-determined threshold or the current terrain control mode probability is zero.

The specific steps for phases (1), (2) and (3) will now be described in more detail.

In phase (1), the continuous driving condition indicator signals in the form of the road surface roughness output 26 and the outputs 22 from the estimator module 18 are provided to the selector module 20. The selector module 20 also receives the discrete driving condition indicators 17 directly from various sensors on the vehicle, including the transfer box (PTU 137) status signal (whether the gear ratio is set to a HI range or a LO range), the DSC status signal, cruise control status (whether the vehicle's cruise control system 11 is ON or OFF), and trailer connect status (whether or not a trailer is connected to the vehicle). Driving condition indicator signals indicative of ambient temperature and atmospheric pressure are also provided to the selector module 20.

The selector module 20 is provided with a probability algorithm 20a for calculating the most suitable control mode for the vehicle subsystems 12a-e based on the discrete driving condition indicator signals 17 received directly from the sensors and the continuous driving condition indicators 22, 26 calculated by the estimator module 18 and the road surface roughness module 24, respectively. That is, the probability algorithm 20a calculates the most suitable system control mode, which determines the respective subsystem configuration mode in which each subsystem is to be operated, based on the discrete driving condition indicator signals 17 and the continuous driving condition indicators 22, 26.

The control modes typically include a grass/gravel/snow control mode (GGS mode) that is suitable for when the vehicle is travelling in grass, gravel or snow terrain, a mud/ruts control mode (MR mode) which is suitable for when the vehicle is travelling in mud and ruts terrain, a rock crawl/boulder mode (RC mode) which is suitable for when the vehicle is travelling in rock or boulder terrain, a sand mode which is suitable for when the vehicle is travelling in sand terrain (or deep soft snow) and a special programs OFF mode (SP OFF mode or SPO mode, also referred to as a Highway mode) which is a suitable compromise mode, or general mode, for all terrain conditions and especially vehicle travel on motorways and regular roadways. Many other control modes are also envisaged including those disclosed in US2003/0200016, the content of which is hereby incorporated by reference.

The different terrain types are grouped according to the friction of the terrain and the roughness of the terrain. For example, it is appropriate to group grass, gravel and snow

together as terrains that provide a low friction, smooth surface and it is appropriate to group rock and boulder terrains together as high friction, very high roughness terrains.

FIG. 4 is a table taken from US2003/0200016 showing the particular sub-system configuration modes that may be assumed by the subsystems 12 of a vehicle according to some embodiments of the invention in the respective different driving modes or operating modes in which the VCU 10 may operate in some embodiments. These operating modes may be considered to be sub-system control modes.

The driving modes are:

(a) A motorway (or highway) mode;
(b) A country road mode;
(c) A city driving (urban) mode;
(d) A towing (on-road) mode;
(e) A dirt track mode;
(f) A snow/ice (on-road) mode;
(g) A GGS mode;
(h) A sand mode;
(i) A rock crawl or boulder crossing mode (RC); and
(j) A mud/ruts (MR) mode

In the present embodiment, the vehicle 100 is limited to operating in the GGS mode, MR mode, RC mode, Sand mode and SPO (Highway) mode, however it will be appreciated that the invention is not limited to such an arrangement and any combination of on and off road control modes may be used within the scope of the present invention. In some embodiments the vehicle may have a 'Wade' mode in which vehicle handling is optimised for wading operations in which the vehicle travels through water. For example, in some embodiments, in the Wade mode the vehicle headlights are switched on, the suspension is raised to off-road height when the PTU 137 is in the 'high' range and cabin intake air vents are closed. In some embodiments the engine air cooling fan speed may be adjusted according to the prevailing conditions.

With reference to FIG. 4, the configuration of the suspension system 12e is specified in terms of ride height (high, standard or low) and side/side air interconnection. The suspension system 12e is a fluid suspension system, in the present embodiment an air suspension system, allowing fluid interconnection between suspensions for wheels on opposite sides of the vehicle in the manner described in US2003/0200016. The plurality of subsystem

configuration modes provide different levels of said interconnection, in the present case no interconnection (interconnection closed) and at least partial interconnection (interconnection open).

The configuration of the ePAS steering unit 12c may be adjusted to provide different levels of steering assistance, wherein steering wheel 181 is easier to turn the greater the amount of steering assistance. The amount of assistance may be proportional to vehicle speed in some driving modes. As shown in FIG. 4, the amount of assistance is 'speed proportional' in each mode shown except the Rock Crawl (RC) mode.

The brakes system 12d may be arranged to provide relatively high brake force for a given amount of pressure or 'effort' applied to the brake pedal 163 or a relatively low brake force, depending on the driving mode.

The brakes system 12d may also be arranged to allow different levels of wheel slip when an anti-lock braking system is active, depending on the surface coefficient of friction between wheels and the driving surface. For example, in some embodiments the brakes system 12d may allow relatively low amounts on low friction ("low-mu" surfaces) and relatively large amounts on high friction surfaces. In the case of fragile surfaces such as grass this may reduce the amount by which the surface is modified when wheel slip occurs during braking. In some alternative embodiments the brakes system 12d may allow relatively high amounts of slip on low friction ("low-mu" surfaces) and relatively small amounts on high friction surfaces.

An electronic traction control (ETC) system may be operated in a high mu or low mu configuration. In some embodiments the system may tolerate greater wheel slip in the low mu configuration before intervening in vehicle control compared with the high mu configuration. Other arrangements may be useful in some embodiments.

A dynamic stability control system (DSC) may also be operated in a high mu or low mu configuration. In some embodiments the system may tolerate a greater deviation from expected turn rate (yaw rate) for a given steering angle in the low mu configuration compared with the high mu configuration. Other arrangements may be useful in some embodiments.

The PTU 137 may be operated in a high range (HI) subsystem configuration mode or low range (LO) subsystem configuration mode as described herein.

In some embodiments, a centre differential and a rear differential each include a clutch pack and are controllable to vary the degree of locking between a "fully open" and a "fully locked" state. The actual degree of locking at any one time may be controlled on the basis of a number of factors in a known manner, but the control can be adjusted so that the differentials are "more open" or "more locked". Specifically the pre-load on the clutch pack can be varied which in turn controls the locking torque, i.e. the torque across the differential that will cause the clutch, and hence the differential, to slip. A front differential could also be controlled in the same or similar way.

For each driving mode (subsystem control mode), i.e. GGS, MR, RC, Sand or SPO in the present embodiment, the algorithm 20a within the selector module 20 performs a probability calculation, based on the driving condition indicators, to determine a probability that each of the different control modes is appropriate. The selector module 20 includes a tuneable data map which relates the continuous driving condition indicators 22, 26 (e.g. vehicle speed, road roughness, steering angle) to a probability that a particular control mode is appropriate. Each probability value typically takes a value of between 0 and 1. So, for example, the vehicle speed calculation may return a probability of 0.7 for the RC mode if the vehicle speed is relatively low, whereas if the vehicle speed is relatively high the probability for the RC mode will be much lower (e.g. 0.2). This is because it is much less likely that a high vehicle speed is indicative that the vehicle is travelling over a rock or boulder terrain.

