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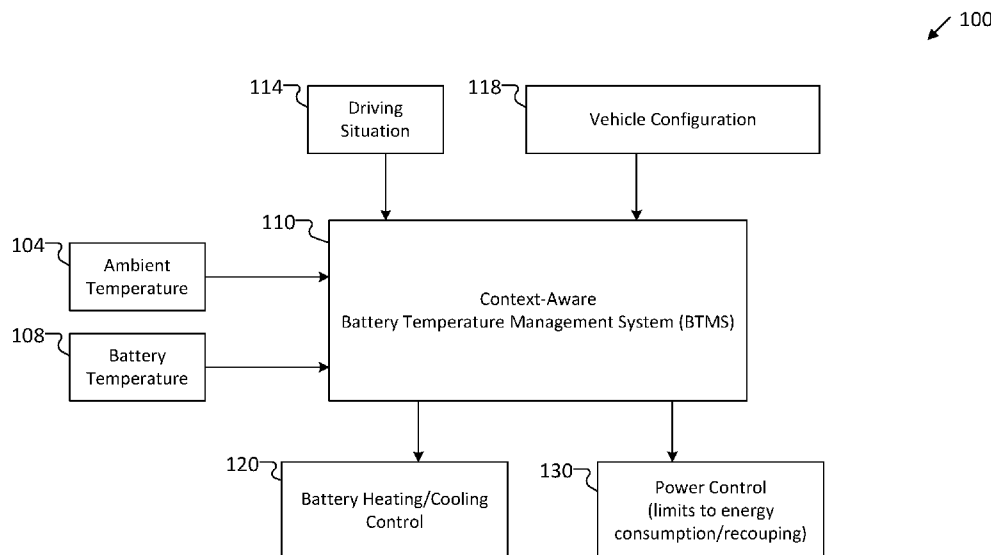


FIG. 1

(57) Abstract: Disclosed herein are devices, apparatuses, and systems for context-aware battery temperature management of a battery-powered vehicle. A battery temperature management system may determine a predicted operation of a vehicle based on a driving situation of the vehicle and/or an operational configuration of the vehicle. The battery temperature management system may determine a temperature action plan for a battery of the vehicle based on a current state of the battery and the predicted operation of the vehicle, wherein the temperature action plan comprises an operational parameter for controlling a temperature of the battery. The battery temperature management system may generate instructions based on the temperature action plan to control a temperature controller of the battery according to the operational parameter.

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ENERGY SUPPLY- AND DEMAND-BASED CONFIGURATION AND OPERATION OF ELECTRIC VEHICLES

Technical Field

[0001] The disclosure relates generally to vehicles, and in particular to electric/hybrid vehicles that have a rechargeable battery that can operate/propel the vehicle.

Background

[0002] In recent years, consumers and manufacturers have been moving from combustion engine vehicles to electric vehicles or hybrid vehicles. Electric and/or hybrid vehicles often include some form of energy storage, such as a rechargeable battery, that provides the vehicle a source of energy for operating the vehicle. Because the temperature of the battery is often critical to safety and performance, electric and/or hybrid vehicles may have a heating/cooling system for the battery that may be enabled or disabled in order to heat or cool the battery to a target temperature. In addition, depending on the current temperature of the battery, electric or hybrid vehicles may adjust the limits for how much (and/or how quickly) energy may be withdrawn from or recouped to the battery during a vehicle maneuver or how much (and/or how quickly) energy may be discharged to or supplied from a charging station. However, it may not be optimal to base the activation of the heating/cooling and/or the limits to the energy consumption/recoup on the temperature of the battery alone.

Brief Description of the Drawings

[0003] In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the exemplary principles of the disclosure. In the following description, various exemplary aspects of the disclosure are described with reference to the following drawings, in which:

FIG. 1 shows an example of a battery management system with context-aware battery temperature management that may generate instructions for heating/cooling the battery and/or for limiting the power consumption/recoup from/to the battery that may take into account the driving situation and/or operational configuration of the vehicle;

FIG. 2 shows an exemplary schematic flow diagram of exemplary inputs and outputs for analyzing driving situations with respect to battery management optimization; and

FIG. 3 shows an example of a battery management system with context-aware battery temperature management that may generate instructions for heating/cooling the battery and/or for limiting the power consumption/recoup from/to the battery that may take into account the driving situation and/or operational configuration of the vehicle;

FIG. 4 shows an exemplary schematic drawing of a device for managing the temperature of a battery of a vehicle that takes into account the driving situation of the vehicle; and

FIG. 5 depicts a schematic flow diagram of an exemplary method for context-aware battery temperature management of a battery-powered vehicle.

Description

[0004] The following detailed description refers to the accompanying drawings that show, by way of illustration, exemplary details and features.

[0005] The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any aspect or design described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects or designs.

[0006] Throughout the drawings, it should be noted that like reference numbers are used to depict the same or similar elements, features, and structures, unless otherwise noted.

[0007] The phrase “at least one” and “one or more” may be understood to include a numerical quantity greater than or equal to one (*e.g.*, one, two, three, four, [...], etc.). The phrase “at least one of” with regard to a group of elements may be used herein to mean at least one element from the group consisting of the elements. For example, the phrase “at least one of” with regard to a group of elements may be used herein to mean a selection of: one of the listed elements, a plurality of one of the listed elements, a plurality of individual listed elements, or a plurality of a multiple of individual listed elements.

[0008] The words “plural” and “multiple” in the description and in the claims expressly refer to a quantity greater than one. Accordingly, any phrases explicitly invoking the aforementioned words (*e.g.*, “plural [elements]”, “multiple [elements]”) referring to a quantity of elements expressly refers to more than one of the said elements. For instance, the phrase “a plurality” may be understood to include a numerical quantity greater than or equal to two (*e.g.*, two, three, four, five, [...], etc.).

[0009] The phrases “group (of)”, “set (of)”, “collection (of)”, “series (of)”, “sequence (of)”, “grouping (of)”, etc., in the description and in the claims, if any, refer to a quantity equal to or greater than one, i.e., one or more. The terms “proper subset”, “reduced subset”, and “lesser subset” refer to a subset of a set that is not equal to the set, illustratively, referring to a subset of a set that contains less elements than the set.

[0010] The term “data” as used herein may be understood to include information in any suitable analog or digital form, *e.g.*, provided as a file, a portion of a file, a set of files, a signal or stream, a portion of a signal or stream, a set of signals or streams, and the like. Further, the term “data” may also be used to mean a reference to information, *e.g.*, in the form of a pointer. The term “data”, however, is not limited to the aforementioned examples and may take various forms and represent any information as understood in the art.

[0011] The terms “processor” or “controller” as, for example, used herein may be understood as any kind of technological entity (*e.g.*, hardware, software, and/or a combination of both) that

allows handling of data. The data may be handled according to one or more specific functions executed by the processor or controller. Further, a processor or controller as used herein may be understood as any kind of circuit, *e.g.*, any kind of analog or digital circuit. A processor or a controller may thus be or include an analog circuit, digital circuit, mixed-signal circuit, software, firmware, logic circuit, processor, microprocessor, Central Processing Unit (CPU), Graphics Processing Unit (GPU), Digital Signal Processor (DSP), Field Programmable Gate Array (FPGA), integrated circuit, Application Specific Integrated Circuit (ASIC), etc., or any combination thereof. Any other kind of implementation of the respective functions, which will be described below in further detail, may also be understood as a processor, controller, or logic circuit. It is understood that any two (or more) of the processors, controllers, or logic circuits detailed herein may be realized as a single entity with equivalent functionality or the like, and conversely that any single processor, controller, or logic circuit detailed herein may be realized as two (or more) separate entities with equivalent functionality or the like.

[0012] As used herein, “memory” is understood as a computer-readable medium (*e.g.*, a non-transitory computer-readable medium) in which data or information can be stored for retrieval. References to “memory” included herein may thus be understood as referring to volatile or non-volatile memory, including random access memory (RAM), read-only memory (ROM), flash memory, solid-state storage, magnetic tape, hard disk drive, optical drive, 3D XPoint™, among others, or any combination thereof. Registers, shift registers, processor registers, data buffers, among others, are also embraced herein by the term memory. The term “software” refers to any type of executable instruction, including firmware.

[0013] Unless explicitly specified, the term “transmit” encompasses both direct (point-to-point) and indirect transmission (via one or more intermediary points). Similarly, the term “receive” encompasses both direct and indirect reception. Furthermore, the terms “transmit,” “receive,” “communicate,” and other similar terms encompass both physical transmission (*e.g.*, the transmission of radio signals) and logical transmission (*e.g.*, the transmission of digital data

over a logical software-level connection). For example, a processor or controller may transmit or receive data over a software-level connection with another processor or controller in the form of radio signals, where the physical transmission and reception is handled by radio-layer components such as radio frequency (RF) transceivers and antennas, and the logical transmission and reception over the software-level connection is performed by the processors or controllers. The term “communicate” encompasses one or both of transmitting and receiving, i.e., unidirectional or bidirectional communication in one or both of the incoming and outgoing directions. The term “calculate” encompasses both “direct” calculations via a mathematical expression/formula/relationship and ‘indirect’ calculations via lookup or hash tables and other array indexing or searching operations.

[0014] A “vehicle” may be understood to include any type of driven object. By way of example, a vehicle may be a driven object with a combustion engine, a reaction engine, an electrically driven object, a hybrid driven object, or a combination thereof. A vehicle may be or may include an automobile, a bus, a mini bus, a van, a truck, a mobile home, a vehicle trailer, a motorcycle, a bicycle, a tricycle, a train locomotive, a train wagon, a moving robot, a personal transporter, a boat, a ship, a submersible, a submarine, a drone, an aircraft, or a rocket, among others. As used herein, references to an “electric vehicle,” “EV,” and “hybrid vehicle” include any type of vehicle with an energy storage (e.g., a battery) that is capable of operating (e.g. propelling) the vehicle, irrespective of other sources of energy, if any, from which the vehicle may be alternatively or additionally operated (e.g., sources such as a combustion engine, solar panels, etc.).

