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(54) Title: METHOD AND SYSTEM OF OPTIMIZING OPERATION OF AN ELECTRIC VEHICLE

(57) Abstract: A method and a system of optimizing operation of an electric vehicle is disclosed. The method may include receiving at least one navigation attribute associated with an upcoming length of a route to be followed by the vehicle from a navigation service provider. The method may further include obtaining at least one current working attribute associated with the vehicle from an electronic control unit (ECU) of the vehicle. The method may further include correlating the at least one navigation attribute associated with the upcoming length of the route to be followed by the vehicle and the at least one current working attribute associated with the vehicle. The method may further include determining one or more optimizing parameters corresponding to the upcoming length of the route to be followed by the vehicle based on the correlation.

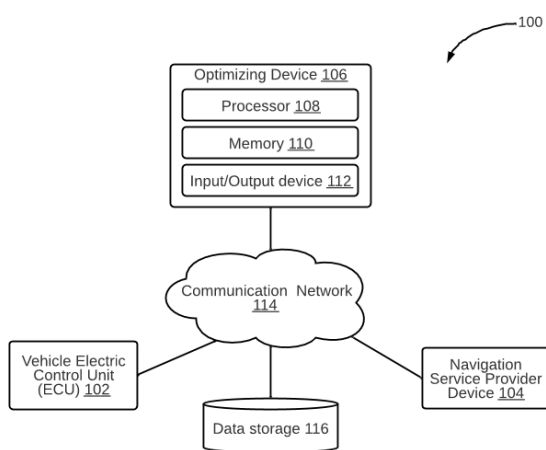


FIG. 1

FORM 2

THE PATENTS ACT 1970
(39 OF 1970)
&
The Patent Rules, 2003

Complete Specification

(See Section 10 and Rule 13)

1. TITLE OF THE INVENTION

**METHOD AND SYSTEM OF OPTIMIZING OPERATION OF AN ELECTRIC
VEHICLE**

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification describes the invention
and the manner in which it is to be performed

DESCRIPTION

Technical Field

[001] This disclosure relates generally to vehicle operations, and more particularly to a method and system of optimization operation of electric vehicles.

Background

[002] Energy management plays an important role in vehicles, and in particularly with electric vehicles (EV). Most of the EVs are equipped with multiple drive modes. As such, managing these modes is vital to manage the range of the EV. As will be appreciated by those skilled in the art, range anxiety has been proving to be a bottleneck in mass adoption of the EVs. As EVs are becoming prevalent, the need to eliminate range anxiety is therefore a high priority. Further, it is desirable to predict future vehicle operating conditions and environments in order to make better use of motor power and available battery charge, to thereby enhance the range of the vehicle using the available battery charge.

[003] Accordingly, there is a need for a solution for optimizing the operational parameters associated with the vehicle, so as to optimize energy consumption, enhance range of the vehicle, and improve drivability and user experience.

SUMMARY OF THE INVENTION

[004] In an embodiment, a method of optimizing operation of an electric vehicle is disclosed. The method may include receiving at least one navigation attribute associated with an upcoming length of a route to be followed by the vehicle. The at least one navigation attribute may be received from a navigation service provider. The method may further include obtaining at least one current working attribute associated with the vehicle from an electronic control unit (ECU) of the vehicle. The method may further include correlating the at least one navigation attribute associated with the upcoming length of the route to be followed by the vehicle and the at least one current working attribute associated with the vehicle. The method may further include determining one or more optimizing parameters corresponding to the upcoming length of the route to be followed by the vehicle based on the correlation. Additionally, in an embodiment, the method may include

obtaining a driving pattern of a driver of the vehicle and determining the one or more optimizing parameters for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle based on the driving pattern using a machine learning (ML) model.

[005] In another embodiment, a system for optimizing operation of an electric vehicle is disclosed. The system may include an optimizing device and a navigation service provider device. The optimizing device includes a processor and a memory which stores a plurality of instructions. The plurality of instructions, upon execution by the processor, may cause the processor to receive, from the navigation service provider device, at least one navigation attribute associated with an upcoming length of a route to be followed by the vehicle. The plurality of instructions may further cause the processor to obtain at least one current working attribute associated with the vehicle from an electronic control unit (ECU) of the vehicle. The plurality of instructions may further cause the processor to correlate the at least one navigation attribute associated with the upcoming length of the route to be followed by the vehicle and the at least one current working attribute associated with the vehicle. The plurality of instructions may further cause the processor to determine one or more optimizing parameters corresponding to the upcoming length of the route to be followed by the vehicle based on the correlation. Additionally, the plurality of instructions may further cause the processor to obtain a driving pattern of a driver of the vehicle and determine the one or more optimizing parameters for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle based on the driving pattern using a machine learning (ML) model.

[006] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[007] The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate exemplary embodiments and, together with the description, serve to explain the disclosed principles.

[008] **FIG. 1** illustrates a block diagram of an exemplary system for optimizing operation of an electric vehicle, in accordance with some embodiments of the present disclosure.

[009] **FIG. 2** illustrates a functional block diagram of an optimizing device, in accordance with some embodiments.

[010] **FIG. 3** illustrates a schematic view of a navigation path for a vehicle from a current location of the vehicle, in accordance with some embodiments.

[011] **FIG. 4** illustrates a schematic view of a navigation path for a vehicle from a current location to a destination location of the vehicle, in accordance with some embodiments.

[012] **FIG. 5** illustrates a flowchart of the method of optimizing operation of an electric vehicle, in accordance with some embodiments.

[013] **FIG. 6** illustrates a method of optimizing operation of a vehicle based on the learning patterns of driving, in accordance with some embodiments.

DETAILED DESCRIPTION

[014] Exemplary embodiments are described with reference to the accompanying drawings. Wherever convenient, the same reference numbers are used throughout the drawings to refer to the same or like parts. While examples and features of disclosed principles are described herein, modifications, adaptations, and other implementations are possible without departing from the spirit and scope of the disclosed embodiments. It is intended that the following detailed description

be considered as exemplary only, with the true scope and spirit being indicated by the following claims. Additional illustrative embodiments are listed below.

[015] Energy management can play an important role in range prediction for the EVs. Most of the recent EVs are equipped with a navigation system and even vehicle control units, i.e. electronic control units (ECU). The present disclosure aims to optimize the operation of the EVs by utilizing the navigation system and the vehicle control units. In particular, the present disclosure provides for predicting and managing the energy consumption of the vehicle. As such, the techniques of the present disclosure can be used in all the vehicles equipped with the navigation system and modern ECUs.