In addition, for each subsystem control mode, each of the discrete driving condition indicators 17 (e.g. trailer connection status ON/OFF, cruise control status ON/OFF) is also used to calculate an associated probability for each of the control modes, GGS, RC, Sand, MR or SP OFF. So, for example, if cruise control is switched on by the driver of the vehicle, the probability that the SP OFF mode is appropriate is relatively high, whereas the probability that the MR control mode is appropriate will be lower.

For each of the different subsystem control modes, a combined probability value, Pb, is calculated based on the individual probabilities for that control mode, as described above, as derived from each of the continuous or discrete driving condition indicators 17, 22, 26. In the following equation, for each control mode the individual probability as determined for each driving condition indicator is represented by a, b, c, d…*n*. The combined probability value, Pb, for each control mode is then calculated according to the probability algorithm 20a as follows:

$$Pb = (a.b.c.d.\ldots.n) / ((a.b.c.d\ldots n) + (1\text{-}a).\ (1\text{-}b).\ (1\text{-}c).\ (1\text{-}d)\ldots.(1\text{-}n))$$

Any number of individual probabilities may be input to the probability algorithm 20a and any one probability value input to the probability algorithm may itself be the output of a combinational probability function.

Once the combined probability value for each control mode has been calculated, the subsystem control program corresponding to the control mode with the highest probability is selected within the selector module 20. The benefit of using a combined probability function based on multiple driving condition indicators is that certain indicators may make a control mode (e.g. GGS or MR) more or less likely when combined together, compared with basing the selection on just a single driving condition indicator alone.

The first step of the integration process is to determine whether there is a positive difference between the combined probability value for each of the alternative control modes compared with the combined probability value for the current control mode.

By way of example, assume the current control mode is GGS with a combined probability value of 0.5. If a combined probability value for the sand control mode is 0.7, a positive difference is calculated between the two probabilities (i.e. a positive difference value of 0.2). The positive difference value is integrated with respect to time. If the difference remains positive and the integrated value reaches a predetermined change threshold (referred to as the change threshold), or one of a plurality of predetermined change thresholds, the selector module 20 determines that the current terrain control mode (GGS) is to be updated to a new, alternative control mode (in this example, the sand control mode). A control output signal 30 is then output from the selector module 20 to the subsystem control module 14 to initiate the sand control mode for the vehicle subsystems.

In phase (3), the probability difference is monitored and if, at any point during the integration process, the probability difference changes from a positive value to a negative value, the integration process is cancelled and reset to zero. Similarly, if the integrated value for one of the other alternative control modes (i.e. other than the currently selected control mode, in the present example the sand control mode) reaches the predetermined change threshold before the probability result for the sand control mode, the integration process for the sand control mode is cancelled and reset to zero and the other alternative control mode, with a higher probability difference, is selected.

A further control signal 31 from the selector module 20 is provided to a control module 34. The outputs from the control module 34 to the subsystem control module 14 include a transfer box (PTU 137) setting signal 54 indicative of the setting (HI/LO) of the PTU 137, an air suspension setting signal 52 indicative of the air suspension configuration such as ride height, and a further signal 50. In the sub-system control module 14 a validation check or fault detection process 14a is carried out. The validation and fault detection process 14a operates so as to ensure that if one of the subsystems cannot support a selected control mode, for example because of a fault, appropriate action is taken (e.g. in the form of a warning).

As described above, the selector module 20 is configured to determine which of the plurality of control modes is most appropriate for a given set of driving condition indicators. When the VCU 10 is operated in the automatic mode, the VCU 10 causes the vehicle subsystems 12 to be operated in the control mode that is most appropriate to the current driving condition indicators. If the VCU 10 is operated in the manual mode, the VCU 10 causes the vehicle subsystems 12 to be operated in the control mode selected by the user.

As noted above, the engine management system 12a receives inputs from drive torque control module 60 in addition to subsystem controller 14. The function of the drive torque control module 60 will now be described.

In the present embodiment, the drive torque module 60 is implemented within the VCU 10. However in some alternative embodiments the module 60 may be implemented within a separate controller or module. In some embodiments the module 60 may be implemented within the engine management system 12a. The drive torque module 60 is configured to calculate values of parameters that are employed by the engine management system 12a to control the amount of torque generated by the engine 121. The drive torque module 60 receives the driving condition indicator signals 22, 26 from the estimator module 18 and the road roughness module 24, and the discrete signals 17. In addition, the drive torque module 60 receives a signal 161S from accelerator pedal 161 indicative of the amount by which accelerator pedal 161 has been depressed, in terms of percent of full stroke.

The drive torque module 60 is configured to generate a set of seven ‘modifier factors’, the value of each of which is calculated in dependence on the value of an associated discrete or continuous driving condition indicator received via signals 17, 22, 26 as shown in FIG. 3. The driving condition indicators received and employed are:

(i) Ambient temperature, A_T
(ii) Surface roughness, R_rough
(iii) Rolling resistance, R_res
(iv) Surface coefficient of friction, S_fric
(v) Driving surface gradient, R_grad
(vi) Suspension articulation, A
(vii) Ambient pressure, A_p

The corresponding modifier factors associated with each driving condition indicator and which are calculated by the drive torque module 60 are:

(i) Ambient temperature, A_T_mod
(ii) Surface roughness, R_rough_mod
(iii) Rolling resistance, R_res_mod
(iv) Surface coefficient of friction, S_fric_mod
(v) Driving surface gradient, R_grad_mod
(vi) Suspension articulation, A_mod
(vii) Ambient pressure, A_p_mod

The drive torque module 60 stores a set of one or more multiplier values for each driving condition indicator for each of the control modes of the vehicle. In use, the drive torque module 60 selects the set of one or more multiplier values for the prevailing control mode as determined by reference to the control output signal 30 generated by the selector module 20. The module 60 then calculates the value of each of the seven modifier factors that are to be multiplied together. The drive torque module 60 multiplies the value (in percent of full stroke) of signal 161S by each of the modifier factors in order to generate a 'scaled' accelerator pedal output signal 161SC.

Where the set of one or more multiplier values of a particular control mode has only a single multiplier value, that single multiplier value is used as the modifier factor for the corresponding driving condition indicator. Where the set of one or more multiplier values of a particular control mode has a plurality of multiplier values, one for each of a predetermined range of possible values of the driving condition indicator, the multiplier value corresponding to the value of the prevailing value of the corresponding driving condition indicator is selected to be the modifier factor to be employed. By way of example, FIG. 5 illustrates the manner in which the drive torque module 60 of the present embodiment calculates the value

of signal 161SC based on signal 161S input thereto. For the illustrated example, the vehicle is operating in the Sand driving mode (terrain response (RTM) mode).