[0015] The term “autonomous vehicle” may describe a vehicle capable of implementing at least one vehicle maneuver without driver input. A vehicle maneuver may describe or include a change in one or more of steering, braking, acceleration/deceleration, etc. of the vehicle. A vehicle may be described as autonomous even where the vehicle is not fully automatic (for example, is fully operational with driver input or without driver input). Autonomous vehicles may include

those vehicles that can operate under driver control during certain time periods and without driver control during other time periods. Autonomous vehicles may also include vehicles that control only some aspects of vehicle navigation, such as steering (e.g., to maintain a vehicle course between vehicle lane constraints) or some steering operations under certain circumstances, but may leave other aspects of vehicle navigation to the driver during other circumstances (e.g., braking under certain circumstances). Autonomous vehicles may also include vehicles that share the control of one or more aspects of vehicle maneuver implementation/planning under certain circumstances (e.g., hands-on, such as responsive to a driver input) and vehicles that control one or more aspects of vehicle maneuvering under certain circumstances (e.g., hands-off, such as independent of driver input). Autonomous vehicles may also include vehicles that control one or more aspects of vehicle navigation under certain circumstances, such as under certain environmental conditions (e.g., spatial areas, roadway conditions). In some aspects, autonomous vehicles may handle some or all aspects of braking, speed control, velocity control, and/or steering of the vehicle.

[0016] An autonomous vehicle may include those vehicles that can operate without a driver. The level of autonomy of a vehicle may be described or determined by the Society of Automotive Engineers (SAE) level of the vehicle (e.g., as defined by the SAE, for example in SAE J3016 2018: Taxonomy and definitions for terms related to driving automation systems for on road motor vehicles) or by other relevant professional organizations. The SAE level may have a value ranging from a minimum level, e.g. level 0 (illustratively, substantially no driving automation), to a maximum level, e.g. level 5 (illustratively, full driving automation).

[0017] Hybrid and electric vehicles may connect to charging stations in order to replenish their energy storage (e.g., one or more batteries), where energy may be withdrawn from the energy grid through the charging station to replenish the energy storage (e.g., recharge the battery). In addition, charging stations may be bidirectional, meaning that energy could be offloaded (e.g., dispensed) to the energy grid from the energy storage of the electric vehicle. Hybrid and electric

vehicles may have the capability to generate their own power (e.g., through solar panels on the roof) or to recoup power from changes in motion (e.g., a braking system may recoup energy to the battery by transferring energy of motion into electrical energy that may be returned to the battery).

[0018] As noted above, the temperature of the battery may be critical to its safe operation and to its overall performance. As such, electric vehicles often have a heating/cooling system that may be enabled depending on the temperature of the battery. In addition, electric vehicles may adjust, depending on the temperature of the battery, the limits for how much (and/or how quickly) energy may be withdrawn from or recouped to the battery during a vehicle maneuver or how much (and/or how quickly) energy may be discharged to or supplied from a charging station. This means that if the battery temperature is very hot, the vehicle may limit the energy withdrawal to only a small trickle of energy. This may mean that the acceleration, velocity, or other high-energy consumption actions of the vehicle may be limited. However, conventional systems that base the activation of the heating/cool system or base the energy limits simply on a battery temperature may not provide optimal, overall performance and safety of the battery and vehicle.

[0019] Generally, the temperature of the battery may need to be maintained at a target temperature to ensure that the battery is capable of supplying energy and to prevent battery degradation. For example, if the temperature of a typical rechargeable vehicle battery drops below freezing (e.g., below 0 °C or 32 °F), electrochemical reactions slow with a corresponding decrease in effective available output power and thus driving performance (e.g., decrease in acceleration, velocity, driving range, etc.). In addition, at below-freezing temperatures, there is an increased risk of battery damage during a charging operation. At temperatures above 30 °C (86 °F), for example, battery performance may also degrade effective available output power and driving performance. These high temperatures are additionally problematic because there may already be high power demands on the battery because, for example, at high temperatures, there may be a need to operate the in-cabin air conditioner. If the battery temperature reaches about 40 °C (104 °F), irreversible damage to the battery may occur. At between 70 and 100 °C, thermal

runaway may occur, causing a chain reaction that may destroy one or more cells and may spread to adjacent cells, eventually destroying the entire battery.

[0020] Battery temperature is not only influenced by external temperatures (e.g., ambient temperatures of the environment in which the vehicle may be operating), but also the amount of energy being withdrawn from the battery (e.g., by usage, by discharging to a charging station, etc.) or the amount of energy being supplied to the battery (e.g., while recouping energy from vehicle motion (e.g. through braking), by charging the battery from a charging station, etc.). As such, electric vehicles may use a Battery Temperature Management System (BTMS) to ensure that the temperature of the battery remains at a target temperature or within a target temperature range. A BTMS may include an active or passive cooling/heating system that may be enabled or disabled in order to set/maintain a target temperature or target temperature range. If the cooling/heating system is an active system (e.g., a liquid heat exchanger, a fan, a heater, etc.), activating the system may itself expend energy of the battery. In addition to or as an alternative to activating a cooling/heating system, a BTMS may also limit the amount of power extracted from or delivered to the battery. Limiting the amount of power consumed/recouped, may, in turn, limit the vehicle operation (e.g., limited acceleration, limited velocity, limited air-conditioning, etc.). In a conventional BTMS, activation of the heating/cool system or placing limits of the vehicle operation is based solely on battery temperature and may not be optimum for the overall situation.

[0021] In contrast to conventional systems, the battery management system disclosed in more detail below may be able to improve the overall battery performance by taking into account the actual/predicted driving situation and/or vehicle operation. In particular, the battery temperature management system may be enhanced to not only consider the current temperature of the battery but also to consider the specific driving situation, the specific operational configuration, and/or other factors that may be used to optimize the management of the battery temperature. For example, if an electric vehicle is driving on an empty highway and needs to reduce battery temperature, the disclosed battery management system might set a limit to the maximum power

consumptions during accelerations, which may reduce the battery temperature and save energy. On the other hand, if an electric vehicle is driving in dense traffic and may be frequently overtaking other vehicles, braking, and reaccelerating, the disclosed battery management system might prioritize safety over energy savings and provide higher limits (e.g., no limit) to the vehicle's power consumption for accelerations, braking, etc. while also expending more energy on the battery's active cooling system.

[0022] As another example, the disclosed battery management system might provide context-aware braking. As noted earlier, an electric vehicle may be equipped with an energy-recovery braking system, where the motors that drive the wheels may also spin in the opposite direction to decelerate the vehicle while harvesting energy from the deceleration (also called energy recoup, recouping, recoupment, or recuperation). If the vehicle's battery is operating within a particular temperature range where energy recoup from the braking system would normally be disabled, the disclosed battery management system may detect an emergency braking situation that, to prioritize driving safety, the vehicle may need to use all possible deceleration capabilities of the vehicle, so the disclosed battery management system may enable energy recoup from the braking system, even at this particular temperature range.

[0023] In sum, the disclosed battery management system may consider more than battery temperature when determining whether to enable/disable the heating/cooling system and/or whether to limit vehicle operation. By considering the particular driving situation, the preferences of the driver, the safety needs of the vehicle, etc., the disclosed battery management system may provide instructions to the vehicle systems (e.g., the heating/cooling system and/or the driving system) that provides optimal battery temperature management for the given situation. For example, the disclosed battery management system may take into account static environment information such as road slope, distance to junctions, the destination, etc., to precondition the battery temperature for energy harvesting on descents and smarter deceleration (e.g., adaptive energy recuperation) when approaching intersections. The disclosed battery management system

may also take into account dynamic environment information such as weather forecasts, the current traffic situation, the predicted traffic situation, etc. so that, for example, the disclosed battery management system may optimize battery temperature control settings to prioritize improved deceleration in emergency situations or improved energy recuperation when considering the right-of-way at intersections.

[0024] FIG. 1 shows a battery management system 100 with a context-aware battery temperature management system 110 that may generate instructions for heating/cooling the battery and/or for limiting the power consumption/recoup from/to the battery that may take into account not only temperature but also the driving situation and/or operational configuration of the vehicle. The context-aware battery temperature management system 110 may receive information about the ambient temperature 104 (e.g., from an air temperature sensor that senses the environment in which the vehicle is operating), the battery temperature 108 (e.g., from a temperature sensor of the battery), or any other parameters related to the state of the battery (e.g., the amount of current being drawn/injected from/to the battery, the power density, the voltage, etc.). As should be understood, the temperatures or other battery state parameters may be the current values or forecasted values for later point(s) in time. The context-aware battery temperature management system 110 may also receive information about the driving situation 114 of the vehicle. This may include, for example, information about the road geometries along a planned route (e.g., distances, changes in elevation (inclines/declines), curvature, traction), traffic along the planned route (e.g., current/expected traffic density, timings of traffic lights, average speeds along roads, etc.), weather along the planned route, the status of a safety system (e.g., a driver assistance system, an automated driving system, an advanced driver assistance system) that may maintain the current and predicted safety of the vehicle (e.g., its static and dynamic relationship to other objects within the environment), etc. As should be appreciated, the driving situation, traffic situation, weather information, etc. may be received from internal or external sensors, or received via messages received by the battery management system 100 (e.g., wirelessly via a receiver/transceiver). For

example, the battery management system 100 may receive such information from an external/cloud-based server.

