Title: ROUTE RECOGNITION APPARATUS AND METHOD

Abstract: In an aspect of the invention there is provided apparatus configured to predict at least a portion of a route that a vehicle is travelling, the apparatus being operable to compare data recorded in respect of a history of a current route a vehicle is travelling with data in respect of one or more routes a vehicle may travel thereby to predict at least a portion of a current route of a vehicle, the apparatus being further configured to control operation of a hybrid electric vehicle (HEV) in dependence on data in respect of said at least a portion of a predicted route.
ROUTE RECOGNITION APPARATUS AND METHOD

FIELD OF THE INVENTION

The present invention relates to apparatus and to a method for recognising a route travelled by a motor vehicle.

BACKGROUND

It is known to provide apparatus for tracking a route travelled by a vehicle using location determining apparatus. The apparatus comprises a satellite global positioning system (GPS) or cellular network positioning system. The apparatus may alternatively or in addition provide route guidance functionality.

In some cases however a vehicle may not be equipped with location determining apparatus. It may however still be desirable to track a route travelled by the vehicle. It is against this background that the present invention has been conceived.

STATEMENT OF THE INVENTION

Aspects of the invention provide an apparatus, a method and a vehicle as claimed in the appended claims.

According to another aspect of the invention for which protection is sought there is provided an apparatus configured to predict at least a portion of a route that a vehicle is travelling, the apparatus being operable to compare data recorded in respect of a history of a current route a vehicle is travelling with data in respect of one or more routes a vehicle may travel thereby to predict at least a portion of a current route of a vehicle, the apparatus being further configured to control operation of a hybrid electric vehicle (HEV) in dependence on or responsive to data in respect of said at least a portion of a predicted route.

It is to be understood that reference to data in respect of a history of a current route refers to data in respect of a current journey being conducted by a vehicle.
Embodiments of the invention have the advantage that one or more HEV parameters may be controlled in order to optimise vehicle performance once the route that is being travelled has been predicted, i.e. once the future course of the vehicle has been predicted.

It is to be understood that it is desirable to optimise control of a HEV in order to minimise or at least reduce one or more performance parameters such as an amount of C02 emitted by the vehicle on a given journey or an amount of fuel consumed.

For example in the case of parallel and series hybrid electric vehicles (HEVs) having a fuel burning actuator (FBA) (such as an engine) and an electric machine, the vehicle may be operable in a number of different configurations of the FBA and electric machine. For example a parallel HEV may be operable in an EV only mode in which the engine is switched off and only an electric machine drives the vehicle, a parallel boost mode in which an engine and electric machine drive the vehicle and a parallel recharge mode in which the engine drives the vehicle and an engine-driven electric machine acts as a generator to recharge a battery. In the case of a series hybrid vehicle where one or more electric machines develop traction to drive the vehicle and not a fuel burning actuator, the vehicle may be operable in an electric vehicle (EV) only mode in which an engine is switched off, a recharge mode in which the engine recharges a battery whilst the at least one electric machine drives the vehicle and a boost mode in which the engine develops further charge to deliver extra power to the electric machine whilst the electric machine is driving the vehicle.

If a route to be travelled by a vehicle on a given journey is known in advance of the journey it is possible to implement optimisation methodologies that determine in which mode a HEV should be operated over a given segment of the journey in order to minimise a given vehicle parameter such as C02 emissions or fuel consumption.

Embodiments of the invention are particularly relevant to hybrid vehicles of the plug-in type, i.e. HEVs having a capability to be connected to an external power source in order to recharge the battery for powering the electric machine to deliver traction. Such vehicles typically have battery packs of larger capacity allowing extended range operation. An aim of some embodiments of the present invention is to provide a vehicle having a controller operable to control the vehicle to arrive at a destination with the minimum battery state of charge acceptable for the journey and having used the least amount of fuel possible.
Some embodiments of the invention have the advantage that a given performance parameter of a vehicle (such as an amount of CO2 emitted, an amount of one or more other gases emitted, or an amount of fuel consumed), may be reduced further than known arrangements in which route prediction is not employed.

As noted above some embodiments of the invention are useful in the control of a series HEV, a parallel HEV or a HEV operable in both a series mode and a parallel mode.

Embodiments of the present invention are useful in that some embodiments are suitable for use in vehicles not having location determining apparatus such as a GPS system (global satellite positioning system) or a system based on GPRS (general packet radio service).

Thus, it is to be understood that some embodiments of the present invention are operable to predict a route a vehicle will follow in the absence of vehicle geographic location information.

Thus, optionally the apparatus may be arranged not to receive vehicle geographical location data, such as vehicle location data from an external source. Rather, the apparatus determines whether the route a vehicle is travelling corresponds to a route the vehicle has previously travelled by reference to data recorded by the apparatus not being data in respect of vehicle geographical location, for example as vehicle location data received from an external source such as a location determining apparatus.

Furthermore, the apparatus may be operable wherein data in respect of a start location of the vehicle is not required in order for the apparatus to determine which previous journey the current journey corresponds to, and therefore determine a route the vehicle will most likely follow.

Furthermore, it is to be understood that some embodiments of the present invention are operable to predict a route a vehicle will follow in the absence of destination information.

Thus, some embodiments of the invention are operable to predict a route a vehicle is following in the absence of destination information and current vehicle geographical location information. Some embodiments are further operable to predict the route the vehicle is following in the absence of start location geographical information.

In one aspect of the invention for which protection is sought there is provided an apparatus configured to predict at least a portion of a route that a hybrid electric vehicle (HEV) is
travelling, the apparatus being operable to compare data recorded by the apparatus in respect of a current route a vehicle is travelling with data in respect of one or more routes a vehicle may travel thereby to predict at least a portion of a current route of a vehicle, the apparatus being further configured to control operation of a vehicle in dependence on data in respect of said at least a portion of a predicted route.

Advantageously, the data recorded by the apparatus in respect of a route of travel of a vehicle may comprise data in respect of turns made by the vehicle.

Further advantageously the apparatus may be arranged to detect that the vehicle is turning by reference to steering wheel or steerable road wheel angle.