To calculate the required ambient temperature modifier factor, A_T_mod, the drive torque module extracts from a memory of the module the value of parameter A_T_mod corresponding to the prevailing value of ambient temperature A_T received via one of the signals 17, 22, 26 input thereto. In the example shown in FIG. 5 the driving condition indicator values are as follows:

(i) Ambient temperature, A_T = 35C
(ii) Surface roughness, R_rough = 10 units
(iii) Rolling resistance, R_res = 4000 units
(iv) Surface coefficient of friction, S_fric = 0.9
(v) Driving surface gradient, R_grad = 5%
(vi) Suspension articulation, A = 0
(vii) Ambient pressure, A_p = 900mbar

The drive torque module 60 determines the value of the corresponding modifier factor for each of the driving condition indicators based on the value of each driving condition indicator. With reference to FIG. 5 these values are:

(i) Ambient temperature, A_T_mod = 1
(ii) Surface roughness, R_rough_mod = 1
(iii) Rolling resistance, R_res_mod = 1.3
(iv) Surface coefficient of friction, S_fric_mod = 0.9
(v) Driving surface gradient, R_grad_mod = 1.05
(vi) Suspension articulation, A_mod = 1
(vii) Ambient pressure, A_p_mod = 1

The above modifier factor values are multiplied by one another to generate a scale factor F. The prevailing value of accelerator pedal raw signal 161S (20%) is then multiplied by the scale factor F to produce a scaled accelerator pedal signal 161SC. This value is output to the engine management system 12a. Thus:

$$161SC = F \times 161S,$$

where

F = f (A_T_mod, R_rough_mod, R_res_mod, S_fric_mod, R_grad_mod, A_mod, A_p_mod)

As noted above, in the present embodiment F is given by the product of each of the modifiers, i.e.:

F = A_T_mod x R_rough_mod x R_res_mod x S_fric_mod x R_grad_mod x A_mod x A_p_mod

In the example given above, using the values provided:

161SC = 20 x 1.23 = 24.6%

Thus, a pedal depression of 20% of full scale travel would translate to a depression of 24.6% for the prevailing driving condition indicators, in the Sand driving mode. It is to be understood that the values of the modifiers may be different in different driving modes, in order to permit further optimisation of the engine response to accelerator pedal depression, in some embodiments.

The scaled accelerator pedal signal 161SC is then converted to a torque demand signal TQ_demand that is output by the drive torque module 60 to the engine management system 12a via signal 62S. A portion of the engine management system 12a is illustrated in FIG. 6. As can be seen from FIG. 6, the engine management system 12a includes a drivability filter DRF to which the torque demand signal TQ_demand is applied. The drivability filter DRF has two time constants associated with it that are also controlled by the drive torque module 60, being (1) an accelerator pedal depression time constant, DRFC_D, employed by the filter to damp the response of the engine to depression of the accelerator pedal 161 (increase in torque), and (2) an accelerator pedal release time constant, DRFC_R, employed by the filter to damp the response of the engine to release of the accelerator pedal 161 (decrease in torque). The drivability filter DRF outputs a signal TQ_inst corresponding to the instant amount of torque that is to be generated by the engine 121 at a given moment in time. The value of instant torque TQ_inst is input to an engine controller 121C that in turn causes the engine 121 to develop an amount of torque corresponding to the value of TQ_inst.

In the present embodiment, the drive torque module 60 is configured to calculate the value of the drivability filter time constants for accelerator pedal depression DRFC_D and accelerator pedal release DRFC_R based on the prevailing values of the same driving

condition indicators employed to generate the scaled accelerator pedal output signal 161SC. The module also takes into account engine speed W when calculating DRFC_D and DRFC_R.

The manner of calculation of the drivability filter time constants DRFC_D, DRFC_R will now be described with respect to FIG. 7, which shows an example of a calculation of the drivability filter time constants for accelerator pedal depression DRFC_D in one particular scenario. In the example shown in FIG. 7, the vehicle is operating in the automatic driving mode selection mode, and the VCU 10 has determined that the GGS driving mode is most appropriate based on the prevailing values of the driving condition indicators. Accordingly, the drive torque module 60 has selected values of driving condition indicator modifier that are associated with the GGS mode. This may be referred to as the 'GGS calibration' or 'GGS cal'. In the example shown, each driving condition indicator has a number of modifiers associated therewith, corresponding to different ranges of values of the driving condition indicator. The drive torque module 60 determines, for each of the driving condition indicators, the value of modifier parameter that is to be used to calculate a factor that is subsequently used to modify a default value of each of the drivability filter time constants, DRFC_D_default, DRFC_R_default, to obtain scaled values of the time constants, DRFC_D_SC, DRFC_R_SC. The drive torque module 60 calculates values of DRFC_D_SC and DRFC_R_SC and outputs them to the engine management system 12a. In some embodiments, the drive torque module 60 may simply output the value of the factor rather than the actual value of drivability filter time constant. In some embodiments, the factor itself may be arranged to be the value of one of the drivability filter time constants.

In the example shown in FIG. 7, the driving condition indicators have the following values:

(i) Ambient temperature, A_T = -5C
(ii) Surface roughness, R_rough = 10 units
(iii) Rolling resistance, R_res = 500 units
(iv) Surface coefficient of friction, S_fric = 0.4
(v) Driving surface gradient, R_grad = 5%
(vi) Suspension articulation, A = 0
(vii) Ambient pressure, A_p = 1000mbar

As noted above, the drive torque module 60 also employs the value of engine speed, W, to generate an engine speed modifier W_mod.

The module 60 employs the values of these parameters to determine the value of modifier parameter to be employed to calculate the scaled values of the time constants, DRFC_D_SC, DRFC_R_SC. In the example of FIG. 7 the modifier values that are calculated are as follows:

(i) Engine speed, W_mod = 1 (W = 2000rpm)
(ii) Ambient temperature, A_T_mod = 1.05
(iii) Surface roughness, R_rough_mod = 1
(iv) Rolling resistance, R_res_mod = 1
(v) Surface coefficient of friction, S_fric_mod = 1.1
(vi) Driving surface gradient, R_grad_mod = 1
(vii) Suspension articulation, A_mod = 1
(viii) Ambient pressure, A_p_mod = 1

The drive torque module 60 calculates the product of each of these modifiers, F, being 1.2, and multiplies the value of DRFC_D_default by F to generate the scaled value of DRFC_D_default, DRFV_D_SC:

DRFC_D_SC = F x DRFC_D_default = 1.2 x DRFC_D_default

In an analogous manner, the drive torque module 60 also calculates the value of DRFC_R_SC based on a set of modifier values for accelerator pedal release, and outputs the value of DRFC_R_SC to the engine management system 12a via signal 62S.

It is to be understood that, in some embodiments, the calculated values of signal TQ_demand, DRFC_D_SC and DRFC_R_SC may be output to the engine management system 12a for a predetermined time period before fresh values are calculated and output. The predetermined time period may be 0.5s, 1s, 5s, 10s or any other suitable value. In some alternative embodiments, the drive torque module 60 repeatedly calculates values of the signal TQ_demand, DRFC_D_SC and DRFC_R_SC and outputs fresh values. In the present embodiment, the drive torque module 60 repeatedly calculates values of the signal TQ_demand, DRFC_D_SC and DRFC_R_SC but outputs fresh values of a given signal only when the value of the signal changes by more than a predetermined amount relative to the prevailing value being output. In the present embodiment, the predetermined amount is substantially 10%.

FIG. 8 illustrates schematically the manner in which the amount of torque generated by the engine 121 as a function of accelerator pedal input is arranged to depend upon the selected driving mode.

At step S201, the driver depresses the accelerator pedal 161 of the vehicle 100 and an accelerator pedal position signal (signal 161S, FIG. 3) indicative of the extent of the depression is received by the VCU 10.

The VCU 10 also receives the continuous and discrete driving condition indicators 17, 22, 26 at step S203a of FIG. 8. The driving condition indicator signals are subject to low pass filtering at step S203b and at step S203c the VCU 10 scales the accelerator pedal position signal according to the driving condition indicator signals in order to generate a scaled accelerator pedal output signal 161SC. The manner in which the scaled accelerator pedal output signal 161SC is generated is discussed in more detail above with reference to FIG. 5.