[0025] The context-aware battery temperature management system 110 may also receive information about the vehicle configuration 118, which may include, for example driver preferences for vehicle operation (e.g., a preferred driving mode (e.g., a “sport” mode that prioritizes acceleration over energy consumption efficiency, a “green” mode that prioritizes energy saving over speed/acceleration)), operational limits of the vehicle (e.g., safety-related limits from a safety system (e.g., limits to acceleration/deceleration for current road conditions, limits to velocity when rounding a curve, limits to braking force in icy conditions, etc.)).

[0026] Based on the received information, the context-aware battery temperature management system 110 may determine an optimized temperature action plan that contains the operational parameters for controlling, at battery heating/cooling control 120, the temperature of the battery (e.g., operational parameters for when, how, and what extent to activate the battery cooling/heating system (e.g., a heater, an air conditioner, a liquid heat exchanger, etc.)). The temperature action plan may also include power control 130 that may adjust/place limits on the amount of energy that may be withdrawn from or supplied to the battery at a given time, where the power control 130 may be associated with vehicle instructions that may adapt the driving configuration of the vehicle so as to satisfy the limits. In this manner, the context-aware battery temperature management system 110 may optimize the received inputs into a dynamic plan that is not simply a static controller based solely on the temperature of the battery.

[0027] The schematic flow diagram 200 of FIG. 2 shows exemplary inputs and outputs for analyzing driving situations, which may be used and/or determined by the battery management system (e.g., battery management system 100). For example, the battery management system may use information about the driving situation of the vehicle (e.g., at driving situation 114) to estimate driving distances, heights, velocities, etc. and expected energy consumption corresponding thereto. As one example, the battery management system may receive information about the planned path

of the vehicle, such as the height/elevations along the driving path 201, traffic information 203, driving distances, speed limits, etc., and use this information to perform battery-related road/path analysis 250. Based on this information, the battery management system may predict an expected velocity for the vehicle along each segment in the planned path, where each segment is defined by a series of waypoints along the planned path to a destination. Then, from the change in height along each segment, combined with the expected velocity for the segment, the battery management system may predict an estimated requirement 253 (e.g., the energy consumption/recoupment required from/to the battery to travel the planned path). As should be appreciated, any information about the driving situation may be used by the battery management system to estimate the expected requirements for the vehicle's energy consumption/recoupment along the planned path.

[0028] In addition to road/path analysis 250, the battery management system may perform a battery-related situational analysis 260 to estimate relevant operational limits/requirements 265 associated with the current/predicted situation 205. As one example, the situational analysis may be safety-related, where the vehicle's relationship to other objects in the environment may be analyzed for safety. For example, the current or predicted road conditions, road curvature, nearby pedestrians, and/or vehicle density, as examples, may suggest limits or requirements for acceleration, braking, velocity, etc., each of which, when limited or when a minimum level is required, may impact the battery energy consumption. Using acceleration as an example, the situational analysis 260 may determine how demanding the current driving situation is and how aggressive the vehicle should accelerate/decelerate to be able to safely maneuver in the current situation. This acceleration/deceleration may be understood as an acceleration aggressiveness requirement or score that may be used by the battery management system to plan the controls for operating the heating/cooling and for the energy consumption/recoup of the battery. As should be appreciated, any information about the driving situation may be used by the battery management system to estimate the expected operational limits/requirements 265.

[0029] One example of how an analysis of the driving situation may impact the battery management system is where a vehicle approaches an intersection (e.g. a round-about) with good visibility. If there is a large amount of traffic at the intersection, there is a high likelihood that the vehicle will need to slow down and yield the right-of-way to other vehicles before entering the intersection. In such a situation, the battery management system may prioritize energy recuperation settings by setting the recuperation requirement to maximum and setting the maximum allowed acceleration to a minimum. In the opposite situation, where there is a low amount of traffic at the intersection, the battery management system may prioritize acceleration by setting the recuperation requirement to a minimum (e.g., only a small amount of deceleration may be needed to slow the vehicle just enough to safely traverse through the intersection), but acceleration operations may be unlimited. This type of operation of the disclosed battery management system is in contrast to conventional systems, where the recuperation and available acceleration would be independent of the situation and set to static values based on the battery temperature. Thus, in a conventional system, the vehicle may decelerate too quickly (e.g., too much recuperation) or too slowly (e.g., too little recuperation). This may be improved by the disclosed battery management system, which may dynamically adapt the operational limits to the driving situation.

[0030] Another example is an alpine road that has long ascents/descents. By analyzing the route and the road profile (e.g., elevation changes along segments of the road along the path) within the battery management system, the battery temperature management system may begin configuring settings to preconditioning the battery so as to maximize energy recuperation in the corresponding road segments of descent (or minimize energy loss in the corresponding road segments of ascent). This may mean that the battery management system may limit the possible acceleration on the last portion of an ascending road segment so that the battery will be properly conditioned for recoupment on the decent. Or, the battery management system may activate the

cooling system to cool the temperature of the battery so that it is at an optimum value when the vehicle starts the descent.

[0031] Another example is an emergency situation. The battery management system may detect as part of the driving situation analysis that an emergency situation requires configuration settings that prioritize safety over battery health (e.g., an emergency override). Such an emergency situation may occur, for example, where a vehicle is overtaking another vehicle and an unexpected object appears in the vehicle's overtaking path. In such a situation, the battery management system may configure the acceleration so as to allow for faster acceleration (e.g., to allow the vehicle to quickly overtake the other vehicle to avoid a collision) than would be normally allowed for the current battery temperature and/or configure the braking to allow for more forceful, higher-recoup braking (e.g., to allow the vehicle to quickly brake and end the overtake to avoid a collision) than would be normally allowed for the current battery temperature. A battery management system with such a feature would enhance the safety of the vehicle beyond conventional battery management systems, where there would be a fixed limit to the acceleration/braking based solely on the temperature of the battery.

[0032] FIG. 3 shows a battery management system 300 with a context-aware battery temperature management system 310 that may generate instructions for heating/cooling the battery and/or for limiting the power consumption/recoup from/to the battery that may take into account not only temperature but also the driving situation and/or operational configuration of the vehicle. The battery management system 300 may be similar to battery management system 100 (e.g., context-aware battery temperature management system 310 may correspond to context-aware battery temperature management system 110, ambient temperature 304 may correspond to ambient temperature 104, battery temperature 308 may correspond to battery temperature 108, driving situation 314 may correspond to driving situation 114, driver preference/vehicle operation configuration 318 may correspond to vehicle configuration 118), and the description of battery management system 100 and schematic flow diagram 200 may also apply to battery management

system 300. For simplicity, corresponding features described above may not be repeated below. As should be appreciated, while battery management system 300 may show features in additional detail as compared to battery management system 100, this is not intended to limit battery management system 100.

[0033] The context-aware battery temperature management system 310 may include a parameter optimizer 380 that may, based on the estimated energy requirements, operational limits/requirements, driver-based requirements/limits from the analysis of the driving situation 314 and/or the driver preference/vehicle operational configuration 318, optimize a temperature action plan for the vehicle. The temperature action plan may include instructions for controlling, at 320, the battery's heating/cooling system and/or instructions for power control 330 that may adjust/place limits on the amount of energy that may be withdrawn from or supplied to the battery at a given time, where the power control 330 may be associated with vehicle instructions that may adapt the driving configuration of the vehicle so as to satisfy the limits. Thus, the optimization may be designed to optimize a cooling/heating power parameter for controlling, at 320, the heating/cooling system and a power restriction parameter for the power control 330.

[0034] The parameter optimizer 380 may utilize a vehicle model 381 to predict the required power for the given set of inputs for the driving situation 314 and/or driver preference/vehicle operational configuration 318. For example, the parameter optimizer 380 may receive estimated energy requirements for a given driving path (e.g., changes in height along with a velocity for road segments along the driving path) and operational limits/restrictions (e.g., an acceleration aggressiveness). Once suitable parameter setting(s) are determined, the parameter optimizer 380 may send the parameter setting(s) to the battery model 390 that generates instructions for battery conditioning (e.g., using the battery heating/cooling control 320 to heat, cool and/or using power control 330 to limit energy withdrawn from or recuperated to the battery, etc.). One example of the determined parameter settings is shown in table 385, where the determined cooling power (e.g.,

a cooling/heating power parameter) and the determined driving power (e.g., a power restriction parameter) are shown for the different road segments (δ_1 , δ_2 , δ_3).

[0035] The battery model 390 may include a state prediction modeler that makes predictions for the estimated battery conditioning (e.g., estimated target temperatures for the battery 395) at future points in time. Such battery conditioning predictions may be helpful for avoiding continuously changing parameters (e.g., where the instructions for battery conditioning change from one time step to the next and may not be effective over a longer time horizon). Thus, the battery conditioning predictions may be provided back to the parameter optimizer 380 so that the parameter optimizer 380 may take them into account during optimization, so that it may consider the impact of its determined parameter setting(s) on future battery conditions. For example, after the estimated the parameter optimizer 380 receives the predictions for the estimated battery conditioning (e.g., estimated temperatures), it may check to see whether quality requirements/goals (e.g., predefined criterion associated with a parameter) have been reached and/or whether the determined parameter(s) were the optimal parameters, including, for example, whether the predictions for estimated temperatures fulfills the requirements of the expected temperature range, whether the acceleration profile (e.g., acceleration limits) meets the driver's preferences for acceleration, whether the cooling power has been minimized, etc.