[016] An objective of the present disclosure is to create powertrain system functions that utilize the navigation system data to calculate energy consumption of the EV. Another objective of the present disclosure is to optimize the range estimation accuracy and optimize the energy/mode management of the vehicle to increase range. A yet another objective of the present disclosure is to optimize usage of energy recuperation/regenerative braking. Further, another objective of the present disclosure is to suggest the user most optimum route to enhance range. A yet another objective of the present disclosure is to implement machine learning (ML) algorithms to learn the driving pattern and further optimize the operations of the vehicle.

[017] As will be appreciated, most modern EVs are equipped with navigation systems (for example, implementing Google Maps, or other navigation maps provided by third-party navigation service providers) which provide accurate distance, traffic and elevation data. Further, the EVs include motor controllers that can obtain average speed and elevation information of the road ahead. By using this data, the techniques of the present disclosure are able to predict the energy required for a certain distance, using fundamental road load equation. Further, this prediction is repeated after predefined intervals or distance, to optimize energy usage and drivability

[018] For example, in some scenarios, the route includes a downhill and an uphill length. Conventionally, in such scenarios, during the downhill drive, the driver lifts off the throttle as there is a downhill which leads the motor controller to engage regenerative braking with the preset level of regeneration. By the end of the downhill, the vehicle would have slowed down significantly

depending on the level of regeneration applied by the driver. As the vehicle moves ahead, the driver will have to engage the throttle to climb the uphill, and accordingly, the motor provides torque as required by the motor controller. In this regard, the techniques of the present disclosure enable the motor controller to be informed in advance about the downhill and the subsequent uphill. As such, the speed and the torque required to climb the uphill at existing vehicle speed are calculated, based on the traffic. Further, the motor controller is able to decide the degree of regenerative braking that can be applied during downhill, so that the vehicle can climb the subsequent uphill with minimal energy consumption from the motor, thereby saving energy.

[019] The techniques of the present disclosure obtain elevation, traffic, and average speed data for the route ahead from the navigation system. Using this data, the motor controller calculates forces acting on the vehicle and the energy required to propel the vehicle. Based on predictive calculation, an accurate estimation of the range of the vehicle is obtained. The techniques further decide the modes in which the vehicle should be driven and the level of brake regeneration that can be used to optimize energy usage. Further, based on the navigation data, the most energy efficient route may be selected from a plurality of possible routes. Further, if the vehicle is using cruise control, the techniques further provide for managing the drive modes, torque delivery, and speed. Moreover, with the implementation of ML, the techniques provide for learning of driving patterns and accordingly improving the predictive calculations.

[020] Referring now to **FIG. 1**, a block diagram of an exemplary system 100 for optimizing operation of electric vehicle is illustrated, in accordance with an embodiment of the present disclosure. The system 100 may include an optimizing device 106. Further, in some embodiments, the system 100 may include a navigation service provider device 104. The optimizing device 106 may be a computing device having data processing capability. In particular, the optimizing device 106 may have capability to optimize the operation of electric vehicle. Examples of the optimizing device 106 may include, but are not limited to a desktop, a laptop, a notebook, a netbook, a tablet, a smartphone, a mobile phone, an application server, a web server, or the like. The system 100 may further include a data storage 116. For example, the data storage 116 may store various types of data required by the optimizing device 106 for optimizing the operation of electric vehicle. The

optimizing device 106 may be communicatively coupled to the data storage 116 via a communication network 114.

[021] The communication network 114 may be a wired or a wireless network and the examples may include, but are not limited to the Internet, Wireless Local Area Network (WLAN), Wi-Fi, Long Term Evolution (LTE), Worldwide Interoperability for Microwave Access (WiMAX), and General Packet Radio Service (GPRS). In some embodiments, the communication network 114 can be any kind of wireless network, including but limited to, any cellular telephone network using, for example, any one of the following standards: CDMA, TDMA, GSM, AMPS, PCS, analog, and/or W-CDMA. Various devices in the system 100 may be configured to connect to the communication network 114, in accordance with various wired and wireless communication protocols. Examples of such wired and wireless communication protocols may include, but are not limited to, a Transmission Control P Protocol and Internet Protocol (TCP/IP), User Datagram Protocol (UDP), Hypertext Transfer Protocol (HTTP), File Transfer Protocol (FTP), Zig Bee, EDGE, IEEE 802.11, light fidelity(Li-Fi), 802.16, IEEE 802.11s, IEEE 802.11g, multi-hop communication, wireless access point (AP), device to device communication, cellular communication protocols, and Bluetooth (BT) communication protocols.

[022] In some embodiments, the navigation service provider device 104 may operate as a standalone device that processes information onboard of the electric vehicle. However, it will be understood that in other embodiments, the electric vehicle may include a dedicated navigation service provider device 104 for controlling one or more operating functions in a vehicle. The navigation service provider device 104 may include global positioning system (Global Positioning System (GPS)) and geographic information system (Geographic Information System (GIS)) or may be based, for example, on the GPS constellation of satellites, or on other navigation technologies. Further, the navigation service provider device 104 may be able to provide road conditions or information such as the average speed of running car on the highway section, road gradient, the magnitude of traffic flow, speed limit, and so on. Additional information may include information regarding one or more route parameters for each of a plurality of routes. For example, navigation service provider device 104 may provide information that includes information related to traffic congestion along a predetermined route. The navigation information (or navigation

attribute) may also include information related to the gradient (elevation) of a roadway. This navigation attributes may then be used by the optimizing device 106 to predict the energy required (by the vehicle) for each of the plurality of routes, in order to optimize operation of the electric vehicle and further to minimize energy consumption. In another embodiment, the evaluation and selection of optimal route of travel may be executed by one or more specifically programmed machine learning (ML) model based on a driving pattern of a driver of the vehicle.

[023] In an embodiment, electric vehicle may include an electronic control unit 102, hereby referred to as ECU 102. The ECU 102 may be configured to communicate with, and/or control, various components of the electric vehicle (EV). In an embodiment, the electric vehicle may communicate with navigation service provider device 104 using the communication network 114.