The apparatus may be arranged to detect the direction in which the vehicle is turning by reference to a direction of change of steering wheel or steerable road wheel angle.

Advantageously the apparatus is arranged to detect that the vehicle is turning by reference to steering wheel or steerable road wheel angle, in combination with road wheel speed data.

In some embodiments, the apparatus may detect that a vehicle is turning by reference to a change in wheel speed (typically a decrease in wheel speed) as a vehicle slows down before making a turn. Thus steering wheel or steerable road wheel angle may be monitored and correlated with road wheel speed.

It is to be understood that steering wheel or steerable road wheel angle may be converted into a rate of change of steering wheel or steerable road wheel angle. Data in respect of rate of change of steering wheel or steerable road wheel angle may be useful in detecting turns made by a vehicle.

Thus, the apparatus may be arranged to detect that the vehicle is turning at least in part by reference to a rate of change of steering wheel or steerable road wheel angle.

The apparatus may be arranged to detect that the vehicle is turning by reference to an output of an accelerometer.

The accelerometer may comprise a gyroscope.
Advantageously the data in respect of one or more routes a vehicle may travel may comprise data in respect of one or more routes a vehicle has previously travelled.

Further advantageously the apparatus may be configured to predict a route a vehicle is travelling by comparing data in respect of a history of a current route of travel with the data in respect of one or more routes a vehicle has previously travelled.

In particular, data for a current journey in respect of turns made by a vehicle including a direction of a turn and a distance between turns may be correlated with data in respect of data in respect of one or more other journeys, which may include previous journeys made by the vehicle.

The apparatus may be configured to store data in respect of a route travelled by a vehicle during a given journey upon completion of a journey.

Advantageously the apparatus may be configured to predict a route a vehicle is currently travelling by comparing data in respect of an initial portion of a route a vehicle is currently travelling and data in respect of a corresponding initial portion of a route a vehicle may travel.

Thus in some arrangements the apparatus may be configured to compare only data corresponding to a 'start of travel dead band' of one or more routes. Alternatively the apparatus may be configured not to compare a portion of a dataset corresponding to the 'start of travel dead band'. This feature increases a likelihood that the vehicle predicts correctly a route being travelled by a vehicle within a reasonable timescale and within computational constraints of a vehicle controller. It is to be understood that data in respect of a route a vehicle may travel may differ initially due to a vehicle having been parked at different precise locations of the same general starting location. For example, different locations of a given street, different locations of a given car park, different car parks of a given city and so forth. Portions of the route after the initial portion (referred to as the 'start of travel dead band') may be compared in order to more reliably determine a likely route of travel of a vehicle.

The apparatus may be operable to predict a route a vehicle is currently travelling further in dependence on at least one selected from a time of day, a day of a week, a day of a month or a day of a year on which a journey is being made.
Thus in addition to data in respect of a route a vehicle is travelling the apparatus may take into account one or more further factors. This has the advantage that the apparatus may in some cases correctly predict a route more quickly and/or more reliably.

As noted above, advantageously the data in respect of a route of travel of a vehicle may comprise data in respect of steering wheel angle or steerable road wheel angle and a wheel speed.

The wheel speed data may include for example an average speed of a wheel between turns or an average speed of two or more wheels between turns. Other definitions of wheel speed are also useful.

It is to be understood that wheel speed may be monitored in order to record an average speed between turns. In addition or instead, wheel speed may be monitored in combination with steering wheel or steerable road wheel angle and/or data from an accelerometer in order to detect when a turn is being executed by a vehicle. Thus, if vehicle speed decreases and at the same or substantially the same time a change in steering wheel or steerable road wheel angle takes place (and/or an accelerometer detects turning), the apparatus may determine that a turn has taken place. The apparatus may log the distance travelled since the last turn in a memory. In addition the apparatus may log a direction of the turn in the memory.

Advantageously the apparatus may be configured to store during the course of a journey data in respect of at least one selected from amongst whether a left or right turn is made; a distance travelled since the last turn was made; an average vehicle speed between turns; an average vehicle speed over a whole journey; a variance of vehicle speed between turns; a variance of vehicle speed over a whole journey; a deviation from average vehicle speed between turns; a deviation from average vehicle speed over a whole journey; a time of day of each turn; a time of day on which a journey commenced; a time of day on which a journey ended; and a day of a week on which a journey was undertaken.

In some embodiments other information may be stored in addition or instead.

The apparatus may be configured to store data in respect of each journey in a database.
Advantageously the apparatus may be arranged to control a state of charge of an energy storage device of a vehicle in dependence on data in respect of a predicted route, an energy storage device being configured to store energy for powering an actuator for driving a vehicle.

The energy storage device may for example be a battery. The actuator for driving a vehicle may be an electric machine operable to provide torque to propel a vehicle.

Advantageously the apparatus may be configured to set a target value of state of charge for a given stage of a predicted journey and to control a vehicle such that the target state of charge value is achieved by an end of a given stage.

Thus in some embodiments the apparatus may be configured to set a target value of state of charge of a battery of a vehicle at a given stage of a predicted journey and to control a vehicle to achieve the target state of charge at that stage of a journey. A journey may comprise a plurality of segments, an end of each segment corresponding to a journey stage having a target value of battery SoC associated therewith.

The apparatus may be configured to set a target value of state of charge in dependence on data in respect of a predicted route in order to optimise one or more performance parameters of a vehicle.

A performance parameter may for example be an amount of a given gas emitted by an engine of the vehicle over the course of the journey such as an amount of $CO_2$, an amount of fuel consumed by the engine over the course of the journey, an amount of time for which the engine is switched on over the course of the journey or any other suitable parameter.

Advantageously the apparatus may be configured to store data in respect of an average vehicle speed over one selected from amongst a prescribed period of time before an end of a journey and a prescribed distance before an end of a journey.

The prescribed period may be a fixed period regardless of the length of time taken to complete the journey or a period in dependence on the length of time taken to complete the journey, such as a period that is 1% of the total length of time taken to complete the journey. Other values are also useful.
Similarly, the prescribed distance may be a fixed distance regardless of the total distance travelled during a journey or a distance in dependence on the total distance travelled during a journey, for example a distance that corresponds to 1% of the total distance travelled by a vehicle. Other values are also useful.