The VCU 10 also receives a signal W indicative of engine speed. At step S205 the scaled pedal output signal 161SC, in combination with the signal W indicative of engine speed, is converted to an engine torque demand signal.

At step S207, the VCU 10 implements a function that controls the rate of rise or fall of the torque demand signal TQ_demand generated by the controller at step S205 in dependence on the low pass filtered driving condition indicator signals generated at step S203b and the current engine speed signal W. In some embodiments, if more recently generated low pass filtered driving condition indicator signals to those generated at step S203b are available when step S207 is performed, the more recently generated signals are employed at step S207.

At step S209 the controller outputs the signal generated at step S207 as an engine torque request output signal TQ_inst as illustrated in FIG. 6.

Embodiments of the present invention have the advantage that the response of the engine 121 to accelerator pedal input may be further optimised when the vehicle 100 is operating in a given driving mode, in response to receipt of the driving condition indicator signals. It is to be understood that a substantial refinement in a user's driving experience may be enjoyed, for a given set of driving condition indicator signals, compared with vehicles in which a fixed engine response is employed when the vehicle is operating in a given driving mode.

It will be understood that the embodiments described above are given by way of example only and are not intended to limit the invention, the scope of which is defined in the appended claims.

Throughout the description and claims of this specification, the words “comprise” and “contain” and variations of the words, for example “comprising” and “comprises”, means “including but not limited to”, and is not intended to (and does not) exclude other moieties, additives, components, integers or steps.

Throughout the description and claims of this specification, the singular encompasses the plural unless the context otherwise requires. In particular, where the indefinite article is used, the specification is to be understood as contemplating plurality as well as singularity, unless the context requires otherwise.

Features, integers, characteristics, compounds, chemical moieties or groups described in conjunction with a particular aspect, embodiment or example of the invention are to be understood to be applicable to any other aspect, embodiment or example described herein unless incompatible therewith.

The reader's attention is directed to all papers and documents which are filed concurrently with or previous to this specification in connection with this application and which are open to public inspection with this specification, and the contents of all such papers and documents are incorporated herein by reference.

CLAIMS:

1. A vehicle control system for at least one vehicle subsystem of a vehicle, the vehicle control system comprising:

a subsystem controller for initiating control of the or each vehicle subsystem in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle, and

means for receiving and/or generating at least one driving condition indicator,

wherein whilst the or each vehicle subsystem is operated in the selected one of the plurality of subsystem control modes, the control system is configured to control a response of an engine of the vehicle to drive torque demand in dependence at least in part on the at least one driving condition indicator, and to adjust the engine response in dependence on changes in the at least one driving condition indicator.

2. A control system according to claim 1 comprising evaluation means configured to evaluate at least one driving condition indicator and determine the most appropriate state or value of at least one control parameter of at least one vehicle subsystem, the subsystem controller being configured to adjust the state or value of said at least one control parameter in dependence on the most appropriate state or value determined by the evaluation means.

3. A control system according to claim 2 wherein the evaluation means is further configured to evaluate at least one driving condition indicator to determine the extent to which each of the subsystem control modes is appropriate and provide an output indicative of the subsystem control mode that is most appropriate, the subsystem controller being configured to initiate automatically control of the or each of the vehicle subsystems in the subsystem control mode that is most appropriate.

4. A control system according to any one of claims 1 to 3 configured to control a response of the engine of the vehicle to drive torque demand at least in part in dependence on a raw drive demand signal indicative of drive torque demand from at least one of a user-operable drive demand control and an automatic speed control system.

5. A control system according to claim 3 configured to control the response of the engine to drive torque demand in dependence at least in part on a raw drive torque demand signal generated in dependence at least in part on the position of a user-movable element of a user-operable drive demand control relative to a range of allowable positions thereof, and engine speed.

6. A control system according to claim 4 or claim 5 wherein the user-operable drive demand control comprises a pedal.

7. A control system according to any one of claims 4 to 6 configured to generate a scaled drive demand signal in dependence on the raw drive demand signal according to a predetermined relationship between scaled drive demand signal and raw drive demand signal, the scaled drive demand signal being employed to determine an instant value of drive torque to be developed by the engine.

8. A control system according to claim 7 wherein the scaled drive demand signal is applied to a drivability reference filter, an output of the drivability reference filter being employed to generate an output corresponding to the instant value of drive torque to be developed by the engine.

9. A control system according to any one of claims 4 to 8 wherein the raw drive demand signal is applied to a drivability reference filter, an output of the drivability reference filter being employed to generate an output corresponding to the instant value of drive torque to be developed by the engine.

10. A control system according to claim 8 or claim 9 configured to control a response of the engine to drive torque demand in dependence at least in part on the at least one driving condition indicator by controlling a rate of increase of the output of the drivability reference filter as a function of rate of increase of the drive torque demand signal applied to the input thereof, in dependence at least in part on the at least one driving condition indicator.

11. A control system according to claim 8 or claim 9 configured to control a response of the engine to drive torque demand in dependence at least in part on the at least one driving condition indicator by controlling a rate of decrease of the output of the drivability reference filter as a function of rate of decrease of the drive torque demand signal applied to the input thereof, in dependence at least in part on the at least one driving condition indicator.

12. A control system according to any preceding claim wherein the control modes comprise at least one control mode adapted for driving on a driving surface of relatively low surface coefficient of friction.

13. A control system according to claim 12 wherein the control modes comprise at least one driving mode adapted for driving on at least one of a snowy surface, an icy surface, grass, gravel, snow, mud and sand.

14. A control system according to any preceding claim wherein the subsystems include at least one of a powertrain subsystem, a brakes subsystem, a power assisted steering (PAS) subsystem and a suspension subsystem.

15. A control system according to any preceding claim comprising an electronic processor having an electrical input for receiving a signal indicative of at least one said driving condition indicator, and an electronic memory device electrically coupled to the electronic processor and having instructions stored therein,

wherein the processor is configured to access the memory device and execute the instructions stored therein such that it is operable to:

control a response of an engine of the vehicle to drive torque demand in dependence at least in part on the at least one driving condition indicator, and

whilst the at least one vehicle subsystem is operated in the selected one of the plurality of subsystem control modes, adjust the response of the engine to drive torque demand in dependence at least in part on changes in the at least one driving condition indicator.

16. A control system according to claim 15 wherein the processor is configured to access the memory device and execute the instructions stored therein such that it is operable to: evaluate at least one driving condition indicator and determine the most appropriate state or value of at least one control parameter of at least one vehicle subsystem and adjust the state or value of said at least one control parameter in dependence on the most appropriate state or value determined by the evaluation means.

17. A vehicle comprising a control system according to any preceding claim.

18. A method of controlling at least one vehicle subsystem of a vehicle by means of a control system, the method comprising:

initiating control of the at least one vehicle subsystem in a selected one of a plurality of subsystem control modes, each of which corresponds to one or more different driving conditions for the vehicle; and

whilst the or each vehicle subsystem is operated in the selected one of the plurality of subsystem control modes, controlling a response of an engine of the vehicle to drive torque

demand in dependence at least in part on the at least one driving condition indicator, and adjusting the engine response in response to changes in the at least one driving condition indicator.