[024] The optimizing device 106 may be configured to perform one or more functionalities, which may include receiving at least one navigation attribute associated with an upcoming length of a route to be followed by the vehicle from the navigation service provider device 104. It should be noted that the navigation attribute may include a gradient associated with the upcoming length of the route to be followed by the vehicle and an average speed of traffic along the upcoming length of the route. The one or more functionalities may further include obtaining at least one current working attribute associated with the vehicle from an electronic control unit (ECU) 102 of the vehicle. It should further be noted that the working attribute associated with the vehicle may include a current speed of the vehicle. The one or more functionalities may further include correlating the at least one navigation attribute associated with the upcoming length of the route to be followed by the vehicle and at least one current working attribute associated with the vehicle. The one or more functionalities may further include determining one or more optimizing parameters corresponding to the upcoming length of the route to be followed by the vehicle based on the correlation.

[025] Additionally, the one or more functionalities may further include determining one or more optimizing actions for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle based on the correlation. It should further be noted that the one or more optimizing actions may include triggering a motor controller of the vehicle to

maintain the optimal speed, triggering the motor controller to generate the optimal torque, and triggering the motor controller to apply the degree of regenerative braking. The one or more functionalities may further include obtaining a driving pattern of a driver of the vehicle and determining the one or more optimizing parameters for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle, based on the driving pattern, using a machine learning (ML) model.

[026] In order to perform the above-discussed functionalities, the optimizing device 106 may include a processor 108 and a memory 110. The processor 108 may include suitable logic, circuitry, interfaces, and/or code that may be configured to assess the working attribute associated with the electric vehicle. The processor 108 may be implemented based on temporal and a spatial number of processor technologies, which may be known to one ordinarily skilled in the art. Examples of implementations of the processor 108 may be a Graphics Processing Unit (GPU), a Reduced Instruction Set Computing (RISC) processor, an Application-Specific Integrated Circuit (ASIC) processor, a Complex Instruction Set Computing (CISC) processor, a microcontroller, Artificial Intelligence (AI) accelerator chips, a co-processor, a central processing unit (CPU), and/or a combination thereof.

[027] The memory 110 may include suitable logic, circuitry, and/or interfaces that may be configured to store instructions executable by the processor 108. The memory 110 may store instructions that, when executed by the processor 108, may cause the processor 108 to optimize the operation of the vehicle. The memory 110 may be a non-volatile memory or a volatile memory. Examples of non-volatile memory may include, but are not limited to a flash memory, a Read-Only Memory (ROM), a Programmable ROM (PROM), Erasable PROM (EPROM), and Electrically EPROM (EEPROM) memory. Examples of volatile memory may include but are not limited to Dynamic Random-Access Memory (DRAM), and Static Random-Access memory (SRAM). The memory 110 may also store various data that may be captured, processed, and/or required by the system.

[028] The optimizing device 106 may further include Input/Output (I/O) devices 112. Examples may include, but are not limited to a display, keypad, microphone, audio speakers, vibrating motor,

LED lights, etc. The I/O devices 112 may receive input from the navigation service provider device 104 and the ECU 102 of the vehicle and may further display an output of the computation performed by the processor 108. For example, the input may include at least one navigation attribute associated with an upcoming length of a route to be followed by the vehicle and at least one current working attribute associated with the vehicle. Further, the I/O devices 112 may display information related to the one or more optimizing parameters.

[029] Additionally, the optimizing device 106 may be communicatively coupled to ECU 102 of the vehicle for sending and receiving various data. The optimizing device 106 may connect to the ECU 102 of the vehicle wirelessly, for example via Bluetooth® or WiFi. The optimizing device 106 may connect to ECU 102 of the vehicle via a wired connection, for example via Universal Serial Bus (USB). The ECU 102 may be configured to set the vehicle in a desired driving state. The ECU 102 may receive inputs from different parts of the vehicle, depending on its function. For example, the ECU 102 may receive information about the driver inputs of speed when the driver presses the accelerator, and the ECU 102 may determine the amount of electrical energy which should be supplied to the electric motor to generate that speed. Further, the ECU 102 may manage switching between different travel modes using motor controller.

[030] Referring now to **FIG. 2**, a functional block diagram of an optimizing device 106 is illustrated, in accordance with an embodiment of the present disclosure. The optimizing device 106 may include a navigation attribute receiving module 202, a working attribute obtaining module 204, a correlation module 206, an optimizing parameter determining module 208, an optimizing action determining module 210, and a pattern obtaining module 212. It should be noted that the functionalities of the above modules may be performed individually by each module, or alternately the functionalities of multiple modules may be combined in a single module.

[031] The navigation attribute receiving module 202 may be configured to receive at least one navigation attribute associated with an upcoming length of a route to be followed by the vehicle. In some embodiments, the navigation attribute receiving module 202 may receive the at least one navigation attribute from the navigation service provider device 104. It should be noted that the at least one navigation attribute may include a gradient (i.e. elevation) associated with the upcoming

length of the route to be followed by the vehicle, and an average speed of traffic along the upcoming length of the route. The navigation attribute receiving module 202 may further, in coordination with the user interface of the input/output device 112, allow a user to provide an input of the location to be followed by the vehicle. By way of an example, in some cases, a user can input a current location and a destination location. Further, the navigation system provider device 104 may provide one or more routes along with the navigation information for the user to travel. As mentioned above, the navigation service provider device 104 may be communicatively coupled to the navigation attribute receiving module 202 of the optimizing device 106 via the communication network 114. By way of an example, the optimizing device 106 may communicate with the navigation service provider device 104 via a Controller area network (CAN).

[032] The working attribute obtaining module 204 may be configured to obtain the at least one current working attribute associated with the vehicle. For example, the working attribute obtaining module 204 may obtain the at least one current working attribute from the ECU 102 of the vehicle. It should be noted that the at least one current working attribute associated with the vehicle may include a current speed of the vehicle, a current torque being generated by the vehicle, and a current energy consumption of the vehicle.

[033] The correlation module 206 may be configured to correlate the at least one navigation attribute associated with the upcoming length of the route to be followed by the vehicle and the at least one current working attribute associated with the vehicle.

[034] The optimizing parameter determining module 208 may be configured to determine one or more optimizing parameters corresponding to the upcoming length of the route to be followed by the vehicle, based on the correlation. In some embodiments, the one or more optimizing parameters may include at least one first-type optimizing parameter for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle. In such embodiments, the upcoming length of the route is a predetermined distance from a current location of the vehicle. For example, in such embodiments, the destination location is not available. As such, for example, the predetermined distance from the current location of the vehicle may be selected as one kilometer, or two kilometers, or three kilometers, or five kilometers, etc. In other

words, the optimizing parameters may be determined for optimizing the vehicle operation for the predetermined distance from the current location of the vehicle. Therefore, the optimizing parameter determining module 208 may iteratively determine the optimizing parameters after every interval of the predetermined distance. For example, if the predetermined distance is selected to be two kilometers, the optimizing parameter determining module 208 may determine the optimizing parameters for every two kilometers of the upcoming length of a route which the vehicle is supposed to follow.