This feature has the advantage that the apparatus may take into account the fact that a route travelled by a vehicle immediately before a journey ends may be different from stored data in respect of a route a vehicle may travel, due for example to the availability of a parking space or a precise destination of a vehicle within a given destination area such as within a given city. Thus in some embodiments instead of storing turn by turn data in respect of a final portion of a journey, the apparatus may store a more limited amount of data, such as overall average speed data for a prescribed time period or distance before a journey ends.

Advantageously the apparatus may be configured to set a target value of at least one parameter of a vehicle that is to be achieved at a destination of a vehicle in dependence on data in respect of a particular destination.

Further advantageously the apparatus may be configured to set a target state of charge of an energy storage device of a vehicle at a destination.

Advantageously the apparatus may be configured to set a target state of charge in dependence on a determination whether an energy storage device will be recharged at a destination.

The apparatus may be operable to determine whether a recharging facility is available at a destination in dependence on at least one selected from amongst data in respect of a destination obtained by means of a database independently of data in respect of a historical journey and data in respect of a historical journey made by a vehicle.

Thus in respect of each vehicle journey the controller may store data indicating whether a vehicle's energy storage device was recharged at the destination.

Further advantageously the apparatus may be operable to predict at least a portion of a route that a vehicle is travelling without reference to data in respect of a geographical location of the apparatus.
That is, embodiments of the invention are suitable for use where geographical location information such as global satellite positioning system (GPS) data or other geographical location information is unavailable.

Alternatively or in addition the apparatus may be operable to predict at least a portion of a route that a vehicle is travelling with further reference to data in respect of a geographical location of the apparatus.

Optionally the apparatus is operable to store geographical location information of a vehicle during the course of a journey. The geographical location information may be obtained for example by means of location determining apparatus such as a GPS device, a device measuring relative signal strength of a cellular network to determine location, a gyroscopic location determining device or any other suitable apparatus.

The apparatus may be operable to store geographical location information of a vehicle each time a turn is made together with data in respect of whether the turn is a left turn or a right turn.

According to a further aspect of the invention for which protection is sought there is provided a hybrid electric vehicle comprising apparatus according to the preceding aspect.

According to a still further aspect of the invention for which protection is sought, there is provided a method of control of a hybrid electric vehicle comprising:

- comparing data in respect of a history of a current route a vehicle is travelling with data in respect of one or more routes that a vehicle may travel;
- predicting at least a portion of a current route of a vehicle; and
- controlling operation of a vehicle in dependence on data in respect of said at least a portion of a predicted route.

The method may comprise controlling a state of charge of an energy storage device of a vehicle in dependence on data in respect of said at least a portion of a predicted route.

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. For example, features described in connection with one embodiment are applicable to all embodiments, unless such features are incompatible.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will now be described, by way of example only, with reference to the accompanying figures in which:

10 FIGURE 1 is a schematic illustration of a hybrid electric vehicle according to an embodiment of the present invention;

FIGURE 2 shows an example of route data generated in respect of a journey; and

15 FIGURE 3 shows a plurality of routes travelled by the vehicle of FIG. 1 and for which data is stored in a database of a controller of the vehicle.

DETAILED DESCRIPTION

20 FIG. 1 shows a hybrid electric vehicle (HEV) 100 according to an embodiment of the present invention. The vehicle 100 has an internal combustion engine 121 releasably coupled to a crankshaft integrated motor/generator (CIMG) 123 by means of a clutch 122. The CIMG 123 is in turn coupled to an automatic transmission 124. The vehicle 100 is operable to provide drive torque to the transmission 124 by means of the engine 121 alone, the CIMG 123 alone or the engine 121 and CIMG 123 in parallel.

It is to be understood that in some embodiments the transmission 124 may be a manual transmission instead of an automatic transmission. The transmission may comprise a manual gearbox, a continually variable transmission or any other suitable transmission.

30 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 111, 112 or only a pair of rear wheels 114, 115, i.e. front wheel drive or rear wheel drive vehicles in addition to all wheel drive or selectable two wheel drive/four wheel drive vehicles. Embodiments of the invention are also suitable for vehicles having less than four wheels or more than four wheels.
The vehicle 100 has a battery 150 connected to an inverter 151 that generates a three-phase electrical supply that is supplied to the CIMG 123 when the CIMG 123 is operated as a motor. The battery 150 is arranged to receive charge from the CIMG 123 when the CIMG 123 is operated as a generator.

The vehicle 100 is configured to operate in one of a hybrid electric vehicle (HEV) mode, a HEV inhibit mode in which hybrid functionality is suspended and the engine 121 alone drives the vehicle and a selectable electric vehicle only (EV-only) mode according to the state of a HEV mode selector 169.

In the HEV mode of operation the vehicle 100 is arranged to operate in one of a parallel boost mode, a parallel recharge mode, a parallel idle mode and a vehicle-selected EV mode.

In the parallel boost mode the engine 121 and CIMG 123 both apply positive torque to the transmission 124 (i.e. clutch 122 is closed) to drive the vehicle 100. In the parallel recharge mode the engine 121 applies a positive torque whilst the CIMG 123 applies a negative torque whereby charge is generated by the CIMG 123 to charge the battery 150. In the parallel idle mode the engine 121 applies a positive torque whilst the CIMG 123 applies substantially no torque. In the vehicle-selected EV mode (and in the driver selected EV-only mode) the clutch 122 is opened and the engine 121 is switched off.

The vehicle has a controller 140 configured to control the vehicle 100 to operate in the parallel boost mode, parallel recharge mode or EV mode according to an energy management strategy implemented by the controller 140. The energy management strategy may also be referred to as a HEV control methodology.