[0036] The context-aware battery temperature management system 310 may also include a memory 388 (e.g., a database) for storing past parameter setting(s) along with the given set of inputs that led to the determined parameter setting(s). The parameter optimizer 380 may utilize past parameter setting(s) from memory 388 to accelerate finding parameter setting(s) for the current set of inputs. The memory 388 may be understood as a long-short-term memory (LSTM), where short term decisions avoid that the parameter optimizer 380 toggles between multiple states of parameter setting(s) and long term decisions are used to accelerate finding new solutions for the current set of inputs. As should be appreciated, the memory 388 may also include data from other vehicles (e.g., received from an external server/cloud-based platform). For example, the memory

288 may communicate with an external server (e.g., wirelessly via a receiver/transceiver) to receive a database of context-specific power management decisions and the inputs they were based on. In this manner, the parameter optimizer 380 may utilize the experience of other vehicles in its optimization algorithm. In addition, the battery management system may transmit (e.g., wirelessly via a transmitter/transceiver), information it collects in memory 388 to the external database of context-specific power management decisions and corresponding inputs. By sharing such data, the context awareness of the parameter optimizer 380 may be improved over time.

[0037] As should be appreciated, the parameter optimizer 380 may use any type of algorithm to determine the parameter setting(s) based on the inputs. For example, the optimizer may prioritize competing goals with a weighting system, select parameter setting(s) based on a mixed-integer program solver (linear or non-linear), an iterative solver such as simulated annealing, a learn-based model that utilizes a trained set of parameter setting(s) and inputs, etc.

[0038] As should be understood, the battery management systems discussed above are not necessarily limited to situations where the vehicle is actively in use (e.g., traveling toward a destination). The battery management systems discussed above may also apply to idle times where the vehicle is connected to a charging station. For example, the battery management system may set power control limits the transfer of power between the vehicle's battery and the charging station while charging/discharging the battery based on the received information. For example, if the weather at the charging station is expected to change while the vehicle is connected, the battery management system may wait to begin transferring power from/to the charging station until after the weather even occurs, when the battery may be in a better condition to charge/discharge.

[0039] FIG. 4 is a schematic drawing illustrating a device 400 for a battery management system of a vehicle. Device 400 may include any of the features of the battery management systems described above (e.g., battery management system 100, battery management system 300) with respect to FIGs. 1-3. The battery management system of FIG. 4 may be implemented as a device, a method, and/or a computer readable medium that, when executed, performs the features

of the battery management systems described above. It should be understood that device 400 is only an example, and other configurations may be possible that include, for example, different components or additional components.

[0040] Device 400 includes a processor 410. In addition to or in combination with any of the features described in the following paragraphs, processor 410 is configured to determine a predicted operation of a vehicle based on a driving situation of the vehicle and/or an operational configuration of the vehicle. In addition to or in combination with any of the features described in the following paragraphs, processor 410 is also configured to determine a temperature action plan for a battery of a vehicle based on a current state of the battery and the predicted operation of the vehicle, wherein the temperature action plan includes an operational parameter for controlling a temperature of the battery. In addition to or in combination with any of the features described in the following paragraphs, processor 410 is also configured to generate instructions based on the temperature action plan to control a temperature controller of the battery according to the operational parameter.

[0041] Furthermore, in addition to or in combination with any of the features described in this or the preceding paragraph with respect to device 400, the temperature action plan may further include a vehicle configuration parameter for controlling a driving configuration of the vehicle, wherein the instructions further include vehicle instructions to adjust the driving configuration according to the vehicle configuration parameter. Furthermore, in addition to or in combination with any of the features described in this or the preceding paragraph, the instructions may include an indication to enable or to disable a heat exchanger of the battery, wherein the heat exchanger is controllable by the operational parameter to heat or cool the battery. Furthermore, in addition to or in combination with any of the features described in this or the preceding paragraph, the vehicle configuration parameter for controlling operations of the vehicle may define an operating limit to a motion parameter of the vehicle based on an energy consumption from or an energy recouping to the battery that is associated with the motion parameter. Furthermore, in addition to or in

combination with any of the features described in this or the preceding paragraph, the motion parameter may include an acceleration or deceleration of the vehicle. Furthermore, in addition to or in combination with any of the features described in this or the preceding paragraph, the operating limit may include a maximum permitted acceleration and/or a minimum permitted acceleration of the vehicle.

[0042] Furthermore, in addition to or in combination with any of the features described in this or the preceding two paragraphs with respect to device 400, the current state of the battery may include a temperature of the battery. Furthermore, in addition to or in combination with any of the features described in this or the preceding two paragraphs, the current state of the battery may include at least one of a temperature of the battery, an amount of energy currently being withdrawn from the battery, an amount of energy currently being dispensed to the battery, a power density of the battery, and a voltage of the battery. Furthermore, in addition to or in combination with any of the features described in this or the preceding two paragraphs, the predicted operation of the vehicle may include an expected maximum acceleration or an expected minimum acceleration, wherein processor 410 may be further configured to determine the expected maximum acceleration or the expected minimum acceleration based on the driving situation of the vehicle. Furthermore, in addition to or in combination with any of the features described in this or the preceding two paragraphs, the predicted operation of the vehicle may include an estimated amount of energy expended in order to heat/cool the battery to a target temperature. Furthermore, in addition to or in combination with any of the features described in this or the preceding two paragraphs, the target temperature may include an optimum temperature for charging/discharging the battery in the driving situation.

[0043] Furthermore, in addition to or in combination with any of the features described in this or the preceding three paragraphs with respect to device 400, the predicted operation of the vehicle may include an estimated amount of energy expended to operate the vehicle in the driving situation and/or according to the operational configuration. Furthermore, in addition to or in combination

with any of the features described in this or the preceding three paragraphs, processor 410 may be configured to determine the temperature action plan further based on a driving configuration preference of the vehicle. Furthermore, in addition to or in combination with any of the features described in this or the preceding three paragraphs, the operational configuration of the vehicle may include a user-defined setting. Furthermore, in addition to or in combination with any of the features described in this or the preceding three paragraphs, the user-defined setting may include a maximum or minimum preferred acceleration. Furthermore, in addition to or in combination with any of the features described in this or the preceding three paragraphs, processor 410 may be further configured to determine the temperature action plan based on an ambient temperature outside the vehicle.

[0044] Furthermore, in addition to or in combination with any of the features described in this or the preceding four paragraphs with respect to device 400, the current state of the battery may include a current temperature of the battery, wherein the processor is further configured to receive the current temperature from a sensor 420 (e.g. a temperature sensor). Furthermore, in addition to or in combination with any of the features described in this or the preceding four paragraphs, processor 410 may be further configured to receive the ambient temperature from a sensor 420. Furthermore, in addition to or in combination with any of the features described in this or the preceding four paragraphs, sensor 420 may be located onboard the vehicle. Furthermore, in addition to or in combination with any of the features described in this or the preceding four paragraphs, the operational parameter may include a threshold limit to at least one of an amount of energy that is allowed to be withdrawn from the battery or recuperated to the battery, a rate at which energy is allowed to be withdrawn from the battery or recuperated to the battery, or a time at which energy is allowed to be withdrawn from the battery or recuperated to the battery.

[0045] Furthermore, in addition to or in combination with any of the features described in this or the preceding five paragraphs with respect to device 400, processor 410 is configured to determine the driving situation based on a road elevation profile that indicates a change in an

elevation that the vehicle is expected to experience during the predicted operation. Furthermore, in addition to or in combination with any of the features described in this or the preceding five paragraphs, the predicted operation may include movement of the vehicle along a series of waypoints to a destination, wherein each waypoint is associated with a corresponding elevation of a plurality of elevations, wherein the elevation includes one of the plurality of elevations. Furthermore, in addition to or in combination with any of the features described in this or the preceding five paragraphs, processor 410 may be configured to determine the driving situation based a traffic profile that indicates an expected travel time of the vehicle to a destination. Furthermore, in addition to or in combination with any of the features described in this or the preceding five paragraphs, the predicted operation may include movement of the vehicle along a series of waypoints to the destination, wherein each waypoint is associated with a corresponding expected travel time of a plurality of expected travel times, wherein the expected travel time includes one of the plurality of expected travel times.

[0046] Furthermore, in addition to or in combination with any of the features described in this or the preceding six paragraphs with respect to device 400, wherein processor 410 may be configured to determine the driving situation based on a historical database of situations, wherein each historical situation is associated with an expected amount of energy consumption of the battery in the historical situation. Furthermore, in addition to or in combination with any of the features described in this or the preceding six paragraphs, device 400 may further include a memory 430, wherein the processor is configured to store in memory 430 at least one of the predicted operation, the driving situation, the operational configuration, the temperature action plan, the operational parameter, the instructions, and the historical database of situations. Furthermore, in addition to or in combination with any of the features described in this or the preceding six paragraphs, the driving situation may include an expected level of acceleration aggressiveness. Furthermore, in addition to or in combination with any of the features described in this or the preceding six paragraphs, wherein the operational configuration includes a safety-

based requirement associated with the driving situation. Furthermore, in addition to or in combination with any of the features described in this or the preceding six paragraphs, the temperature action plan may include an emergency override of the operational parameter, wherein the emergency override is configured to adjust a value of the operational parameter or to provide a delay to an implementation time of the operational parameter.

[0047] Furthermore, in addition to or in combination with any of the features described in this or the preceding seven paragraphs with respect to device 400, processor 410 configured to determine the temperature action plan may include processor 410 configured to perform a multivariate optimization of the operational parameter based on at least one of a set of variables included of: a maximum/minimum acceleration requirement for the predicted operation, a maximum/minimum velocity requirement for the predicted operation, a safety-based requirement for the predicted operation, a driver-based requirement for the predicted operation, a road slope of the predicted operation, and an environmental condition of the predicted operation. Furthermore, in addition to or in combination with any of the features described in this or the preceding seven paragraphs, the multivariate optimization includes a maximization function configured to maximize each of a predefined criterion associated with each variable of the set of variables. Furthermore, in addition to or in combination with any of the features described in this or the preceding seven paragraphs, the maximization function may include at least one of a mixed-integer program solver, a mixed-integer linear program solver, an iterative solver, a simulated annealing solver, and a learning-based solver.