[035] The at least one first-type optimizing parameter may include an optimal speed to be maintained for the vehicle, an optimal torque to be generated for the vehicle, an energy consumption of the vehicle, a distance range the vehicle can run using an available battery charge, and a degree of regenerative braking applicable.

[036] In some embodiments, the one or more optimizing parameters may further include at least one second-type optimizing parameter for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle. In such embodiments, the upcoming length of the route may be a distance from a current location of the vehicle till a destination location. Therefore, in such embodiments, a destination location of the vehicle is also known along with the current location of the vehicle. The upcoming length of the route may therefore include a length associated with each of a plurality of routes existing between the current location and the destination location of the vehicle.

[037] The at least one second type optimizing parameter may include an overall energy consumption of the vehicle corresponding to each of the plurality of routes between the current location of the vehicle and the destination location, and an optimal route from the plurality of routes based on the overall energy consumption of the vehicle corresponding to the plurality of routes. The first-type optimizing parameters and the second-type optimizing parameters are further explained in detail in conjunction with FIGs. 3-4.

[038] Referring now to **FIG. 3**, a schematic view of a navigation path 300 of a vehicle from a current location of the vehicle is illustrated, in accordance with some embodiments. As shown in FIG. 3, the current location 302 (also denoted as A in FIG. 3) of the vehicle may be known and

received from the navigation service provider device 104. It should be noted that in this scenario, a destination location of the vehicle is not known. Therefore, the optimizing parameter determining module 208 may determine at least one first-type optimizing parameter for optimizing the operation of the vehicle corresponding to an upcoming length of the route to be followed by the vehicle. The upcoming length of the route is a predetermined distance (L1) from the current location 302 of the vehicle. For example, the predetermined distance (L1) from the current location 302 may be selected as one kilometer, or two kilometers, or three kilometers, or five kilometers, etc. Therefore, the optimizing parameter determining module 208 may iteratively determine the optimizing parameters after every interval of the predetermined distance (L1).

[039] The at least one first-type optimizing parameter may include an optimal speed to be maintained for the vehicle, an optimal torque to be generated for the vehicle, an energy consumption of the vehicle, a distance range the vehicle can run using an available battery charge, and a degree of regenerative braking applicable. Therefore, in particular, the optimizing parameter determining module 208 may determine what should be an optimal speed to be maintained for the vehicle for the predetermined distance (L1). The optimal speed may correspond to a speed that provides maximum energy efficiency. Similarly, the optimal torque may correspond to a torque that provides maximum energy efficiency. Further, the energy consumption of the vehicle may indicate an approximate distance that the vehicle can cover using the available battery charge, based on the correlation (i.e. correlation of the at least one navigation attribute associated with predetermined distance (L1) and the at least one current working attribute associated with the vehicle). Additionally, the at least one first-type optimizing parameter may include an optimal temperature of the motor, based on the optimal torque generated for required predictive calculation.

[040] In scenarios, when the vehicle is moving downhill, it may be desirable to use the potential energy of the vehicle to create electrical energy and recharge the batteries. As will be understood, the vehicle may be already equipped with a regenerative braking mechanism. As will be further understood, the regenerative braking allows the vehicle to convert the kinetic energy of the vehicle into electrical energy rather than letting that kinetic energy get dissipated as heat. Therefore, in such scenarios, the optimizing parameter determining module 208 may determine a degree of

regenerative braking that can be applied. The degree of regenerative braking may be based on a desired speed of the vehicle and sufficient amount of electricity generation. In other words, the degree of regenerative braking may seek to strike a balance between the speed of the vehicle and the amount of electricity generation. Further, as will be understood, the regenerative braking may not find relevance when the vehicle is moving uphill, since braking required may be much less as compared to moving downhill.

[041] Referring now to **FIG. 4**, a schematic view of a navigation path 400 of a vehicle from a current location to a destination location of the vehicle is illustrated, in accordance with some embodiments. As shown in FIG. 4, a current location 402 (also denoted as B in FIG. 4) of the vehicle may be known and received from the navigation service provider device 104. Further, a destination location 404 (also denoted as C in FIG. 4) of the vehicle may be known and received from the navigation service provider device 104. The destination location 404 may be, for example, inputted by a user, e.g. a driver of the vehicle.

[042] The optimizing parameter determining module 208 may determine at least one second-type optimizing parameter for optimizing the operation of the vehicle corresponding to an upcoming length of the route to be followed by the vehicle. The upcoming length of the route may be a distance from the current location 402 of the vehicle till the destination location 404. As will be appreciated, a plurality of routes 406A, 406B, 406C (it should be noted that only three routes are shown in FIG. 3 as an example scenario; however, the present disclosure may not be limited to this example scenario) may exist between the current location 402 and the destination location 404.

[043] The optimizing parameter determining module 208 may therefore determine an overall energy consumption of the vehicle corresponding to each of the plurality of routes 406A, 406B, 406C between the current location 402 and the destination location 404 of the vehicle. The overall energy consumption corresponding to each of the plurality of routes 406A, 406B, 406C may be determined based on the correlation between the at least one navigation attribute associated with the upcoming length of each of the routes 406A, 406B, 406C and the at least one current working attribute associated with the vehicle. Further, the at least one second-type optimizing parameter

may include an optimal route from the plurality of routes 406A, 406B, 406C based on the overall energy consumption of the vehicle corresponding to the plurality of routes 406A, 406B, 406C. For example, the optimal route may be the one that is associated with maximum energy efficiency or maximum range of the vehicle.

[044] Returning to FIG. 2, the optimizing action determining module 210 may determine one or more optimizing actions for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle based on the correlation. The one or more optimizing actions may include triggering the motor controller of the vehicle to maintain the optimal speed, or triggering the motor controller to generate the optimal torque, or triggering the motor controller to apply the degree of regenerative braking. In other words, once the optimizing parameter determining module 208 has determined the one or more optimizing parameters (corresponding to the upcoming length of the route to be followed by the vehicle), the optimizing action determining module 210 may determine the one or more optimizing actions for optimizing the operation of the vehicle.