19. A method according to claim 18 comprising evaluating at least one driving condition indicator and determine the most appropriate state or value of at least one control parameter of at least vehicle subsystem and adjusting the state or value of said at least one control parameter in dependence on the most appropriate state or value determined by the evaluation means.

20. A method according to claim 18 or 19 comprising controlling a response of the engine of the vehicle to drive torque demand at least in part in dependence on a raw drive demand signal indicative of drive torque demand from at least one of a user-operable drive demand control and an automatic speed control system.

21. A method according to any one of claims 18 to 20 comprising controlling the response of the engine to drive torque demand in dependence at least in part on a raw drive torque demand signal generated in dependence at least in part on the position of a user-movable element of a user-operable drive demand control relative to a range of allowable positions thereof, and engine speed.

22. A method according to claim 21 wherein the user-operable drive demand control comprises a pedal.

23. A method according to claim 21 or 22 comprising generating a scaled drive demand signal in dependence on the raw drive demand signal according to a predetermined relationship between scaled drive demand signal and raw drive demand signal, and determining an instant value of drive torque to be developed by the engine based on the scaled drive demand signal.

24. A method according to claim 23 comprising applying the scaled drive demand signal to a drivability reference filter, and causing the engine to develop an amount of torque corresponding to the output of the drivability reference filter.

25. A method according to any one of claims 21 to 24 comprising applying the raw drive demand signal to a drivability reference filter, and causing the engine to develop an amount of torque corresponding to the output of the drivability reference filter.

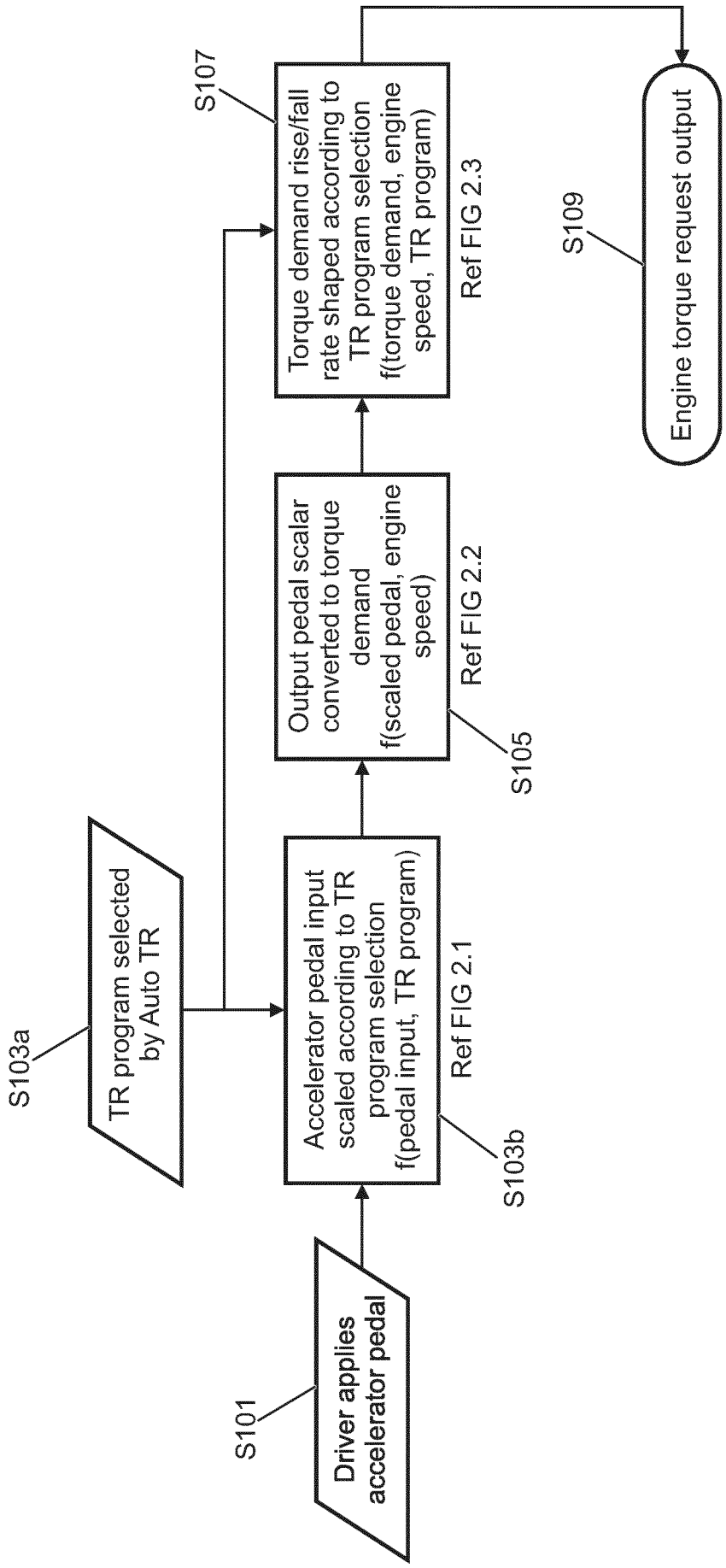
26. A non-transitory computer readable carrier medium carrying a computer readable code for controlling a vehicle to carry out the method according to any one of claims 18 to 25.

27. A computer program product executable on a processor so as to implement the method of any one of claims 18 to 25.

28. A computer readable medium loaded with the computer program product of claim 27.

29. A processor arranged to implement the method of any one of claims 18 to 25, or the computer program product of claim 27.

30. A control system, vehicle, method, non-transitory computer readable carrier medium, computer program product, computer readable medium or processor substantially as hereinbefore described with reference to the accompanying drawings.