[0048] Furthermore, in addition to or in combination with any of the features described in this or the preceding eight paragraphs with respect to device 400 processor 410 may be configured to receive external information associated with the driving situation and/or operational configuration from a server that is external to the vehicle. Furthermore, in addition to or in combination with any of the features described in this or the preceding eight paragraphs, the external information may include weather information in an environment associated with the predicted operation of the

vehicle. Furthermore, in addition to or in combination with any of the features described in this or the preceding eight paragraphs, the external information may include traffic information about traffic conditions associated with the predicted operation of the vehicle. Furthermore, in addition to or in combination with any of the features described in this or the preceding eight paragraphs, the external information may include locations of charging stations associated with the predicted operation of the vehicle. Furthermore, in addition to or in combination with any of the features described in this or the preceding eight paragraphs, the external information may include historical information about previously determined temperature action plans associated with driving situations and/or operation configurations that are similar to the driving situation and/or operation configuration. Furthermore, in addition to or in combination with any of the features described in this or the preceding eight paragraphs, processor 410 may be configured to transmit the temperature action plan, the driving situation, and/or the operation configuration to the server.

[0049] FIG. 5 depicts a schematic flow diagram of a method 500 for a battery management system of a vehicle. Method 500 may implement any of the features of the battery management systems described above (e.g., battery management system 100, battery management system 300) with respect to FIGs. 1-4.

[0050] Method 500 includes, in 510, determining a predicted operation of a vehicle based on a driving situation of the vehicle and/or an operational configuration of the vehicle. Method 500 also includes, in 520, determining a temperature action plan for a battery of a vehicle based on a current state of the battery and the predicted operation of the vehicle, wherein the temperature action plan includes an operational parameter for controlling a temperature of the battery. Method 500 also includes, in 530, generating instructions based on the temperature action plan to control a temperature controller of the battery according to the operational parameter.

[0051] In the following, various examples are provided that may include one or more features of the battery management systems described above (e.g., battery management system 100, battery management system 300, device 400, method 500) with respect to FIGs. 1-5. It may be intended

that aspects described in relation to the devices may apply also to the described method(s), and vice versa.

[0052] Example 1 is a device including a processor configured to determine a predicted operation of a vehicle based on a driving situation of the vehicle and/or an operational configuration of the vehicle. The processor is also configured to determine a temperature action plan for a battery of a vehicle based on a current state of the battery and the predicted operation of the vehicle, wherein the temperature action plan includes an operational parameter for controlling a temperature of the battery. The processor is also configured to generate instructions based on the temperature action plan to control a temperature controller of the battery according to the operational parameter.

[0053] Example 2 is the device of example 1, wherein the temperature action plan further includes a vehicle configuration parameter for controlling a driving configuration of the vehicle, wherein the instructions further include vehicle instructions to adjust the driving configuration according to the vehicle configuration parameter.

[0054] Example 3 is the device of example 2, wherein the instructions include an indication to enable or to disable a heat exchanger of the battery, wherein the heat exchanger is controllable by the operational parameter to heat or cool the battery.

[0055] Example 4 is the device of either one of examples 2 or 3, wherein the vehicle configuration parameter for controlling operations of the vehicle defines an operating limit to a motion parameter of the vehicle based on an energy consumption from or an energy recouping to the battery that is associated with the motion parameter.

[0056] Example 5 is the device of example 4, wherein the motion parameter includes an acceleration or deceleration of the vehicle.

[0057] Example 6 is the device of either one of examples 4 or 5, wherein the operating limit includes a maximum permitted acceleration and/or a minimum permitted acceleration of the vehicle.

[0058] Example 7 is the device of any one of examples 1 to 6, wherein the current state of the battery includes a temperature of the battery.

[0059] Example 8 is the device of any one of examples 1 to 7, wherein the current state of the battery includes at least one of a temperature of the battery, an amount of energy currently being withdrawn from the battery, an amount of energy currently being dispensed to the battery, a power density of the battery, and a voltage of the battery.

[0060] Example 9 is the device of any one of examples 1 to 8, wherein the predicted operation of the vehicle includes an expected maximum acceleration or an expected minimum acceleration, wherein the processor is further configured to determine the expected maximum acceleration or the expected minimum acceleration based on the driving situation of the vehicle.

[0061] Example 10 is the device of any one of examples 1 to 9, wherein the predicted operation of the vehicle includes an estimated amount of energy expended in order to heat/cool the battery to a target temperature.

[0062] Example 11 is the device of example 10, wherein the target temperature includes an optimum temperature for charging/discharging the battery in the driving situation.

[0063] Example 12 is the device of any one of examples 1 to 11, wherein the predicted operation of the vehicle includes an estimated amount of energy expended to operate the vehicle in the driving situation and/or according to the operational configuration.

[0064] Example 13 is the device of any one of examples 1 to 12, wherein the processor is configured to determine the temperature action plan further based on a driving configuration preference of the vehicle.

[0065] Example 14 is the device of example 13, wherein the operational configuration of the vehicle includes a user-defined setting.

[0066] Example 15 is the device of example 14, wherein the user-defined setting includes a maximum or minimum preferred acceleration.

[0067] Example 16 is the device of any one of examples 1 to 15, wherein the processor is further configured to determine the temperature action plan based on an ambient temperature outside the vehicle.

[0068] Example 17 is the device of any one of examples 1 to 16, wherein the current state of the battery includes a current temperature of the battery, wherein the processor is further configured to receive the current temperature from a temperature sensor.

[0069] Example 18 is the device of either one of examples 16 or 17, wherein the processor is further configured to receive the ambient temperature from a temperature sensor.

[0070] Example 19 is the device of either one of examples 17 or 18, wherein the temperature sensor is located onboard the vehicle

[0071] Example 20 is the device of any one of examples 1 to 19, wherein the operational parameter includes a threshold limit to at least one of an amount of energy that is allowed to be withdrawn from the battery or recuperated to the battery, a rate at which energy is allowed to be withdrawn from the battery or recuperated to the battery, or a time at which energy is allowed to be withdrawn from the battery or recuperated to the battery.

[0072] Example 21 is the device of any one of examples 1 to 20, wherein the processor is configured to determine the driving situation based on a road elevation profile that indicates a change in an elevation that the vehicle is expected to experience during the predicted operation.

[0073] Example 22 is the device of example 21, wherein the predicted operation includes movement of the vehicle along a series of waypoints to a destination, wherein each waypoint is associated with a corresponding elevation of a plurality of elevations, wherein the elevation includes one of the plurality of elevations.

[0074] Example 23 is the device of any one of examples 1 to 22, wherein the processor is configured to determine the driving situation based a traffic profile that indicates an expected travel time of the vehicle to a destination.

[0075] Example 24 is the device of example 23, wherein the predicted operation includes movement of the vehicle along a series of waypoints to the destination, wherein each waypoint is associated with a corresponding expected travel time of a plurality of expected travel times, wherein the expected travel time includes one of the plurality of expected travel times.

[0076] Example 25 is the device of any one of examples 1 to 24, wherein the processor is configured to determine the driving situation based on a historical database of situations, wherein each historical situation is associated with an expected amount of energy consumption of the battery in the historical situation.

[0077] Example 26 is the device of any one of examples 1 to 25, the device further including a memory, wherein the processor is configured to store in the memory at least one of the predicted operation, the driving situation, the operational configuration, the temperature action plan, the operational parameter, the instructions, and the historical database of situations.

[0078] Example 27 is the device of any one of examples 1 to 26, wherein the driving situation includes an expected level of acceleration aggressiveness.

[0079] Example 28 is the device of any one of examples 1 to 27, wherein the operational configuration includes a safety-based requirement associated with the driving situation.

[0080] Example 29 is the device of any one of examples 1 to 28, wherein the temperature action plan includes an emergency override of the operational parameter, wherein the emergency override is configured to adjust a value of the operational parameter or to provide a delay to an implementation time of the operational parameter.

[0081] Example 30 is the device of any one of examples 1 to 29, wherein the processor configured to determine the temperature action plan includes the processor configured to perform a multivariate optimization of the operational parameter based on at least one of a set of variables included of: a maximum/minimum acceleration requirement for the predicted operation, a maximum/minimum velocity requirement for the predicted operation, a safety-based requirement

for the predicted operation, a driver-based requirement for the predicted operation, a road slope of the predicted operation, and an environmental condition of the predicted operation.

[0082] Example 31 is the device of example 30, wherein the multivariate optimization includes a maximization function configured to maximize each of a predefined criterion associated with each variable of the set of variables.

[0083] Example 32 is the device of example 31, wherein the maximization function includes at least one of a mixed-integer program solver, a mixed-integer linear program solver, an iterative solver, a simulated annealing solver, and a learning-based solver.

[0084] Example 33 is the device of any one of examples 1 to 32, wherein the processor is configured to receive external information associated with the driving situation and/or operational configuration from a server that is external to the vehicle.

[0085] Example 34 is the device of example 33, wherein the external information includes weather information in an environment associated with the predicted operation of the vehicle.

[0086] Example 35 is the device of either one of examples 33 or 34, wherein the external information includes traffic information about traffic conditions associated with the predicted operation of the vehicle.

[0087] Example 36 is the device of any of examples 33 to 35, wherein the external information includes locations of charging stations associated with the predicted operation of the vehicle.

[0088] Example 37 is the device of any of examples 33 to 36, wherein the external information includes historical information about previously determined temperature action plans associated with driving situations and/or operation configurations that are similar to the driving situation and/or operation configuration.