[045] For example, the optimizing action determining module 210 may coordinate with the motor controller to maintain the optimal speed, generate the optimal torque, or apply the regenerative braking. In some embodiments, the optimizing action determining module 210 may be activated only when the vehicle is not being operated by a human user, i.e. the vehicle is running in autonomous mode or cruise control mode. However, in alternate embodiments, the optimizing action determining module 210 may override the operational control of the human user in order to better optimize the vehicle operation.

[046] The pattern obtaining module 212 may be configured to obtain a driving pattern of a driver of the vehicle. The pattern obtaining module 212 may be further configured to determine the one or more optimizing parameters for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle, based on the driving pattern, using a machine learning (ML) model. The driving patterns of the driver may therefore be analyzed to determine the optimizing parameters and recommend these optimizing parameters to the driver. For example, if the driver exhibits a pattern of driving the vehicle on a route at a particular time

(e.g. early morning) of the day, then based on the navigation attribute (e.g. traffic data) during that particular time, one or more optimizing parameters may be determined using the ML model.

[047] Referring now to **FIG. 5**, a flowchart of the method 500 of optimizing operation of a vehicle is illustrated, in accordance with an embodiment of the present disclosure. By way of an example, the method 500 may be performed by the optimizing device 106.

[048] At step 502, at least one navigation attribute associated with an upcoming length of a route to be followed by the vehicle may be received. The at least one navigation attribute may be received from the navigation service provider (e.g. the navigation service provider device 104). In some embodiments, at least one navigation attribute may include a gradient associated with the upcoming length of the route to be followed by the vehicle, and an average speed of traffic along the upcoming length of the route.

[049] At step 504, at least one current working attribute associated with the vehicle may be obtained from the electronic control unit (ECU) of the vehicle. The at least one current working attribute associated with the vehicle may include a current speed of the vehicle. At step 506, the at least one navigation attribute associated with the upcoming length of the route to be followed by the vehicle may be correlated with the at least one current working attribute associated with the vehicle.

[050] At step 508, one or more optimizing parameters corresponding to the upcoming length of the route to be followed by the vehicle may be determined based on the correlation. In some embodiments, the one or more optimizing parameters may include at least one first-type optimizing parameter for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle. In such embodiments, the upcoming length of the route may be a predetermined distance from a current location of the vehicle. For example, the at least one first-type optimizing parameter may include an optimal speed to be maintained for the vehicle, an optimal torque to be generated for the vehicle, an energy consumption of the vehicle, a distance range the vehicle can run using an available battery charge, and a degree of regenerative braking applicable. Additionally, the at least one first-type optimizing parameter may include an

optimal temperature of the motor, based on the optimal torque generated for required predictive calculation.

[051] Further, in some embodiments, the one or more optimizing parameters may include at least one second-type optimizing parameter for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle. In such embodiments, the upcoming length of the route is a distance from a current location of the vehicle till a destination location. The at least one second-type optimizing parameter may include an overall energy consumption of the vehicle corresponding to each of a plurality of routes between the current location of the vehicle and the destination location, and an optimal route from the plurality of routes based on the overall energy consumption of the vehicle corresponding to the plurality of routes.

[052] In some embodiments, additionally, at step 510, one or more optimizing actions may be determined for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle, based on the correlation. For example, the one or more optimizing actions may include triggering a motor controller of the vehicle to maintain the optimal speed, triggering the motor controller to generate the optimal torque, and triggering the motor controller to apply the degree of regenerative braking.

[053] Referring now to **FIG. 6**, a method 600 of optimizing operation of a vehicle based on the learning patterns of driving is illustrated, in accordance with some embodiments. At step 602, a driving pattern of a driver of the vehicle may be obtained. For example, the driver may exhibit a pattern of driving the vehicle on a route at a particular time (e.g. early morning) of the day. Such pattern may be obtained from historical navigation data associated with the driver. At step 604, the one or more optimizing parameters for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle may be determined, based on the driving pattern, using a machine learning (ML) model.

[054] One or more techniques are disclosed above for optimizing the operation of the vehicle, and in particularly, electric vehicles. The above techniques, therefore, help in eliminating or mitigating range anxiety associated with the EVs. Further, the above techniques utilize existing

technologies (navigation system and ECU) to develop a solution to accurately predict the range of EV. Further, the above techniques improve the drivability and range by predictive energy/mode management, facilitate accurate planning of charging when driving on highways, and help choosing the most optimal route that gives maximum range, thereby improving the overall user experience and saving energy. Furthermore, the above techniques can be implemented on all vehicles equipped with navigation system and ECU. Moreover, the above techniques use Machine Learning (ML) algorithms to further enhance the functionality and efficiency of the vehicles. The above techniques can be implemented (retrofitted) in existing vehicles, to enhance range estimation accuracy, and can be used in two wheelers, cars, and commercial vehicles.

[055] It is intended that the disclosure and examples be considered as exemplary only, with a true scope and spirit of disclosed embodiments being indicated by the following claims.

WE CLAIM:

1. A method of optimizing operation of a vehicle, the method comprising:

receiving, by an optimizing device, from a navigation service provider, at least one navigation attribute associated with an upcoming length of a route to be followed by the vehicle;

obtaining, by the optimizing device, from an electronic control unit (ECU) of the vehicle, at least one current working attribute associated with the vehicle;

correlating, by the optimizing device, the at least one navigation attribute associated with the upcoming length of the route to be followed by the vehicle and the at least one current working attribute associated with the vehicle; and

based on the correlation, determining, by the optimizing device, one or more optimizing parameters corresponding to the upcoming length of the route to be followed by the vehicle.

2. The method as claimed in claim 1, wherein the at least one navigation attribute comprises:

a gradient associated with the upcoming length of the route to be followed by the vehicle;
and

an average speed of traffic along the upcoming length of the route.

3. The method as claimed in claim 1, wherein the one or more optimizing parameters comprises:

at least one first-type optimizing parameter for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle, wherein the upcoming length of the route is a predetermined distance from a current location of the vehicle, wherein the at least one first-type optimizing parameter comprises:

an optimal speed to be maintained for the vehicle;

an optimal torque to be generated for the vehicle;

an energy consumption of the vehicle; and

a distance range the vehicle can run using an available battery charge; and

a degree of regenerative braking applicable.