PRIOR ART

FIGURE 1

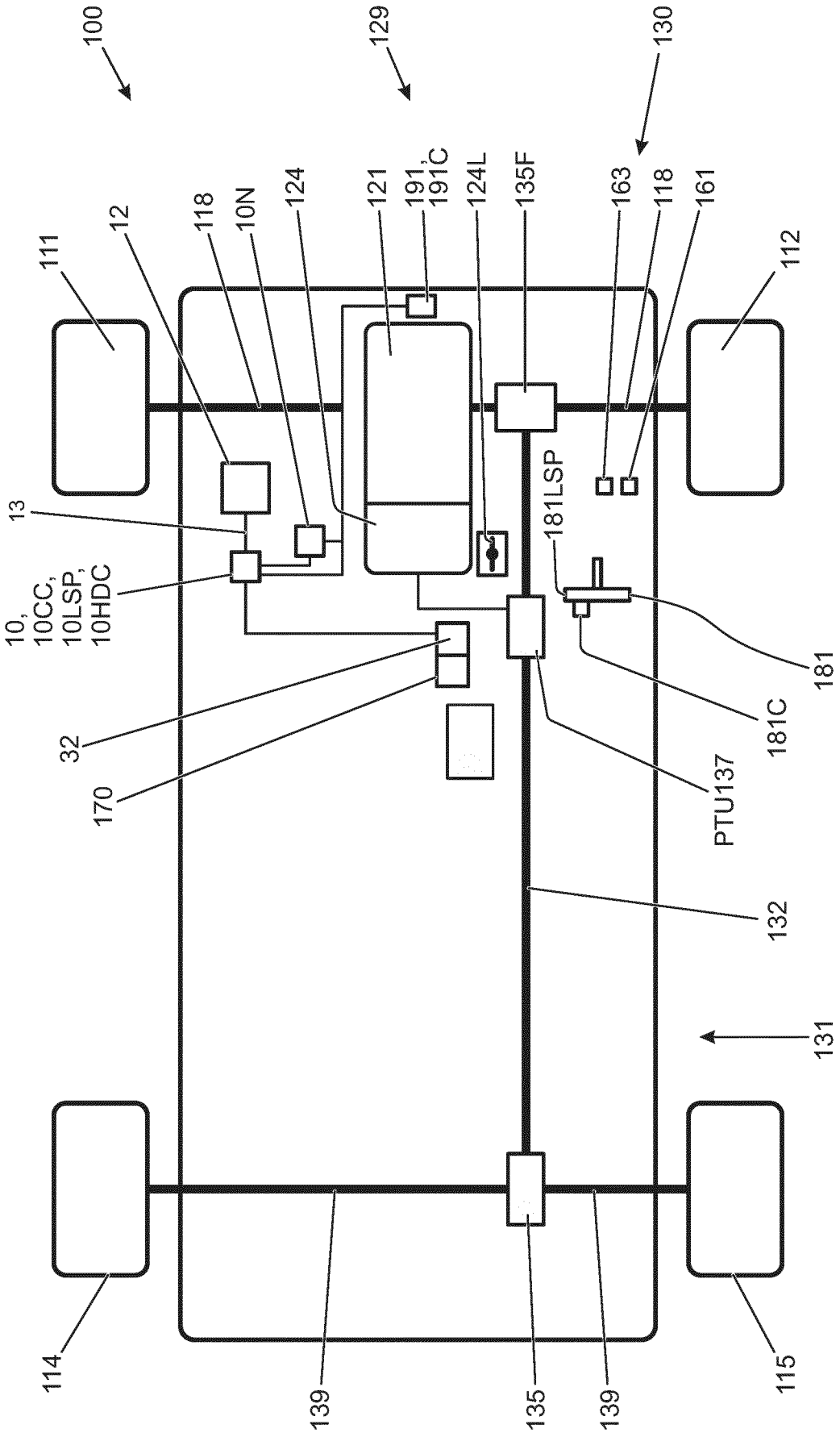

100
129
130
111
12
118
10N
124
121
191,
191C
124L
135F
163
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161
112
13
10,
10CC,
10LSP,
10HDC
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181LSP
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181C
PTU137
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Figure 2

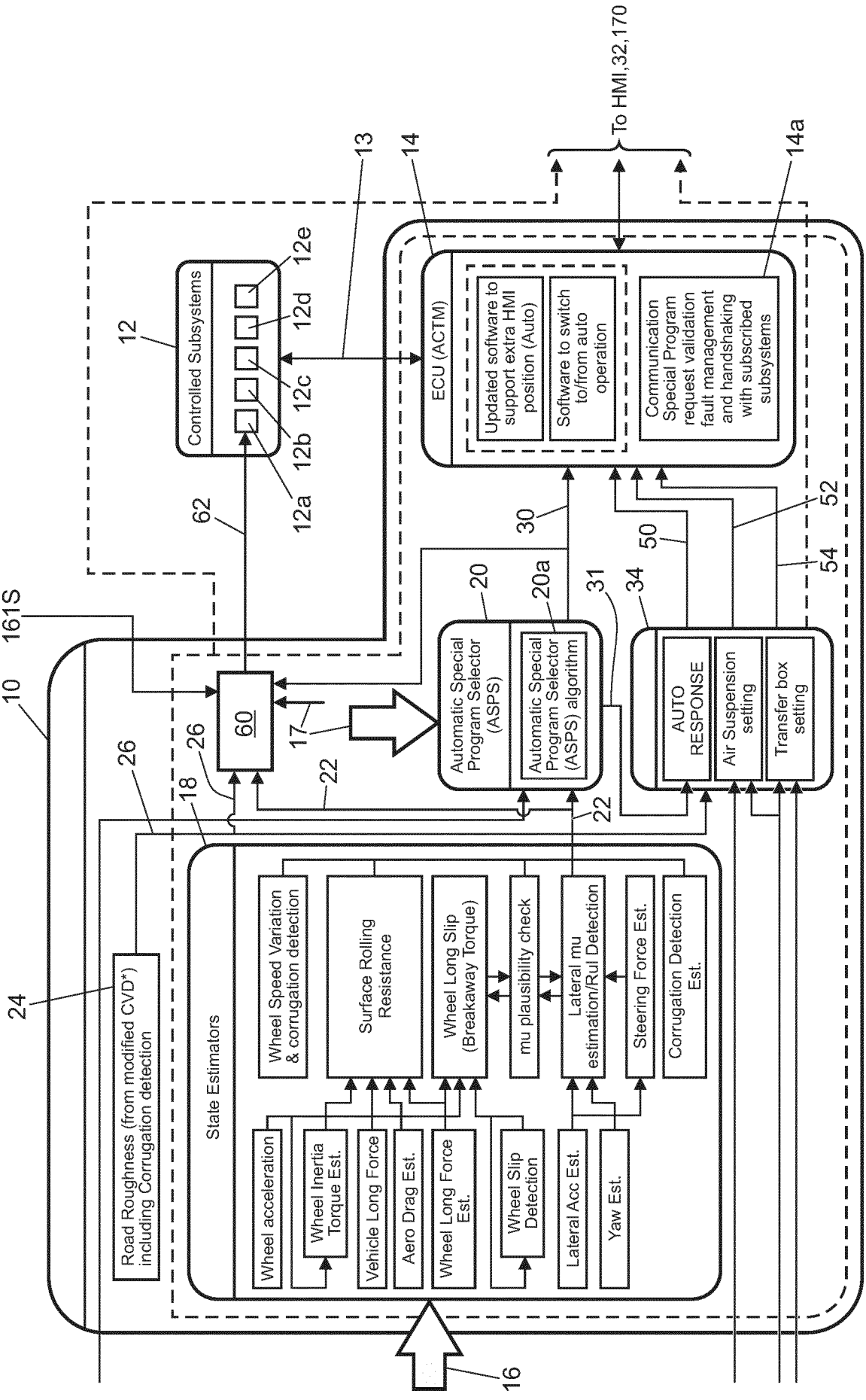

To HMI,32,170
13
14
14a
12
Controlled Subsystems
12e
12d
12c
12b
12a
62
ECU (ACTM)
Updated software to support extra HMI position (Auto)
Software to switch to/from auto operation
Communication Special Program request validation fault management and handshaking with subscribed subsystems
30
50
52
54
161S
10
60
17
20
20a
31
34
Automatic Special Program Selector (ASPS)
Automatic Special Program Selector (ASPS) algorithm
AUTO RESPONSE
Air Suspension setting
Transfer box setting
26
18
22
24
Road Roughness (from modified CVD*) including Corrugation detection
State Estimators
Wheel acceleration
Wheel Inertia Torque Est.
Vehicle Long Force
Aero Drag Est.
Wheel Long Force Est.
Wheel Slip Detection
Lateral Acc Est.
Yaw Est.
Wheel Speed Variation & corrugation detection
Surface Rolling Resistance
Wheel Long Slip (Breakaway Torque)
mu plausibility check
Lateral mu estimation/Rul Detection
Steering Force Est.
Corrugation Detection Est.
16