[0089] Example 38 is the device of any of examples 33 to 37, wherein the processor is configured to transmit the temperature action plan, the driving situation, and/or the operation configuration to the server.

[0090] Example 39 is a method that includes determining a predicted operation of a vehicle based on a driving situation of the vehicle and/or an operational configuration of the vehicle. The method also includes determining a temperature action plan for a battery of a vehicle based on a current state of the battery and the predicted operation of the vehicle, wherein the temperature action plan includes an operational parameter for controlling a temperature of the battery. The method also includes generating instructions based on the temperature action plan to control a temperature controller of the battery according to the operational parameter.

[0091] Example 40 is the method of example 39, wherein the temperature action plan further includes a vehicle configuration parameter for controlling a driving configuration of the vehicle, wherein the instructions further include vehicle instructions to adjust the driving configuration according to the vehicle configuration parameter.

[0092] Example 41 is the method of example 40, wherein the instructions include an indication to enable or to disable a heat exchanger of the battery, wherein the heat exchanger is controllable by the operational parameter to heat or cool the battery.

[0093] Example 42 is the method of either one of examples 40 or 41, wherein the vehicle configuration parameter for controlling operations of the vehicle defines an operating limit to a motion parameter of the vehicle based on an energy consumption from or an energy recouping to the battery that is associated with the motion parameter.

[0094] Example 43 is the method of example 42, wherein the motion parameter includes an acceleration or deceleration of the vehicle.

[0095] Example 44 is the method of either one of examples 42 or 43, wherein the operating limit includes a maximum permitted acceleration and/or a minimum permitted acceleration of the vehicle.

[0096] Example 45 is the method of any one of examples 39 to 44, wherein the current state of the battery includes a temperature of the battery.

[0097] Example 46 is the method of any one of examples 39 to 45, wherein the current state of the battery includes at least one of a temperature of the battery, an amount of energy currently being withdrawn from the battery, an amount of energy currently being dispensed to the battery, a power density of the battery, and a voltage of the battery.

[0098] Example 47 is the method of any one of examples 39 to 46, wherein the predicted operation of the vehicle includes an expected maximum acceleration or an expected minimum acceleration, wherein the method further includes determining the expected maximum acceleration or the expected minimum acceleration based on the driving situation of the vehicle.

[0099] Example 48 is the method of any one of examples 39 to 47, wherein the predicted operation of the vehicle includes an estimated amount of energy expended in order to heat/cool the battery to a target temperature.

[0100] Example 49 is the method of example 48, wherein the target temperature includes an optimum temperature for charging/discharging the battery in the driving situation.

[0101] Example 50 is the method of any one of examples 39 to 49, wherein the predicted operation of the vehicle includes an estimated amount of energy expended to operate the vehicle in the driving situation and/or according to the operational configuration.

[0102] Example 51 is the method of any one of examples 39 to 50, wherein the method further includes determining the temperature action plan further based on a driving configuration preference of the vehicle.

[0103] Example 52 is the method of example 51, wherein the operational configuration of the vehicle includes a user-defined setting.

[0104] Example 53 is the method of example 52, wherein the user-defined setting includes a maximum or minimum preferred acceleration.

[0105] Example 54 is the method of any one of examples 39 to 53, wherein the method further includes determining the temperature action plan based on an ambient temperature outside the vehicle.

[0106] Example 55 is the method of any one of examples 39 to 54, wherein the current state of the battery includes a current temperature of the battery, wherein the method further includes receiving the current temperature from a temperature sensor.

[0107] Example 56 is the method of either one of examples 54 or 55, wherein the method further includes receiving the ambient temperature from a temperature sensor.

[0108] Example 57 is the method of either one of examples 55 or 56, wherein the temperature sensor is located onboard the vehicle.

[0109] Example 58 is the method of any one of examples 39 to 57, wherein the operational parameter includes a threshold limit to at least one of an amount of energy that is allowed to be withdrawn from the battery or recuperated to the battery, a rate at which energy is allowed to be withdrawn from the battery or recuperated to the battery, or a time at which energy is allowed to be withdrawn from the battery or recuperated to the battery.

[0110] Example 59 is the method of any one of examples 39 to 58, wherein the method includes determining the driving situation based on a road elevation profile that indicates a change in an elevation that the vehicle is expected to experience during the predicted operation.

[0111] Example 60 is the method of example 59, wherein the predicted operation includes movement of the vehicle along a series of waypoints to a destination, wherein each waypoint is associated with a corresponding elevation of a plurality of elevations, wherein the elevation includes one of the plurality of elevations.

[0112] Example 61 is the method of any one of examples 39 to 60, wherein the method further includes determining the driving situation based a traffic profile that indicates an expected travel time of the vehicle to a destination.

[0113] Example 62 is the method of example 61, wherein the predicted operation includes movement of the vehicle along a series of waypoints to the destination, wherein each waypoint is associated with a corresponding expected travel time of a plurality of expected travel times, wherein the expected travel time includes one of the plurality of expected travel times.

[0114] Example 63 is the method of any one of examples 39 to 62, wherein the method includes determining the driving situation based on a historical database of situations, wherein each historical situation is associated with an expected amount of energy consumption of the battery in the historical situation.

[0115] Example 64 is the method of any one of examples 39 to 63, the method further including storing (e.g., in a memory) at least one of the predicted operation, the driving situation, the operational configuration, the temperature action plan, the operational parameter, the instructions, and the historical database of situations.

[0116] Example 65 is the method of any one of examples 39 to 64, wherein the driving situation includes an expected level of acceleration aggressiveness.

[0117] Example 66 is the method of any one of examples 39 to 65, wherein the operational configuration includes a safety-based requirement associated with the driving situation.

[0118] Example 67 is the method of any one of examples 39 to 66, wherein the temperature action plan includes an emergency override of the operational parameter, wherein the emergency override is configured to adjust a value of the operational parameter or to provide a delay to an implementation time of the operational parameter.

[0119] Example 68 is the method of any one of examples 39 to 67, wherein determining the temperature action plan includes performing a multivariate optimization of the operational parameter based on at least one of a set of variables included of: a maximum/minimum acceleration requirement for the predicted operation, a maximum/minimum velocity requirement for the predicted operation, a safety-based requirement for the predicted operation, a driver-based requirement for the predicted operation, a road slope of the predicted operation, and an environmental condition of the predicted operation.

[0120] Example 69 is the method of example 68, wherein the multivariate optimization includes a maximization function configured to maximize each of a predefined criterion associated with each variable of the set of variables.

[0121] Example 70 is the method of example 69, wherein the maximization function includes at least one of a mixed-integer program solver, a mixed-integer linear program solver, an iterative solver, a simulated annealing solver, and a learning-based solver.

[0122] Example 71 is the method of any one of examples 39 to 70, wherein the method includes receiving external information associated with the driving situation and/or operational configuration from a server that is external to the vehicle.

[0123] Example 72 is the method of example 71, wherein the external information includes weather information in an environment associated with the predicted operation of the vehicle.

[0124] Example 73 is the method of either one of examples 71 or 72, wherein the external information includes traffic information about traffic conditions associated with the predicted operation of the vehicle.

[0125] Example 74 is the method of any of examples 71 to 73, wherein the external information includes locations of charging stations associated with the predicted operation of the vehicle.

[0126] Example 75 is the method of any of examples 71 to 74, wherein the external information includes historical information about previously determined temperature action plans associated with driving situations and/or operation configurations that are similar to the driving situation and/or operation configuration.

[0127] Example 76 is the method of any of examples 71 to 75, wherein the method includes transmitting the temperature action plan, the driving situation, and/or the operation configuration to the server.

[0128] Example 77 is an apparatus that includes a means for determining a predicted operation of a vehicle based on a driving situation of the vehicle and/or an operational configuration of the vehicle. The apparatus also includes a means for determining a temperature action plan for a battery of a vehicle based on a current state of the battery and the predicted operation of the vehicle, wherein the temperature action plan includes an operational parameter for controlling a

temperature of the battery. The apparatus also includes a means for generating instructions based on the temperature action plan to control a temperature controller of the battery according to the operational parameter.

[0129] Example 78 is the apparatus of example 77, wherein the temperature action plan further includes a vehicle configuration parameter for controlling a driving configuration of the vehicle, wherein the instructions further include vehicle instructions to adjust the driving configuration according to the vehicle configuration parameter.

[0130] Example 79 is the apparatus of example 78, wherein the instructions include an indication to enable or to disable a heat exchanger of the battery, wherein the heat exchanger is controllable by the operational parameter to heat or cool the battery.

[0131] Example 80 is the apparatus of either one of examples 78 or 79, wherein the vehicle configuration parameter for controlling operations of the vehicle defines an operating limit to a motion parameter of the vehicle based on an energy consumption from or an energy recouping to the battery that is associated with the motion parameter.

[0132] Example 81 is the apparatus of example 80, wherein the motion parameter includes an acceleration or deceleration of the vehicle.

[0133] Example 82 is the apparatus of either one of examples 80 or 81, wherein the operating limit includes a maximum permitted acceleration and/or a minimum permitted acceleration of the vehicle.

[0134] Example 83 is the apparatus of any one of examples 77 to 82, wherein the current state of the battery includes a temperature of the battery.

[0135] Example 84 is the apparatus of any one of examples 77 to 83, wherein the current state of the battery includes at least one of a temperature of the battery, an amount of energy currently being withdrawn from the battery, an amount of energy currently being dispensed to the battery, a power density of the battery, and a voltage of the battery.

[0136] Example 85 is the apparatus of any one of examples 77 to 84, wherein the predicted operation of the vehicle includes an expected maximum acceleration or an expected minimum acceleration, wherein the apparatus further includes a means for determining the expected maximum acceleration or the expected minimum acceleration based on the driving situation of the vehicle.