It is to be understood that when in HEV mode the controller 140 is configured to determine a target torque that is to be developed by each of the engine 121 and CIMG 123 and to control the engine 121 and CIMG 123 to apply the respective target torques to an input shaft of the transmission 124. For example, if the controller 140 determines that operation in vehicle-selected EV mode is required, the controller 140 sets the target torque from the engine 121 to zero and provides a control signal to switch off the engine 121. If the controller 140 determines that both the engine 121 and CIMG 123 are required to apply positive torque to the driveline 130 the controller 140 controls the engine 121 and CIMG 123 to provide the required values. If the controller 140 determines that the battery 150 is required to be
charged, the CIMG 123 is controlled to apply a prescribed negative torque to the driveline 130 whereby the CIMG 123 acts as a generator to generate charge to charge the battery 150.

It is to be understood that other arrangements are also useful.

If the driver selects operation of the vehicle 100 in EV-only mode and the engine 121 is running, the vehicle 100 is configured to open the clutch 122 and to switch off the engine 121. Again, the CIMG 123 is then operated either as a motor or as a generator. It is to be understood that the CIMG 123 may be arranged to act as a generator in the EV-only mode in order to effect regenerative braking of the vehicle 100.

As noted above, the vehicle 100 has a controller 140 arranged to control the vehicle 100 to switch the engine 121 on and off when in HEV mode according to an energy management strategy.

In the embodiment of FIG. 1 the controller 140 is operable to modify the energy management strategy in dependence on data in respect of an expected route of travel of the vehicle 100. When available, the expected route of travel is determined in dependence on an indication received from a driver in respect of the expected destination of the vehicle 100. The indication may be provided by means of a graphical interface 180 by means of which the driver selects the intended destination. The driver may also input a route. In some embodiments the controller 140 (or a separate route calculation apparatus) is arranged to calculate a route once the destination has been selected.

In the absence of an indication of vehicle destination the controller 140 is arranged to predict the route that the vehicle 100 is travelling once the driver commences the journey, i.e. once the vehicle 100 is moving and to control operation of the vehicle 100 in dependence on the predicted route.

If data in respect of a location of the vehicle 100 is available to the controller 140 (such as that provided by a satellite global positioning system (GPS) apparatus), the controller 140 tracks the actual route of travel of the vehicle 100 and compares the route with data stored in memory in respect of previous journeys travelled by the vehicle 100. The controller 140 is configured to determine whether the current journey corresponds to a journey the vehicle 100 has previously made. If the controller 140 determines that the current route does
correspond to a previous route, the controller 140 applies a predictive optimisation methodology in respect of the route in order to determine an optimum mode of operation of the vehicle 100 along the route as described in more detail below.

In the absence of data in respect of vehicle location, the controller 140 predicts the route by comparing data in respect of a direction of turns (left or right) performed by the vehicle 100 and the distance travelled between turns as the journey progresses with corresponding stored data in respect of previous journeys made by the vehicle 100. The controller 140 applies a pattern recognition methodology to determine whether the route currently being travelled by the vehicle 100 corresponds to a journey previously made by the vehicle 100. That is, the controller 140 determines whether the journey currently being made by the vehicle 100 may be the same as a journey previously made by the vehicle 100.

The controller 140 characterises a route of travel of a vehicle in 'segments', each segment being a portion of the route between detected turns.

In some embodiments, if the vehicle determines that an average speed of the vehicle is different along two or more different respective portions of a route between turns, the controller 140 is configured to store the journey in a form in which the two or more different portions of the route correspond to different respective segments.

If the controller 140 is able to identify a route of a previous journey as one which may be the same as that which the vehicle 100 is currently following, as noted above the controller 140 is arranged to determine which hybrid mode should be assumed by the vehicle 100 along each remaining segment of the journey by means of a predictive optimisation methodology in order to optimise vehicle operation. The controller 140 is operable subsequently to control the vehicle 100 to assume the determined mode as the journey progresses.

It is to be understood that the energy management strategy is arranged to control the vehicle 100 so as to achieve a suitable balance between one or more vehicle drivability parameters, such as noise, vibration and harshness (NVH) and one or more vehicle performance parameters such as a rate of emission of a gas by the vehicle 100, a rate of consumption of fuel or any other suitable performance parameter. The strategy is also arranged to take into account preferred (or legislated) modes of operation of the vehicle in respect of particular segments of a route. Thus the strategy may control the vehicle 100 to assume the EV mode when operating in an urban area where possible, or on a road where the average speed is
below a prescribed value. Where vehicle location data is available the controller 140 may be
arranged to control the vehicle 100 to assume EV mode whenever operating on a road for
which EV mode is required by law, or at a time when EV mode is required on a particular road.

If the controller 140 determines that there are a plurality of different journeys stored in the
controller database that may correspond to the current journey, the controller 140 is
configured to compare data in respect of the current time and day of the week with
Corresponding data in respect of the plurality of previous journeys. If a time and/or day of
the week of a previous journey is found to correspond to that of the current journey the
controller 140 is configured to select the journey corresponding most closely in time and day
of the week.

Other arrangements are also useful. In some embodiments, in the event that a plurality of
different previous journeys may correspond to the current journey and one of the journeys
has been travelled more than once, the controller 140 is configured to select the journey that
has been travelled the most. In the event this method is still unable to select a single
journey route, then the time of day and day of the week on which the two or more most likely
previous journeys were made may be compared with that of the current journey. If one of
the previous journeys was made on the same day of the week it may be selected as the
most likely journey.

According to the present embodiment, the controller 140 is arranged to determine a route
that the vehicle 100 is following on a given journey and subsequently to determine in which
hybrid mode the vehicle 100 should be operated over a given segment of the route. The
determination in which mode the vehicle 100 should be operated is made in dependence on
data in respect of (i) whether or not the given portion is a built-up area; (ii) a road type over
the given portion; (iii) an expected average vehicle speed over the given portion; (iv) a length
of the given portion; and (v) whether the vehicle must be operated in EV mode (i.e. with the
engine 121 switched off) in a given segment, for example in order to comply with law as
described above. In some embodiments the controller 140 may not be arranged to take into
account data in respect of (v).