4. The method as claimed in claim 3 further comprising:

determining one or more optimizing actions for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle based on the correlation, wherein the one or more optimizing actions comprises:

- triggering a motor controller of the vehicle to maintain the optimal speed;
- triggering the motor controller to generate the optimal torque; and
- triggering the motor controller to apply the degree of regenerative braking.

5. The method as claimed in claim 1, wherein the one or more optimizing parameters further comprises:

at least one second-type optimizing parameter for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle, wherein the upcoming length of the route is a distance from a current location of the vehicle till a destination location, wherein the at least one second-type optimizing parameter comprises:

- an overall energy consumption of the vehicle corresponding to each of a plurality of routes between the current location of the vehicle and the destination location; and
- an optimal route from the plurality of routes based on the overall energy consumption of the vehicle corresponding to the plurality of routes.

6. The method as claimed in claim 1, wherein the at least one current working attribute associated with the vehicle comprises a current speed of the vehicle.

7. The method as claimed in claim 1 further comprising:

- obtaining a driving pattern of a driver of the vehicle; and
- determining the one or more optimizing parameters for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle, based on the driving pattern, using a machine learning (ML) model.

8. A system for optimizing operation of a vehicle, the system comprising:

- a navigation service providing device; and
- an optimizing device comprising:
 - a processor; and

a memory communicatively coupled to the processor, wherein the memory stores processor-executable instructions, which upon execution, cause the processor to:

receive, from the navigation service provider device, at least one navigation attribute associated with an upcoming length of a route to be followed by the vehicle;

obtain, from an electronic control unit (ECU) of the vehicle, at least one current working attribute associated with the vehicle;

correlate the at least one navigation attribute associated with the upcoming length of the route to be followed by the vehicle and the at least one current working attribute associated with the vehicle; and

based on the correlation, determine one or more optimizing parameters corresponding to the upcoming length of the route to be followed by the vehicle.

9. The system as claimed in claim 8,

wherein the at least one navigation attribute comprises:

a gradient associated with the upcoming length of the route to be followed by the vehicle; and

an average speed of traffic along the upcoming length of the route; and

wherein the at least one current working attribute associated with the vehicle comprises:

a current speed of the vehicle.

10. The system as claimed in claim 8, wherein the one or more optimizing parameters comprise:

at least one first-type optimizing parameter for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle, wherein the upcoming length of the route is a predetermined distance from a current location of the vehicle, wherein the at least one first-type optimizing parameter comprises:

an optimal speed to be maintained for the vehicle;

an optimal torque to be generated for the vehicle;

an energy consumption of the vehicle; and

a distance range the vehicle can run using an available battery charge; and

a degree of regenerative braking applicable; and

at least one second-type optimizing parameter for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle, wherein the upcoming length of the route is a distance from a current location of the vehicle till a destination location, wherein the at least one second-type optimizing parameter comprises:

an overall energy consumption of the vehicle corresponding to each of a plurality of routes between the current location of the vehicle and the destination location; and

an optimal route from the plurality of routes based on the overall energy consumption of the vehicle corresponding to the plurality of routes.

11. The system as claimed in claim 10, wherein the processor-executable instructions further cause the processor to:

determine one or more optimizing actions for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle based on the correlation, wherein the one or more optimizing actions comprises:

triggering a motor controller of the vehicle to maintain the optimal speed;

triggering the motor controller to generate the optimal torque; and

triggering the motor controller to apply the degree of regenerative braking.

12. The system as claimed in claim 8, wherein the processor-executable instructions further cause the processor to:

obtain a driving pattern of a driver of the vehicle; and

determine the one or more optimizing parameters for optimizing the operation of the vehicle corresponding to the upcoming length of the route to be followed by the vehicle, based on the driving pattern, using a machine learning (ML) model.

Dated this 19 day of April 2022

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ABSTRACT

METHOD AND SYSTEM OF OPTIMIZING OPERATION OF AN ELECTRIC VEHICLE

A method and a system of optimizing operation of an electric vehicle is disclosed. The method may include receiving at least one navigation attribute associated with an upcoming length of a route to be followed by the vehicle from a navigation service provider. The method may further include obtaining at least one current working attribute associated with the vehicle from an electronic control unit (ECU) of the vehicle. The method may further include correlating the at least one navigation attribute associated with the upcoming length of the route to be followed by the vehicle and the at least one current working attribute associated with the vehicle. The method may further include determining one or more optimizing parameters corresponding to the upcoming length of the route to be followed by the vehicle based on the correlation.