[0137] Example 86 is the apparatus of any one of examples 77 to 85, wherein the predicted operation of the vehicle includes an estimated amount of energy expended in order to heat/cool the battery to a target temperature.

[0138] Example 87 is the apparatus of example 86, wherein the target temperature includes an optimum temperature for charging/discharging the battery in the driving situation.

[0139] Example 88 is the apparatus of any one of examples 77 to 87, wherein the predicted operation of the vehicle includes an estimated amount of energy expended to operate the vehicle in the driving situation and/or according to the operational configuration.

[0140] Example 89 is the apparatus of any one of examples 77 to 88, wherein the apparatus further includes a means for determining the temperature action plan further based on a driving configuration preference of the vehicle.

[0141] Example 90 is the apparatus of example 89, wherein the operational configuration of the vehicle includes a user-defined setting.

[0142] Example 91 is the apparatus of example 90, wherein the user-defined setting includes a maximum or minimum preferred acceleration.

[0143] Example 92 is the apparatus of any one of examples 77 to 91, wherein the apparatus further includes a means for determining the temperature action plan based on an ambient temperature outside the vehicle.

[0144] Example 93 is the apparatus of any one of examples 77 to 92, wherein the current state of the battery includes a current temperature of the battery, wherein the apparatus further includes

a means for receiving (e.g., a receiver/transceiver) the current temperature from a temperature sensor.

[0145] Example 94 is the apparatus of either one of examples 92 or 93, wherein the apparatus further includes a means for receiving (e.g., a receiver/transceiver) the ambient temperature from a temperature sensor.

[0146] Example 95 is the apparatus of either one of examples 93 or 94, wherein the temperature sensor is located onboard the vehicle.

[0147] Example 96 is the apparatus of any one of examples 77 to 95, wherein the operational parameter includes a threshold limit to at least one of an amount of energy that is allowed to be withdrawn from the battery or recuperated to the battery, a rate at which energy is allowed to be withdrawn from the battery or recuperated to the battery, or a time at which energy is allowed to be withdrawn from the battery or recuperated to the battery.

[0148] Example 97 is the apparatus of any one of examples 77 to 96, wherein the apparatus includes a means for determining the driving situation based on a road elevation profile that indicates a change in an elevation that the vehicle is expected to experience during the predicted operation.

[0149] Example 98 is the apparatus of example 97, wherein the predicted operation includes movement of the vehicle along a series of waypoints to a destination, wherein each waypoint is associated with a corresponding elevation of a plurality of elevations, wherein the elevation includes one of the plurality of elevations.

[0150] Example 99 is the apparatus of any one of examples 77 to 98, wherein the apparatus further includes a means for determining the driving situation based a traffic profile that indicates an expected travel time of the vehicle to a destination.

[0151] Example 100 is the apparatus of example 99, wherein the predicted operation includes movement of the vehicle along a series of waypoints to the destination, wherein each waypoint is

associated with a corresponding expected travel time of a plurality of expected travel times, wherein the expected travel time includes one of the plurality of expected travel times.

[0152] Example 101 is the apparatus of any one of examples 77 to 100, wherein the apparatus includes a means for determining the driving situation based on a historical database of situations, wherein each historical situation is associated with an expected amount of energy consumption of the battery in the historical situation.

[0153] Example 102 is the apparatus of any one of examples 77 to 101, the apparatus further including a means for storing (e.g. a memory) at least one of the predicted operation, the driving situation, the operational configuration, the temperature action plan, the operational parameter, the instructions, and the historical database of situations.

[0154] Example 103 is the apparatus of any one of examples 77 to 102, wherein the driving situation includes an expected level of acceleration aggressiveness.

[0155] Example 104 is the apparatus of any one of examples 77 to 103, wherein the operational configuration includes a safety-based requirement associated with the driving situation.

[0156] Example 105 is the apparatus of any one of examples 77 to 104, wherein the temperature action plan includes an emergency override of the operational parameter, wherein the emergency override is configured to adjust a value of the operational parameter or to provide a delay to an implementation time of the operational parameter.

[0157] Example 106 is the apparatus of any one of examples 77 to 105, wherein the means for determining the temperature action plan includes a means for performing a multivariate optimization of the operational parameter based on at least one of a set of variables included of: a maximum/minimum acceleration requirement for the predicted operation, a maximum/minimum velocity requirement for the predicted operation, a safety-based requirement for the predicted operation, a driver-based requirement for the predicted operation, a road slope of the predicted operation, and an environmental condition of the predicted operation.

[0158] Example 107 is the apparatus of example 106, wherein the multivariate optimization includes a maximization function configured to maximize each of a predefined criterion associated with each variable of the set of variables.

[0159] Example 108 is the apparatus of example 107, wherein the maximization function includes at least one of a mixed-integer program solver, a mixed-integer linear program solver, an iterative solver, a simulated annealing solver, and a learning-based solver.

[0160] Example 109 is the apparatus of any one of examples 77 to 108, wherein the apparatus includes a means for receiving external information associated with the driving situation and/or operational configuration from a server that is external to the vehicle.

[0161] Example 110 is the apparatus of example 109, wherein the external information includes weather information in an environment associated with the predicted operation of the vehicle.

[0162] Example 111 is the apparatus of either one of examples 109 or 110, wherein the external information includes traffic information about traffic conditions associated with the predicted operation of the vehicle.

[0163] Example 112 is the apparatus of any of examples 109 to 111, wherein the external information includes locations of charging stations associated with the predicted operation of the vehicle.

[0164] Example 113 is the apparatus of any of examples 109 to 112, wherein the external information includes historical information about previously determined temperature action plans associated with driving situations and/or operation configurations that are similar to the driving situation and/or operation configuration.

[0165] Example 114 is the apparatus of any of examples 109 to 113, wherein the apparatus includes transmitting the temperature action plan, the driving situation, and/or the operation configuration to the server.

[0166] Example 115 is a non-transitory computer-readable medium that includes instructions which, if executed, cause one or more processors to determine a predicted operation of a vehicle based on a driving situation of the vehicle and/or an operational configuration of the vehicle. The instructions are also configured to determine a temperature action plan for a battery of a vehicle based on a current state of the battery and the predicted operation of the vehicle, wherein the temperature action plan includes an operational parameter for controlling a temperature of the battery. The instructions are also configured to generate control instructions based on the temperature action plan to control a temperature controller of the battery according to the operational parameter.

[0167] Example 116 is the non-transitory computer-readable medium of example 115, wherein the temperature action plan further includes a vehicle configuration parameter for controlling a driving configuration of the vehicle, wherein the control instructions further include vehicle instructions to adjust the driving configuration according to the vehicle configuration parameter.

[0168] Example 117 is the non-transitory computer-readable medium of example 116, wherein the control instructions include an indication to enable or to disable a heat exchanger of the battery, wherein the heat exchanger is controllable by the operational parameter to heat or cool the battery.

[0169] Example 118 is the non-transitory computer-readable medium of either one of examples 116 or 117), wherein the vehicle configuration parameter for controlling operations of the vehicle defines an operating limit to a motion parameter of the vehicle based on an energy consumption from or an energy recouping to the battery that is associated with the motion parameter.

[0170] Example 119 is the non-transitory computer-readable medium of example 118, wherein the motion parameter includes an acceleration or deceleration of the vehicle.

[0171] Example 120 is the non-transitory computer-readable medium of either one of examples 118 or 119, wherein the operating limit includes a maximum permitted acceleration and/or a minimum permitted acceleration of the vehicle.

[0172] Example 121 is the non-transitory computer-readable medium of any one of examples 115 to 120, wherein the current state of the battery includes a temperature of the battery.

[0173] Example 122 is the non-transitory computer-readable medium of any one of examples 115 to 121, wherein the current state of the battery includes at least one of a temperature of the battery, an amount of energy currently being withdrawn from the battery, an amount of energy currently being dispensed to the battery, a power density of the battery, and a voltage of the battery.

[0174] Example 123 is the non-transitory computer-readable medium of any one of examples 115 to 122, wherein the predicted operation of the vehicle includes an expected maximum acceleration or an expected minimum acceleration, wherein the instructions are further configured to determine the expected maximum acceleration or the expected minimum acceleration based on the driving situation of the vehicle.

[0175] Example 124 is the non-transitory computer-readable medium of any one of examples 115 to 123, wherein the predicted operation of the vehicle includes an estimated amount of energy expended in order to heat/cool the battery to a target temperature.

[0176] Example 125 is the non-transitory computer-readable medium of example 124, wherein the target temperature includes an optimum temperature for charging/discharging the battery in the driving situation.

[0177] Example 126 is the non-transitory computer-readable medium of any one of examples 115 to 125, wherein the predicted operation of the vehicle includes an estimated amount of energy expended to operate the vehicle in the driving situation and/or according to the operational configuration.

[0178] Example 127 is the non-transitory computer-readable medium of any one of examples 115 to 126, wherein the instructions are configured to determine the temperature action plan further based on a driving configuration preference of the vehicle.

[0179] Example 128 is the non-transitory computer-readable medium of example 127, wherein the operational configuration of the vehicle includes a user-defined setting.

[0180] Example 129 is the non-transitory computer-readable medium of example 128, wherein the user-defined setting includes a maximum or minimum preferred acceleration.

[0181] Example 130 is the non-transitory computer-readable medium of any one of examples 115 to 129, wherein the instructions are further configured to determine the temperature action plan based on an ambient temperature outside the vehicle.

[0182] Example 131 is the non-transitory computer-readable medium of any one of examples 115 to 130, wherein the current state of the battery includes a current temperature of the battery, wherein the instructions are further configured to receive the current temperature from a temperature sensor.