FIG. 2 is a schematic representation of example data stored in a memory of the apparatus in
respect of a route the vehicle is to follow. The route has been broken down into a number of
segments, each segment being identified by a unique segment number (1, 2, 3, etc). A
parameter Built_up is set to 1 if the area through which the segment passes is a built-up area and set to zero if it is not. The parameter Road_Type is given a value corresponding to a type of the road (FC1, FC2, FC3, etc). A parameter Avg_Spd provides an indication of an expected average speed of the vehicle 100 over the segment and a parameter Length provides an indication of the length of the segment. In some embodiments the parameter Avg_Spd is given a value corresponding to the expected average speed of the vehicle 100 at the time at which the vehicle is expected to travel the particular segment. Thus data in respect of average speed over a given segment is stored together with a time and in some embodiments a date on which the segment was previously driven.

The value of parameters Built_up and Road_Type for a given segment are determined based on a value of the variance of vehicle speed over the segment and a value of the parameter Avg_Spd for that segment. Variance of average speed may also be measured and stored.

For each new journey made by the vehicle 100, the controller 140 is configured to determine the destination of the vehicle 100 after the journey has commenced by comparing data in respect of a route the vehicle 100 is taking with stored data in respect of routes the vehicle 100 may follow. In the present embodiment the stored data corresponds to a description of journeys made previously by the vehicle 100. In some embodiments the stored data may in addition or instead correspond to one or more destinations previously indicated by a user or preset by a third party to be destinations the vehicle 100 may be driven to even if the vehicle 100 has not actually made a journey to that destination yet.

The controller 140 is configured to generate data in respect of a route the vehicle 100 is following by reference to data in respect of steering wheel angle or steerable road wheel angle and a differential wheel speed. By differential wheel speed is meant a difference between a speed of an inner wheel and a speed of an outer wheel of the vehicle 100 such as a difference in speed between a left wheel and a right wheel of the vehicle. The controller 140 is configured to detect when the vehicle 100 makes a turn in dependence on this data and to determine that a new segment has begun if a turn is detected. The controller 140 stores in a database data in respect of (i) whether the last turn was a left or right turn; (ii) distance between the last turn and the next turn; (iii) average vehicle speed between the turns; (iv) variance of vehicle speed between the turns; (v) deviation from average vehicle speed between the turns; (vi) time of day; and (vii) day of the week.
When the vehicle 100 is next powered down ('key off'), a dataset in respect of the journey is stored in a memory (such as a flash memory) of the controller 140. When the vehicle 100 is next powered up ('key on') the dataset in respect of that (immediately preceding) journey is stored in a historical database of the controller 140. The dataset is either stored in a form indicating the dataset corresponds to a completed journey, or in a form indicating the dataset corresponds to a journey in respect of which the next journey is a continuation.

In the latter case an identifier is stored in the database at the end of a given dataset to indicate that subsequent data corresponds to continuation data.

In some embodiments, if the battery 150 is recharged whilst the vehicle 100 is powered down by more than a prescribed amount of charge, or if the period of time for which the vehicle 100 is powered down exceeds a prescribed period, the controller 140 is configured to store data in respect of the route travelled before power down and data in respect of the route travelled after power down as separate journey datasets. That is, the controller 140 does not store the data in the form of a single journey dataset. Other arrangements are also useful in some embodiments.

It is to be understood that the controller 140 is therefore able to determine whether a journey has been interrupted, for example due to the driver taking a rest stop during the course of a journey, the driver dropping off or picking up a passenger during the journey or any other reason for which a journey may be interrupted. As described above, if interruption of a journey is detected the controller 140 does not store respective portions of the journey as two separate journeys but as respective portions of a single journey. This increases the likelihood that a subsequent journey following a similar route will correctly identify the full route of the journey and not only a portion of the journey.

When storing data in respect of a new journey, for which the controller 140 has determined that a subsequent journey is not a continuation of the previous journey, in some embodiments the vehicle is arranged not to store turn by turn data in respect of the last 1km of the journey. This portion of the journey may be referred to as an 'end of journey dead band'. In some embodiments the controller 140 stores an average speed of the vehicle over this portion but not turn by turn data.

Other lengths of dead band and other arrangements are also useful. In some embodiments a dead band may correspond to a fixed time period such a 15 minutes. In some
embodiments a dead band may be defined as a proportion of a total journey. For example a dead band may be defined as corresponding to 1% of a journey length in terms of distance or time.

The controller 140 is also configured to detect when the vehicle 100 is performing a 'manoeuvre', for example when exiting or entering a parking space. The controller 140 is configured not to store data in respect of a manoeuvre when a manoeuvre is taking place.

The controller 140 detects that a manoeuvre is in progress when any two successive turns are detected within a prescribed distance of one another and the vehicle speed is less than a prescribed value. In such a case the controller 140 is configured not to store data in respect of the turns.

By way of example, FIG. 3 is a schematic illustration of routes of travel of a vehicle 100. One journey conducted by the vehicle is shown being a journey from point A to point B. Point A is in city CITY1 and point B is in city CITY2.

As the vehicle 100 travels from point A to point B, the vehicle 100 stores data in respect of the journey as detailed above.

During the course of a new journey, in addition to storing data in respect of the journey as described above, the vehicle 100 compares repeatedly data recorded in respect of the current journey with data stored in the database in respect of previous journeys. As noted above a pattern recognition methodology is employed to identify any similar previous journeys for which the controller 140 can access data.

The controller 140 performs the comparison over an initial 'start of journey dead band' being the first 1km of the new journey. For the journey from point A to point B the start of journey dead band corresponds to travel from point A point P1A.

Turn information is compared with the corresponding start of journey dead band of each of the journeys stored by the controller 140 in respect of previous journeys made by the vehicle 100 or for which the controller 140 has journey data. If a matching journey is found, the controller 140 determines that the current journey corresponds to the matching journey stored in the database. As noted above, if the controller 140 determines that the journey may correspond to two or more different journeys for which data is stored, the controller 140
may perform a comparison in respect of the time of day and/or day of the week of the current and previous journeys to determine which of the previous journeys most likely corresponds to the current journey.

If the vehicle subsequently drives from point A to point B again, the controller 140 stores turn by turn data in respect of the new journey from point A to point B with stored data, and determines that over the start of journey dead band from point A to point P1A the journeys are substantially identical and therefore determines that the vehicle 100 is likely travelling from point A to point B. The controller 140 is therefore able to determine an optimum control strategy in respect of selection of a hybrid mode in which the vehicle 100 is to be operated over a remainder of the journey.