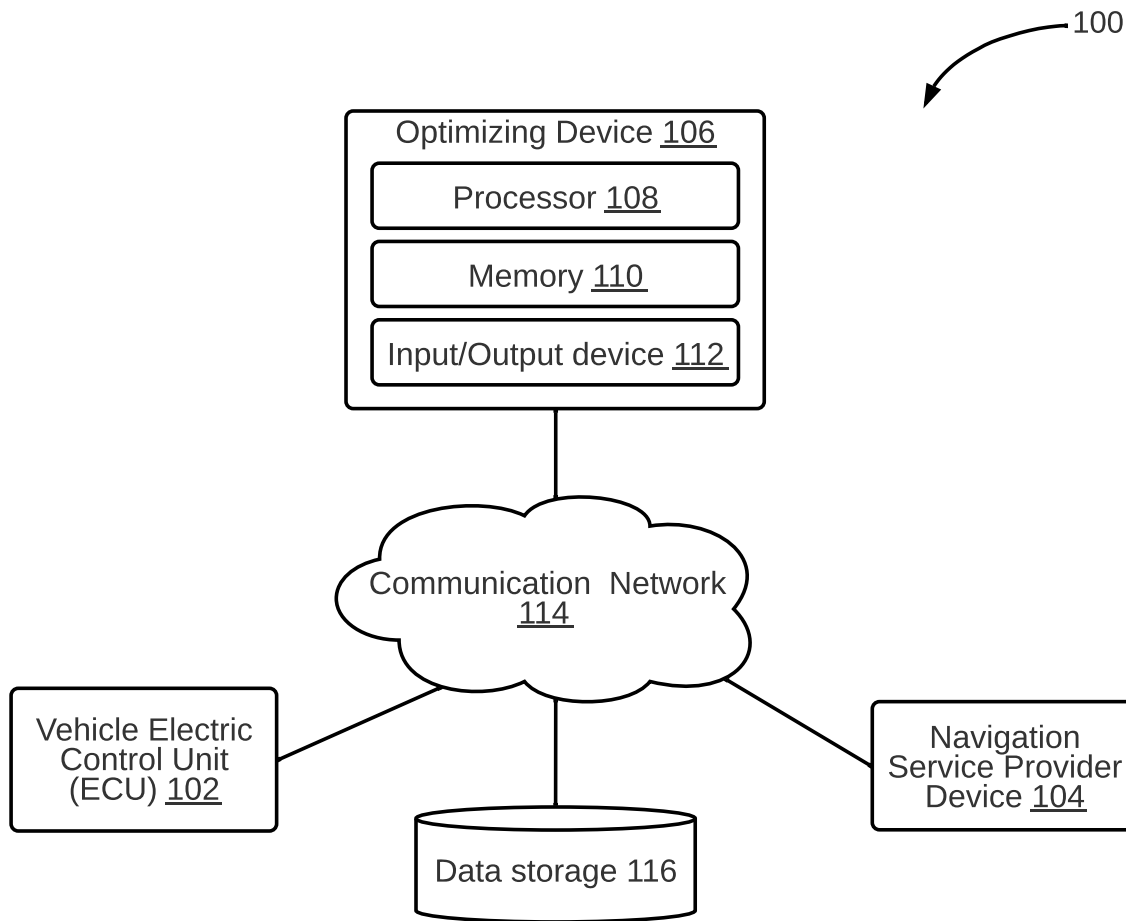


FIG. 1

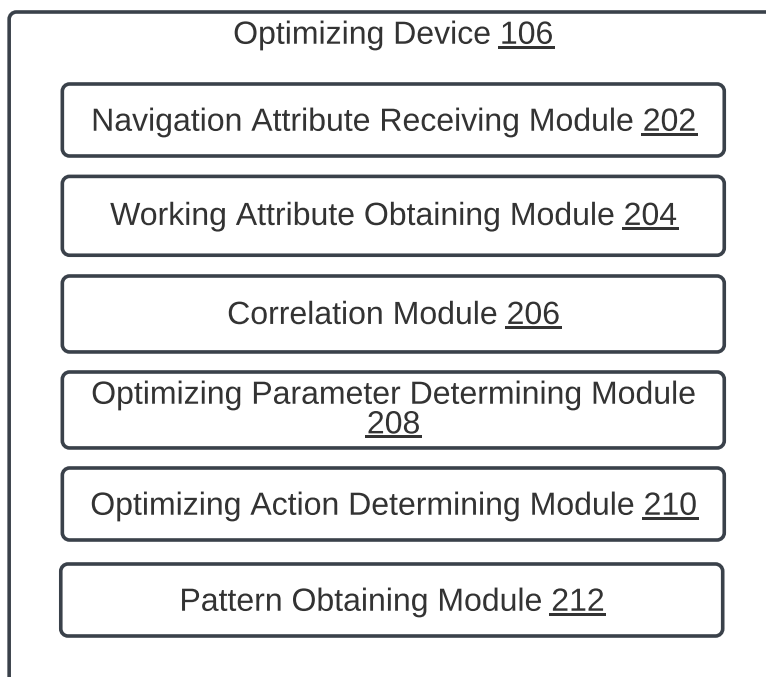


FIG. 2

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FIG. 3

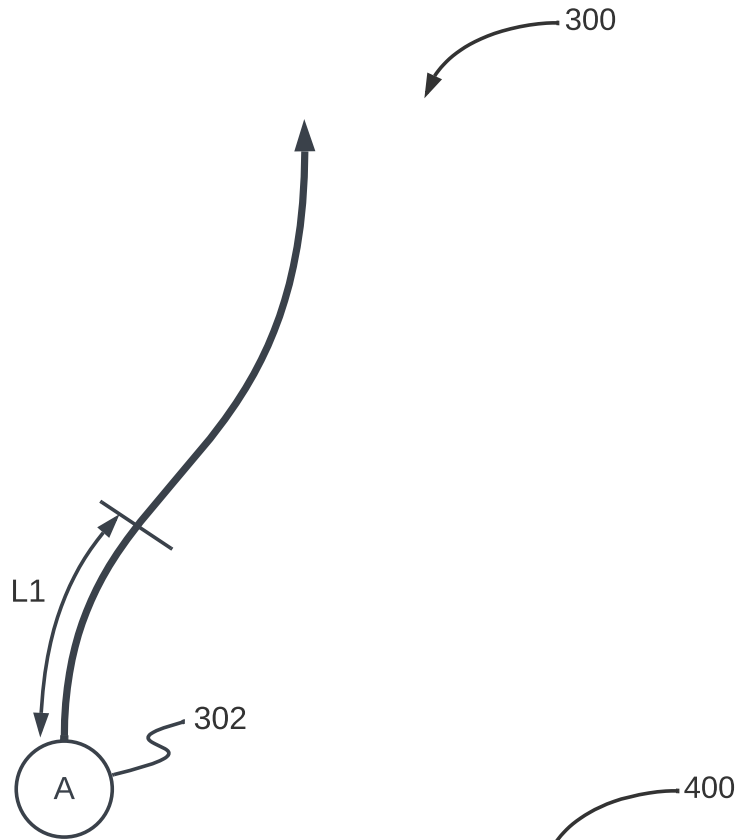
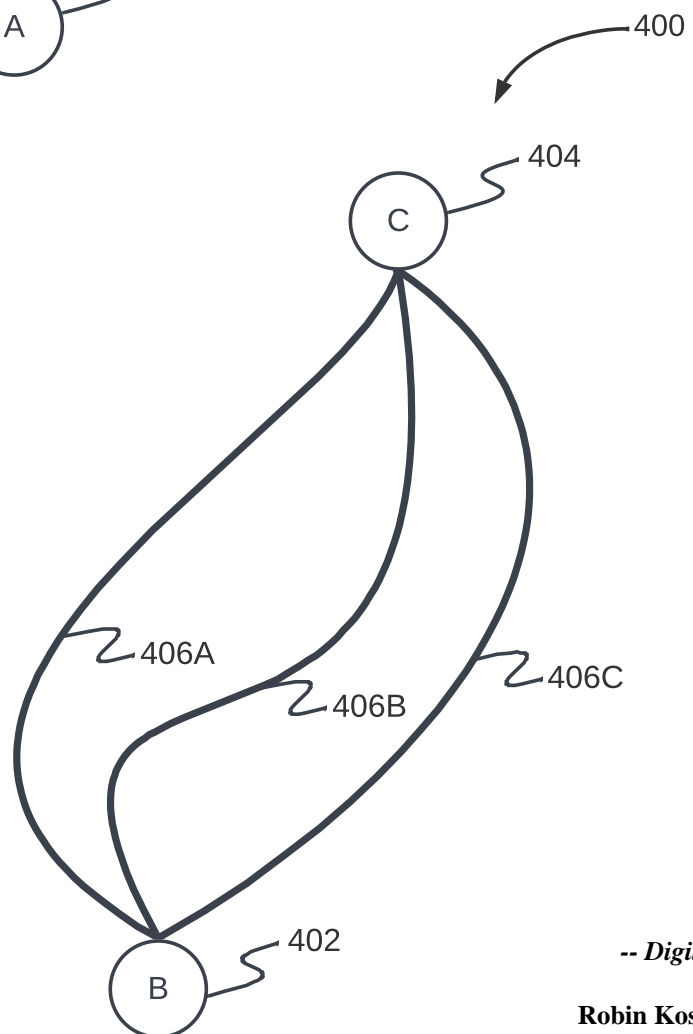