Fig. 3

Column Titles Key (CT1 to CT10)
PAGE 9

		CT1	CT2	CT3	CT4	CT5	CT6	CT7	CT8	CT9	CT10
Suspension Ride Height	High									X	
	Standard		X	X	X	X	X	X	X		X
	Low	X									
Side / Side Air Interconnection	Closed	X	X	X	X	X	X				
	Open							X	X	X	X
Steering Assistance	High	SP	SP	SP	SP	SP	SP	SP	SP	X	SP
	Low										
Brake Pedal Efforts	High	X	X			X	X	X	X		X
	Low		(X)	X	X					X	
A.B.S. Mode	High mu	X	X	X	X					X	
	Low mu					X	X	X			X
	Plough Surface								X		
E.T.C. Mode	High mu	X (2)	X	X	X						
	Low mu					X	X	X		X	X
D.S.C. Mode	High mu	X	X	X	TM					X	
	Low mu					X	X	X	X		X
Throttle Progression	Quick		(X)		(X)				X		
	Slow	X	X	X	X	X	X	X		X	X
Transfer Box	High Range	X	X	X	X	X	X				
	Low Range							X	X	X	X
Centre Diff Lock	Open	X	X	X	X	X	X				
	Locked							X	X	X	X
Rear Diff Lock	Open	X	X	X	X	X	X	X	(X)		
	Locked									X	X

SP = Speed Proportional
TM = Towing Mode

FIGURE 4

Case 3

Vehicle driving across sand

Ambient temp	Surface roughness	Rolling resistance	Surface friction	Road gradient	Articulation	Ambient Pressure
35 deg C	10	4000	0.9%	5%	Negligible	900 mBar

1 Auto TR algorithm determines the Sand program to have the highest probability of appropriate use Therefore Sand cal enabled

2 Submitted idea uses state estimators to evaluate:

Driver pedal input		(A_T) Ambient temp	A_T_mod Modifier		R_rough Surface roughness	R_rough_mod Modifier		R_res Rolling resistance	R_res_mod Modifier		S_fric Surface friction	S_fric_mod Modifier	
20%		-30	0.8		0	1		0	1		0	0.7	
		-15	0.85		10	1		500	1		0.2	0.75	
		-5	0.95		20	1.05		1000	1.05		0.4	0.85	
	X	-3	0.97	X	30	1.1	X	1500	1.05	X	0.6	0.9	X
		0	1		40	1.1		2000	1.1		0.8	0.9	
		3	1		50	1		3000	1.2		1	1	
		5	1		75	0.9		4000	1.3				
		10	1		100	0.9		5000	1.3				
		20	1					6000	1.3				
		30	1					8000	1.3				
		40	1										

Continued

R_grad Road gradient	R_grad_mod Modifier		A Articulation	A_Mod Modifier		A_p Ambient pressure	A_p_mod Modifier		Calculated/scaled pedal output
-20	0.95		0	1		700	1.1		25.9%
-10	0.95		20	1		800	1.1		
0	1		40	1		900	1		
5	1.05	X	60	0.95	X	1000	1	=	
10	1.05		80	0.9					
20	1.1		100	0.9					
30	1.1								

FIGURE 5

FIGURE
Example of pedal calculation using invention disclosure method

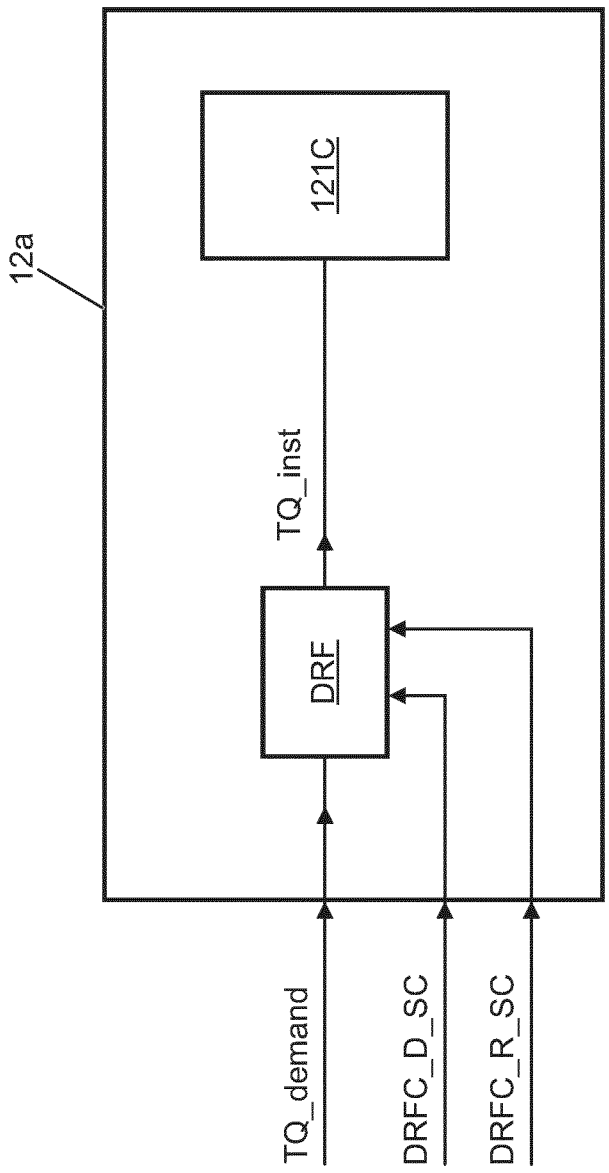


FIGURE 6

Case 1

Vehicle driving across snow

Ambient temp	Surface roughness	Rolling resistance	Surface friction	Road gradient	Articulation	Ambient pressure
-5 deg C	10	500	0.4%	5%	Negligible	1000 mBar

1 Auto TR algorithm determines the Grass Gravel Snow program to have the highest probability of appropriate use Therefore Grass Gravel Snow cal enabled

2 Submitted idea uses state estimators to evaluate:

W Engine speed input	W-mod		A_T Ambient temp	A_T_mod Modifier		R_rough Surface roughness	R_rough_mod Modifier		R_res Rolling resistance	R_res_mod Modifier		S_fric Surface friction	S_fric_mod Modifier	
500	1		-30	1.1		0	1		0	1		0	1.2	
1000	1		-15	1.1		10	1		500	1		0.2	1.2	
1500	1		-5	1.05		20	0.95		1000	1.05		0.4	1.1	
2000	1	X	-3	1	X	30	0.9	X	1500	1.05	X	0.6	0.9	X
2500	1.05		0	1		40	0.8		2000	1.1		0.8	0.9	
3000	1.05		3	1		50	0.8		3000	1.1		1	1	
3500	1.1		5	1		75	0.8		4000	1.2				
4000	1.1		10	1		100	0.8		5000	1.2				
5000	1.2		20	1					6000	1.2				
6000	1.2		30	1					8000	1.2				
			40	1										