In some embodiments the controller 140 may also be operable to compare data in respect of a new journey over the course of a start of journey dead band of the new journey with data in respect of a portion of an end of a journey stored in a database thereby to detect that a new journey corresponds to the reverse of a previous journey such as the immediately previous journey.

A further example is now described where two journeys are undertaken by a vehicle where a substantial portion of each of the journeys follow the same route. FIG. 3 shows route information in respect of a journey from point C to point D in addition to the journey from point A to point B.

If the vehicle 100 begins a new journey from point C to point D at a time after travelling a route from point A to point B, the controller 140 stores turn by turn data in respect of the new journey as described above. Whilst the vehicle 100 is travelling through the start of journey dead band of the journey from point C, stored turn data in respect of this journey is compared repeatedly with data stored in respect of the start of journey dead band of previous journeys including the journey from point A to point B, the dead band of which terminated at point P1A. An end of the start of journey dead band in respect of the journey from point C to point D is shown in FIG. 3 as point P1C.

It is to be understood that after the vehicle has passed point PJ, corresponding to a junction at which the journey from point C to point D begins to follow a similar path to that followed previously from point A to point B, the controller 140 may recognise that the vehicle 100 is likely to travel from its current position to location B (or a location close to point B). The
controller 140 therefore determines the optimum hybrid mode of operation for each segment of the journey stored in respect of the previous journey from location A to location B, from the current vehicle location to location B. Thus the controller 140 determines which hybrid mode the vehicle 100 should assume during the course of each remaining segment of the route.

Even though the vehicle 100 is travelling to location D and not location B, the fact that the controller 140 optimises travel from its current location to point B allows a substantial improvement in vehicle performance compared with controllers that do not incorporate route prediction functionality according to embodiments of the present invention.

After completing the journey from point C to point D, upon key-off the controller 140 stores turn by turn data in respect of the journey from point C to point D in a temporary memory until the subsequent key on operation is performed by the driver.

If the subsequent key-on takes place after a prescribed amount of time has elapsed since key off or if the battery 150 is recharged by a prescribed amount between key off and key on, the journey data stored in the temporary memory is stored in the database as data corresponding to a completed journey. Otherwise, the data is stored as data corresponding to a portion of a journey that has not yet been completed. When data in respect of a subsequent journey is subsequently stored, the subsequently stored data is stored as continuation data in respect of the previously stored journey data.

If after undertaking the journey from A to B and C to D the vehicle undertakes a new journey from point X to point Y, the vehicle 100 compares data in respect of the route from point X with historical data in the manner described above. In this example, no data is stored in respect of a journey having a start of journey dead band matching that of the portion of the new journey route from point X to point Y within the start of journey dead band of the new journey (which ends at location P1X). Accordingly the controller 140 controls the vehicle 100 according to a non-predictive optimisation methodology. However the controller 140 continues to store turn by turn information in respect of the new journey in the database as described above.

The vehicle may subsequently undertake a journey from point E to point D. In the same way as that described above in respect of the journey from point C to point D, over the initial 'start of journey dead band' of the new journey (i.e. from location E to location P1E) the controller
140 compares turn by turn information in respect of the new journey with that stored in respect of existing stored journeys including those from point A to point B and from point C to point D.

After the vehicle 100 has passed point PJ' where the route from point E to point D joins that from point C to point D the controller recognises that the current journey may correspond to that from point C to point D. However after passing point PJ the controller 140 recognises that the current journey may also correspond to that from point A to point B.

Since the controller 140 has identified more than one route that may correspond to the current journey, the controller 140 is configured to compare the time of day and the day of the week of the current journey with those of the routes identified by the controller 140 in order to select one route that most likely corresponds to the current route.

Accordingly the controller 140 compares data in respect of the current time and day of the week with corresponding data in respect of the journeys from point A to point B and point C to point D. In the present example, the journey from point A to point B was made at 7am on a Tuesday morning whilst that from point C to point D was made at 9am on a Saturday morning. If the journey from point E to point D is also made on a Saturday morning, the controller 140 favours the journey from point C to point D as the journey corresponding most closely to the present journey and therefore selects point D as the most likely destination. The controller 140 therefore performs an optimisation calculation to determine in which hybrid mode the vehicle 100 should be operated over each remaining segment of the route from point C to point D.

It is to be understood that other arrangements are also useful.

Once the journey from point E to point D is complete, the controller 140 stores data in respect of the journey from point E to point D as described above.

In FIG. 3 a start location of an end of journey dead band in respect of each of the journeys is indicated by a reference sign in which the corresponding journey destination is prefixed P2.

In some embodiments the controller 140 is operable to determine whether the battery 150 of the vehicle 100 will be recharged at the destination by means of a recharging facility. The
controller 140 controls the vehicle to arrive at the destination with a battery SoC of a prescribed value in dependence on this determination.

For example if the vehicle 100 will be recharged at the destination the controller 140 may be configured to control the vehicle 100 such that a SoC of the battery 150 is depleted to a relatively low level, for example to a minimum level, by the time the journey is complete. This feature allows an amount of gaseous emissions of the engine 121 to be reduced by employing the CIMG 123 as much as possible.

If a recharging facility does not exist at the destination, the controller 140 may be configured to control the vehicle 100 such that the battery SoC is not entirely depleted by the end of the journey. For example, the controller 140 may control the vehicle such that the battery SoC is depleted to around 50% of its capacity. Thus charge remains in the battery 150 and is available for a return journey should such a journey subsequently be made. Other arrangements are also useful.

If whilst the vehicle 100 is being driven the vehicle 100 deviates from the route the controller 140 determined that the vehicle 100 was following, in some embodiments the controller 140 is arranged to compare the new route with data in respect of previous routes followed by the vehicle. The controller 140 determines whether the new route being followed corresponds to a previous route and if a match is found the controller 140 revises the control strategy accordingly. If the new route does not match a previous route, the controller 140 may be configured to control the vehicle 100 such that the SoC of the battery 150 reaches a minimum value by the end of the journey (the destination being unknown) in order to reduce emission of gas by the engine 121. Other arrangements are also useful.