FIG. 4



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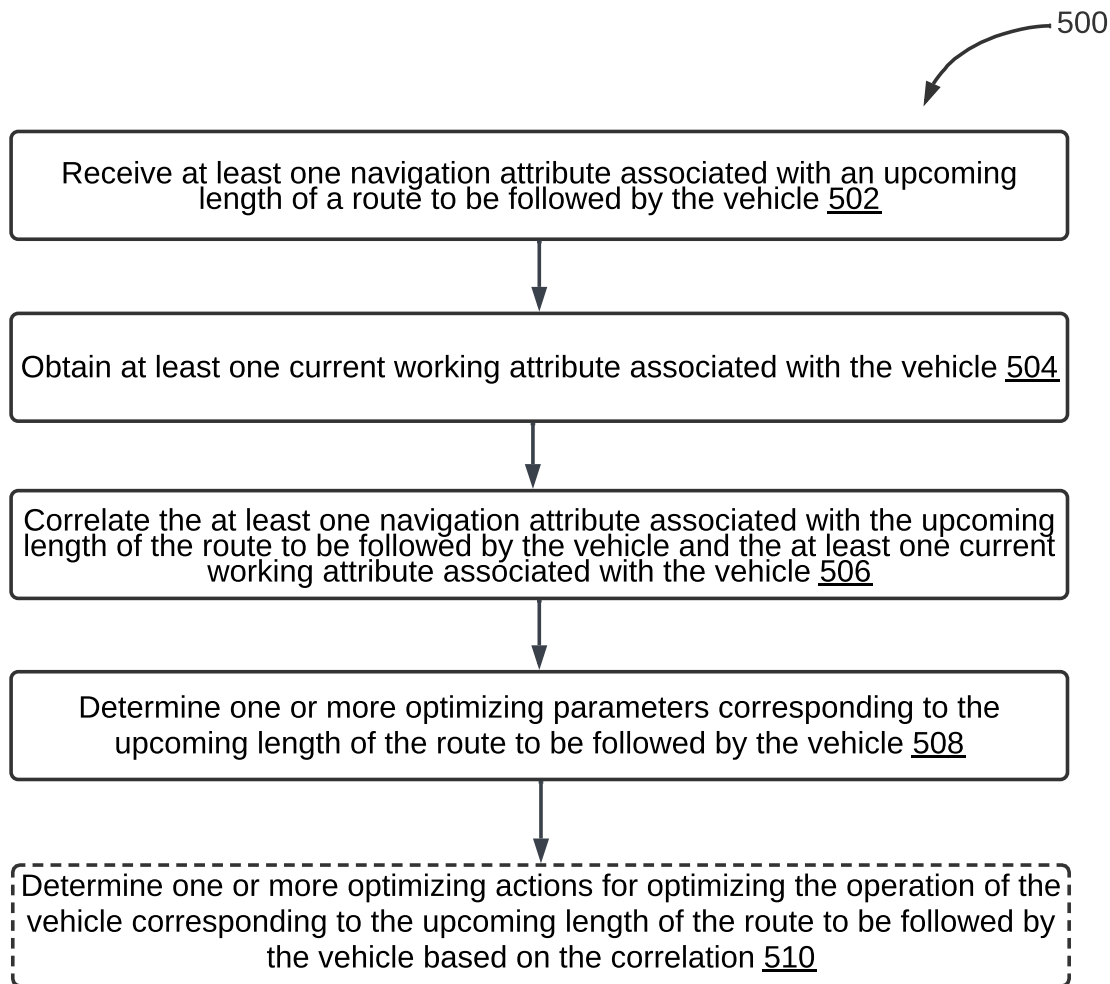


FIG. 5

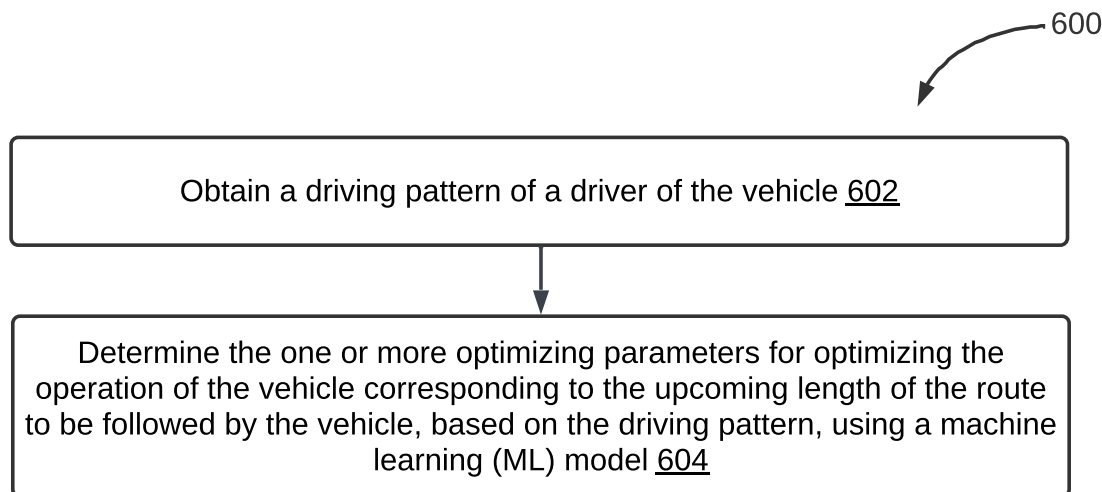


FIG. 6

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