Continued

R_grad Road gradient	R_grad_mod Modifier		A Articulation	A_Mod Modifier		A_P Ambient pressure	A_P_mod Modifier		F Calculated/scaled DRF time constant
-20	0.9		0	1		700	1.1		1.2(-)
-10	0.95		20	1		800	1.1		
0	1		40	1		900	1		
5	1	X	60	0.95	X	1000	1	=	
10	1		80	0.9					
20	0.95		100	0.9					
30	0.9								

FIGURE 7

FIGURE
Example of DRF time constant calculation using invention disclosure method
(Note modifiers for DRF calculation are separate to pedal calculation)

FIG3 - Invention disclosure for greater flexibility in pedal scaling and torque shaping within PCM

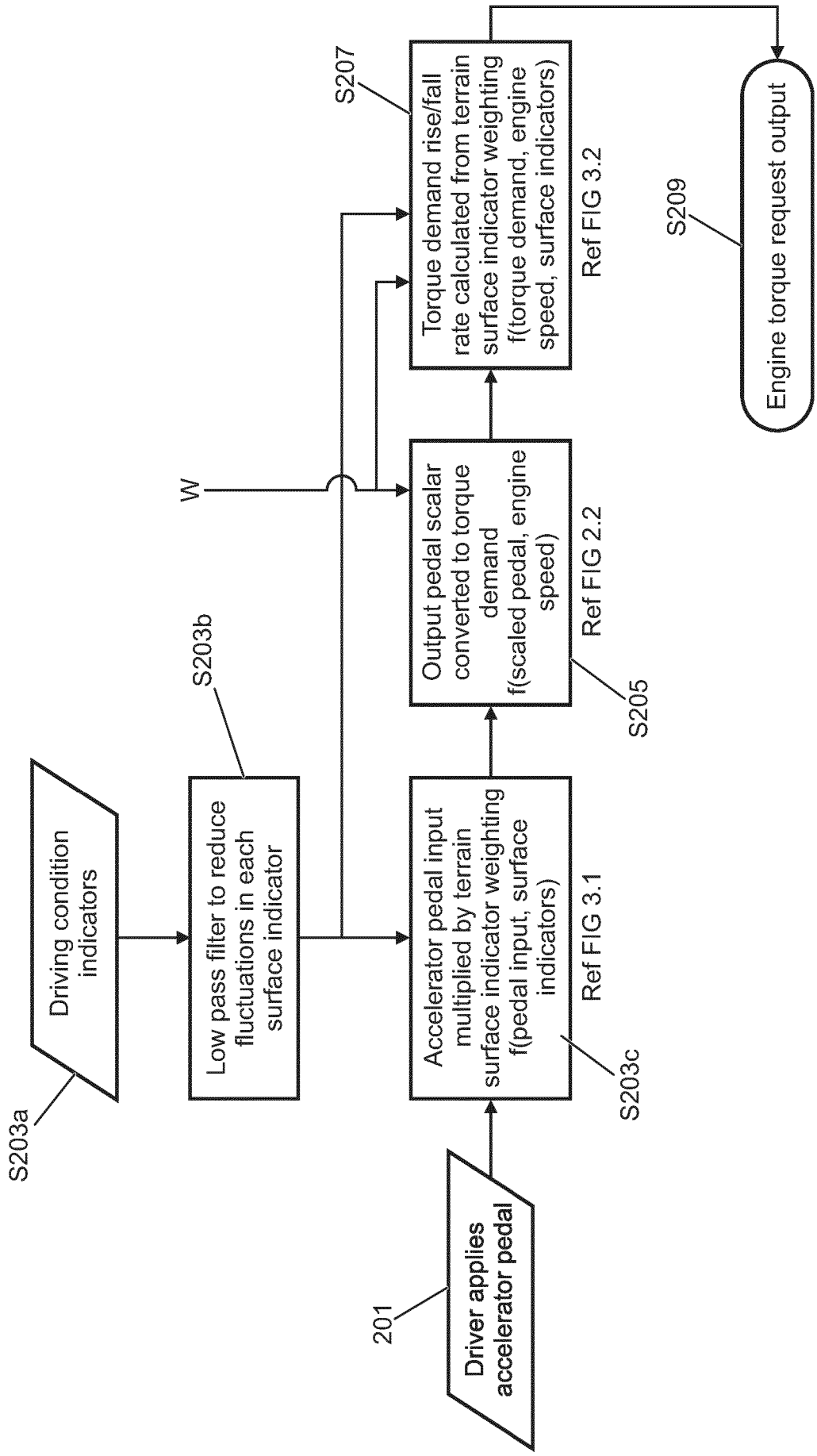


FIGURE 8

Column Titles Key (CT1 to CT10)

CT1	Motorway
CT2	Country Road
CT3	City Driving
CT4	Towing (on Road)
CT5	Dirt Track (Developing World Road)
CT6	Snow / Ice (Scandinavian / North American conditions)
CT7	Grass / gravel / snow
CT8	Sand
CT9	Rock Crawl / Boulder Crossing
CT10	Mud & ruts

FIGURE 4 continued

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/051432

A. CLASSIFICATION OF SUBJECT MATTER
INV. B60W10/04 B60W10/10 B60W10/12 B60W10/18 B60W10/20
B60W10/22 B60W30/02
ADD. B60W50/00
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)
B60W

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014/121929 A1 (MUROFUSHI TORU [JP]) 1 May 2014 (2014-05-01)	1,2,4,6, 12-20, 22,26-29
Y	figure 3	5,21

X	WO 2014/037541 A1 (JAGUAR LAND ROVER LTD [GB]) 13 March 2014 (2014-03-13) the whole document page 24, paragraph 1	1-4,6, 12-20, 22,26-29

Y	FR 3 008 055 A1 (PEUGEOT CITROEN AUTOMOBILES SA [FR]) 9 January 2015 (2015-01-09) page 4, lines 24-31; claim 1	5,21

☐ 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 but 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	Date of mailing of the international search report
13 April 2017	27/06/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Plenk, Rupert

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2017/051432

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☒ Claims Nos.: 30
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

see FURTHER INFORMATION sheet PCT/ISA/210

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-6, 12-22(completely); 26-29(partially)

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-6, 12-22(completely); 26-29(partially)

   vehicle control system and method providing an engine response depending on a driving condition indicator

   ---

2. claims: 7-11, 23-25(completely); 26-29(partially)

   processing the drive demand signal, using a raw signal, a scaled signal and/or a drivability filter
   Claims 26 to 29 can be placed in either group, due to their dependency. However, these claims do not include additional technical features. They have therefore been indicated as partial searched in both groups.

Continuation of Box II.2

Claims Nos.: 30

Claim 30 does not include technical features, but a reference to the drawings, contrary to Rule 6.2(a) PCT).

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guidelines C-IV, 7.2), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2017/051432

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2014121929 A1	01-05-2014	CN 103770787 A	07-05-2014
		DE 102013111565 A1	30-04-2014
		JP 2014084018 A	12-05-2014
		US 2014121929 A1	01-05-2014
WO 2014037541 A1	13-03-2014	AU 2013311582 A1	23-04-2015
		CN 104736408 A	24-06-2015
		EP 2892779 A1	15-07-2015
		GB 2508689 A	11-06-2014
		JP 2015534519 A	03-12-2015
		US 2015203119 A1	23-07-2015
		WO 2014037541 A1	13-03-2014
FR 3008055 A1	09-01-2015	NONE	