In some embodiments where GPS navigation data is available the controller 140 may be configured to store location data in respect of each turn made by the vehicle 100. This location data may be employed to improve a speed and/or accuracy of route predication since the controller 140 is able more reliably to determine whether a new journey corresponds to a previous journey. The controller 140 may therefore employ stored data in respect of average speed along a given route segment with stored speed data to determine an optimum hybrid mode for each remaining segment of the journey.

Embodiments of the invention have the advantage that a controller 140 may optimise a mode of operation of a hybrid powertrain in order to control a vehicle 100 more efficiently to
complete a journey without a requirement for a driver to indicate his or her intended
destination. This has the advantage of reducing a workload imposed on a driver in order to
enjoy enhanced HEV operation.

Embodiments of the present invention may be understood by reference to the following
numbered paragraphs:

1. An apparatus configured to predict at least a portion of a route that a hybrid electric
vehicle (HEV) is travelling, the apparatus being operable to compare data recorded by the
apparatus in respect of a current route a vehicle is travelling with data in respect of one or
more routes a vehicle may travel thereby to predict at least a portion of a current route of a
vehicle, the apparatus being further configured to control operation of a vehicle in
dependence on data in respect of said at least a portion of a predicted route.

2. An apparatus as described in paragraph 1 wherein the data recorded by the
apparatus in respect of a route of travel of a vehicle comprises data in respect of turns made
by the vehicle.

3. An apparatus as described in paragraph 2 arranged to detect that the vehicle is
turning by reference to steering wheel or steerable road wheel angle.

4. An apparatus as described in paragraph 3 wherein the apparatus is arranged to
detect that the vehicle is turning by reference to steering wheel or steerable road wheel
angle, in combination with road wheel speed data.

5. An apparatus as described in paragraph 2 arranged to detect that the vehicle is
turning by reference to an output of an accelerometer.

6. An apparatus as described in paragraph 5 arranged to detect that the vehicle is
turning by reference to an output of an accelerometer, in combination with road wheel speed
data.

7. An apparatus as described in paragraph 1 wherein the data in respect of one or more
routes a vehicle may travel comprises data in respect of one or more routes a vehicle has
previously travelled.
8. An apparatus as described in paragraph 7 wherein the apparatus is configured to predict a route a vehicle is travelling by comparing data in respect of the current route of travel with the data in respect of one or more routes a vehicle has previously travelled.

9. An apparatus as described in paragraph 8 wherein the data recorded by the apparatus in respect of a route of travel of a vehicle comprises data in respect of turns made by the vehicle, the apparatus being operable to compare data recorded by the apparatus in respect of turns made by the vehicle on the current route the vehicle is travelling with data recorded by the apparatus in respect of turns made by the vehicle in respect of one or more routes the vehicle has previously travelled.

10. An apparatus as described in paragraph 1 configured to store data in respect of a route travelled by a vehicle during a given journey upon completion of a journey.

11. An apparatus as described in paragraph 1 configured to predict a route a vehicle is currently travelling by comparing data in respect of an initial portion of a route a vehicle is currently travelling and data in respect of a corresponding initial portion of a route a vehicle may travel.

12. An apparatus as described in paragraph 1 operable to predict a route a vehicle is currently travelling further in dependence on at least one selected from a time of day, a day of a week, a day of a month or a day of a year on which a journey is being made.

13. An apparatus as described in paragraph 1 configured to store during the course of a journey data in respect of at least one selected from amongst whether a left or right turn is made; a distance travelled since the last turn was made; an average vehicle speed between turns; an average vehicle speed over a whole journey; a variance of vehicle speed between turns; a variance of vehicle speed over a whole journey; a deviation from average vehicle speed between turns; a deviation from average vehicle speed over a whole journey; a time of day of each turn; a time of day on which a journey commenced; a time of day on which a journey ended; and a day of a week on which a journey was undertaken.

14. An apparatus as described in paragraph 1 configured to store data in respect of each journey in a database.
15. An apparatus as described in paragraph 1 arranged to control a state of charge of an energy storage device of a vehicle in dependence on data in respect of a predicted route, an energy storage device being configured to store energy for powering an actuator for driving a vehicle.

16. An apparatus as described in paragraph 15 configured to set a target value of state of charge for a given stage of a predicted journey and to control a vehicle such that the target state of charge value is achieved by an end of a given stage.

17. An apparatus as described in paragraph 16 configured to set a target value of state of charge in dependence on data in respect of a predicted route in order to optimise one or more performance parameters of a vehicle.

18. An apparatus as described in paragraph 1 configured to store data in respect of an average vehicle speed over one selected from amongst a prescribed period of time before an end of a journey and a prescribed distance before an end of a journey.

19. An apparatus as described in paragraph 1 configured to set a target value of at least one parameter of a vehicle that is to be achieved at a destination of a vehicle in dependence on data in respect of a particular destination.

20. An apparatus as described in paragraph 19 configured to set a target state of charge of an energy storage device of a vehicle at a destination.

21. An apparatus as described in paragraph 20 configured to set a target state of charge in dependence on a determination whether an energy storage device will be recharged at a destination.

22. An apparatus as described in paragraph 1 operable to predict at least a portion of a route that a vehicle is travelling without reference to data in respect of a geographical location of the apparatus.

23. An apparatus as described in any paragraph 1 operable to predict at least a portion of a route that a vehicle is travelling with further reference to data in respect of a geographical location of the apparatus.
24. An apparatus as described in paragraph 23 operable to store geographical location information of a vehicle during the course of a journey.

25. An apparatus as described in paragraph 24 configured to store during the course of a journey data in respect of at least one selected from amongst whether a left or right turn is made; a distance travelled since the last turn was made; an average vehicle speed between turns; an average vehicle speed over a whole journey; a variance of vehicle speed between turns; a variance of vehicle speed over a whole journey; a deviation from average vehicle speed between turns; a deviation from average vehicle speed over a whole journey; a time of day of each turn; a time of day on which a journey commenced; a time of day on which a journey ended; and a day of a week on which a journey was undertaken, wherein the apparatus is operable to store geographical location information of a vehicle each time a turn is made together with data in respect of whether the turn is a left turn or a right turn.

26. A hybrid electric vehicle comprising an apparatus as described in paragraph 1.

27. A method of control of a hybrid electric vehicle comprising:
   comparing data in respect of a current route a vehicle is travelling with data in respect of one or more routes that a vehicle may travel;
   predicting at least a portion of a current route of a vehicle; and
   controlling operation of a vehicle in dependence on data in respect of said at least a portion of a predicted route.

28. A method as described in paragraph 27 comprising controlling a state of charge of an energy storage device of a vehicle in dependence on data in respect of said at least a portion of a predicted route.

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.
CLAIMS:

1. An apparatus configured to predict at least a portion of a route that a hybrid electric vehicle (HEV) is travelling, the apparatus being operable to compare data recorded by the apparatus in respect of a current route a vehicle is travelling with data in respect of one or more routes a vehicle may travel thereby to predict at least a portion of a current route of a vehicle, the apparatus being further configured to control operation of a vehicle in dependence on data in respect of said at least a portion of a predicted route.

2. An apparatus as claimed in claim 1 wherein the data recorded by the apparatus in respect of a route of travel of a vehicle comprises data in respect of turns made by the vehicle.

3. An apparatus as claimed in claim 2 arranged to detect that the vehicle is turning by reference to steering wheel or steerable road wheel angle.

4. An apparatus as claimed in claim 3 wherein the apparatus is arranged to detect that the vehicle is turning by reference to steering wheel or steerable road wheel angle, in combination with road wheel speed data.

5. An apparatus as claimed in claim 2 arranged to detect that the vehicle is turning by reference to an output of an accelerometer.

6. An apparatus as claimed in claim 5 arranged to detect that the vehicle is turning by reference to an output of an accelerometer, in combination with road wheel speed data.

7. An apparatus as claimed in any preceding claim wherein the data in respect of one or more routes a vehicle may travel comprises data in respect of one or more routes a vehicle has previously travelled.

8. An apparatus as claimed in claim 7 wherein the apparatus is configured to predict a route a vehicle is travelling by comparing data in respect of the current route of travel with the data in respect of one or more routes a vehicle has previously travelled.

9. An apparatus as claimed in claim 8 as depending through claim 2 operable to compare data recorded by the apparatus in respect of turns made by the vehicle on the
current route the vehicle is travelling with data recorded by the apparatus in respect of turns made by the vehicle in respect of one or more routes the vehicle has previously travelled.

10. An apparatus as claimed in any preceding claim configured to store data in respect of a route travelled by a vehicle during a given journey upon completion of a journey.

11. An apparatus as claimed in any preceding claim configured to predict a route a vehicle is currently travelling by comparing data in respect of an initial portion of a route a vehicle is currently travelling and data in respect of a corresponding initial portion of a route a vehicle may travel.

12. An apparatus as claimed in any preceding claim operable to predict a route a vehicle is currently travelling further in dependence on at least one selected from a time of day, a day of a week, a day of a month or a day of a year on which a journey is being made.

13. An apparatus as claimed in any preceding claim configured to store during the course of a journey data in respect of at least one selected from amongst whether a left or right turn is made; a distance travelled since the last turn was made; an average vehicle speed between turns; an average vehicle speed over a whole journey; a variance of vehicle speed between turns; a variance of vehicle speed over a whole journey; a deviation from average vehicle speed between turns; a deviation from average vehicle speed over a whole journey; a time of day of each turn; a time of day on which a journey commenced; a time of day on which a journey ended; and a day of a week on which a journey was undertaken.

14. An apparatus as claimed in any preceding claim configured to store data in respect of each journey in a database.

15. An apparatus as claimed in any preceding claim arranged to control a state of charge of an energy storage device of a vehicle in dependence on data in respect of a predicted route, an energy storage device being configured to store energy for powering an actuator for driving a vehicle.

16. An apparatus as claimed in claim 15 configured to set a target value of state of charge for a given stage of a predicted journey and to control a vehicle such that the target state of charge value is achieved by an end of a given stage.
17. An apparatus as claimed in claim 16 configured to set a target value of state of charge in dependence on data in respect of a predicted route in order to optimise one or more performance parameters of a vehicle.

18. An apparatus as claimed in any preceding claim configured to store data in respect of an average vehicle speed over one selected from amongst a prescribed period of time before an end of a journey and a prescribed distance before an end of a journey.

19. An apparatus as claimed in any preceding claim configured to set a target value of at least one parameter of a vehicle that is to be achieved at a destination of a vehicle in dependence on data in respect of a particular destination.

20. An apparatus as claimed in claim 19 configured to set a target state of charge of an energy storage device of a vehicle at a destination.

21. An apparatus as claimed in claim 20 configured to set a target state of charge in dependence on a determination whether an energy storage device will be recharged at a destination.

22. An apparatus as claimed in any preceding claim operable to predict at least a portion of a route that a vehicle is travelling without reference to data in respect of a geographical location of the apparatus.

23. An apparatus as claimed in any one of claims 1 to 21 operable to predict at least a portion of a route that a vehicle is travelling with further reference to data in respect of a geographical location of the apparatus.

24. An apparatus as claimed in claim 23 operable to store geographical location information of a vehicle during the course of a journey.

25. An apparatus as claimed in claim 24 depending through claim 13 operable to store geographical location information of a vehicle each time a turn is made together with data in respect of whether the turn is a left turn or a right turn.

26. A hybrid electric vehicle comprising an apparatus as claimed in any preceding claim.
27. A method of control of a hybrid electric vehicle comprising:
   comparing data in respect of a current route a vehicle is travelling with data in respect of one or more routes that a vehicle may travel;
   predicting at least a portion of a current route of a vehicle; and
   controlling operation of a vehicle in dependence on data in respect of said at least a portion of a predicted route.

28. A method as claimed in claim 27 comprising controlling a state of charge of an energy storage device of a vehicle in dependence on data in respect of said at least a portion of a predicted route.
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Figure 2