[0183] Example 132 is the non-transitory computer-readable medium of either one of examples 130 or 131, wherein the instructions are further configured to receive the ambient temperature from a temperature sensor.

[0184] Example 133 is the non-transitory computer-readable medium of either one of examples 131 or 132, wherein the temperature sensor is located onboard the vehicle

[0185] Example 134 is the non-transitory computer-readable medium of any one of examples 115 to 133, wherein the operational parameter includes a threshold limit to at least one of an amount of energy that is allowed to be withdrawn from the battery or recuperated to the battery, a rate at which energy is allowed to be withdrawn from the battery or recuperated to the battery, or a time at which energy is allowed to be withdrawn from the battery or recuperated to the battery.

[0186] Example 135 is the non-transitory computer-readable medium of any one of examples 115 to 134, wherein the instructions are configured to determine the driving situation based on a

road elevation profile that indicates a change in an elevation that the vehicle is expected to experience during the predicted operation.

[0187] Example 136 is the non-transitory computer-readable medium of example 135, wherein the predicted operation includes movement of the vehicle along a series of waypoints to a destination, wherein each waypoint is associated with a corresponding elevation of a plurality of elevations, wherein the elevation includes one of the plurality of elevations.

[0188] Example 137 is the non-transitory computer-readable medium of any one of examples 115 to 136, wherein the instructions are configured to determine the driving situation based a traffic profile that indicates an expected travel time of the vehicle to a destination.

[0189] Example 138 is the non-transitory computer-readable medium of example 137, wherein the predicted operation includes movement of the vehicle along a series of waypoints to the destination, wherein each waypoint is associated with a corresponding expected travel time of a plurality of expected travel times, wherein the expected travel time includes one of the plurality of expected travel times.

[0190] Example 139 is the non-transitory computer-readable medium of any one of examples 115 to 138, wherein the instructions are configured to determine the driving situation based on a historical database of situations, wherein each historical situation is associated with an expected amount of energy consumption of the battery in the historical situation.

[0191] Example 140 is the non-transitory computer-readable medium of any one of examples 115 to 139, wherein the instructions are configured to store (e.g., in a memory) at least one of the predicted operation, the driving situation, the operational configuration, the temperature action plan, the operational parameter, the instructions, and the historical database of situations.

[0192] Example 141 is the non-transitory computer-readable medium of any one of examples 115 to 140, wherein the driving situation includes an expected level of acceleration aggressiveness.

[0193] Example 142 is the non-transitory computer-readable medium of any one of examples 115 to 141, wherein the operational configuration includes a safety-based requirement associated with the driving situation.

[0194] Example 143 is the non-transitory computer-readable medium of any one of examples 115 to 142, wherein the temperature action plan includes an emergency override of the operational parameter, wherein the emergency override is configured to adjust a value of the operational parameter or to provide a delay to an implementation time of the operational parameter.

[0195] Example 144 is the non-transitory computer-readable medium of any one of examples 115 to 143, wherein the instructions that determine the temperature action plan includes instructions that perform a multivariate optimization of the operational parameter based on at least one of a set of variables included of: a maximum/minimum acceleration requirement for the predicted operation, a maximum/minimum velocity requirement for the predicted operation, a safety-based requirement for the predicted operation, a driver-based requirement for the predicted operation, a road slope of the predicted operation, and an environmental condition of the predicted operation.

[0196] Example 145 is the non-transitory computer-readable medium of example 144, wherein the multivariate optimization includes a maximization function configured to maximize each of a predefined criterion associated with each variable of the set of variables.

[0197] Example 146 is the non-transitory computer-readable medium of example 145, wherein the maximization function includes at least one of a mixed-integer program solver, a mixed-integer linear program solver, an iterative solver, a simulated annealing solver, and a learning-based solver.

[0198] Example 147 is the non-transitory computer-readable medium of any one of examples 115 to 146, wherein the instructions are configured to receive external information associated with the driving situation and/or operational configuration from a server that is external to the vehicle.

[0199] Example 148 is the non-transitory computer-readable medium of example 147, wherein the external information includes weather information in an environment associated with the predicted operation of the vehicle.

[0200] Example 149 is the non-transitory computer-readable medium of either one of examples 147 or 148, wherein the external information includes traffic information about traffic conditions associated with the predicted operation of the vehicle.

[0201] Example 150 is the non-transitory computer-readable medium of any of examples 147 to 149, wherein the external information includes locations of charging stations associated with the predicted operation of the vehicle.

[0202] Example 151 is the non-transitory computer-readable medium of any of examples 147 to 150, wherein the external information includes historical information about previously determined temperature action plans associated with driving situations and/or operation configurations that are similar to the driving situation and/or operation configuration.

[0203] Example 152 is the non-transitory computer-readable medium of any of examples 147 to 151, wherein the instructions are configured to transmit the temperature action plan, the driving situation, and/or the operation configuration to the server.

[0204] While the disclosure has been particularly shown and described with reference to specific aspects, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the disclosure as defined by the appended claims. The scope of the disclosure is thus indicated by the appended claims and all changes, which come within the meaning and range of equivalency of the claims, are therefore intended to be embraced.

CLAIMS

Claimed is:

1. A device comprising a processor configured to:

determine a predicted operation of a vehicle based on a driving situation of the vehicle and/or an operational configuration of the vehicle;

determine a temperature action plan for a battery of the vehicle based on a current state of the battery and the predicted operation of the vehicle, wherein the temperature action plan comprises an operational parameter for controlling a temperature of the battery; and

generate instructions based on the temperature action plan to control a temperature controller of the battery according to the operational parameter.
2. The device of claim 1,

wherein the temperature action plan further comprises a vehicle configuration parameter for controlling a driving configuration of the vehicle, wherein the instructions further include vehicle instructions to adjust the driving configuration according to the vehicle configuration parameter:
3. The device of claim 2,

wherein the instructions comprise an indication to enable or to disable a heat exchanger of the battery,

wherein the heat exchanger is controllable by the operational parameter to heat or cool the battery.
4. The device of claim 3,

wherein the vehicle configuration parameter for controlling operations of the vehicle defines an operating limit to a motion parameter of the vehicle based on an energy consumption from or an energy recouping to the battery that is associated with the motion parameter.

5. The device of claim 4,
wherein the motion parameter comprises an acceleration or deceleration of the vehicle.
6. The device of claim 5,
wherein the operating limit comprises a maximum permitted acceleration and/or a minimum permitted acceleration of the vehicle.
7. The device of any one of claims 1 to 6,
wherein the current state of the battery comprises a temperature of the battery.
8. The device of any one of claims 1 to 6,
wherein the current state of the battery comprises at least one of a temperature of the battery, an amount of energy currently being withdrawn from the battery, an amount of energy currently being dispensed to the battery, a power density of the battery, and a voltage of the battery.
9. The device of any one of claims 1 to 6,
wherein the predicted operation of the vehicle comprises an expected maximum acceleration or an expected minimum acceleration,
wherein the processor is further configured to determine the expected maximum acceleration or the expected minimum acceleration based on the driving situation of the vehicle.
10. The device of any one of claims 1 to 6,
wherein the predicted operation of the vehicle comprises an estimated amount of energy expended in order to heat/cool the battery to a target temperature.
11. The device of claim 10,
wherein the target temperature comprises an optimum temperature for charging/discharging the battery in the driving situation.

12. The device of claim 10,
wherein the predicted operation of the vehicle comprises an estimated amount of energy expended to operate the vehicle in the driving situation and/or according to the operational configuration.
13. The device of any one of claims 1 to 6,
wherein the processor is configured to determine the temperature action plan further based on a driving configuration preference of the vehicle.
14. The device of claim 13,
wherein the operational configuration of the vehicle comprises a user-defined setting.
15. The device of claim 14,
wherein the user-defined setting comprises a maximum or minimum preferred acceleration.
16. The device of any one of claims 1 to 6,
wherein the processor is further configured to determine the temperature action plan based on an ambient temperature outside the vehicle.
17. The device of any one of claims 1 to 6,
wherein the current state of the battery comprises a current temperature of the battery,
wherein the processor is further configured to receive the current temperature from a temperature sensor.
18. The device of claim 17,
wherein the processor is further configured to receive the ambient temperature from a temperature sensor.

19. The device of claim 17,
wherein the temperature sensor is located onboard the vehicle.
20. The device of claim 17,
wherein the operational parameter comprises a threshold limit to at least one of an amount of energy that is allowed to be withdrawn from the battery or recuperated to the battery, a rate at which energy is allowed to be withdrawn from the battery or recuperated to the battery, or a time at which energy is allowed to be withdrawn from the battery or recuperated to the battery.
21. The device of claim 17,
wherein the processor is configured to determine the driving situation based on a road elevation profile that indicates a change in an elevation that the vehicle is expected to experience during the predicted operation.
22. The device of claim 21,
wherein the predicted operation comprises movement of the vehicle along a series of waypoints to a destination, wherein each waypoint is associated with a corresponding elevation of a plurality of elevations, wherein the elevation comprises one of the plurality of elevations.
23. The device of any one of claims 1 to 6,
wherein the processor is configured to determine the driving situation based on a traffic profile that indicates an expected travel time of the vehicle to a destination.
24. The device of any one of claims 1 to 6,
wherein the processor is configured to determine the driving situation based on a historical database of situations, wherein each historical situation is associated with an expected amount of energy consumption of the battery in the historical situation.

25. The device of any one of claims 1 to 6,
- the device further comprising a memory, wherein the processor is configured to store in the memory at least one of the predicted operation, the driving situation, the operational configuration, the temperature action plan, the operational parameter, the instructions, and the historical database of situations.

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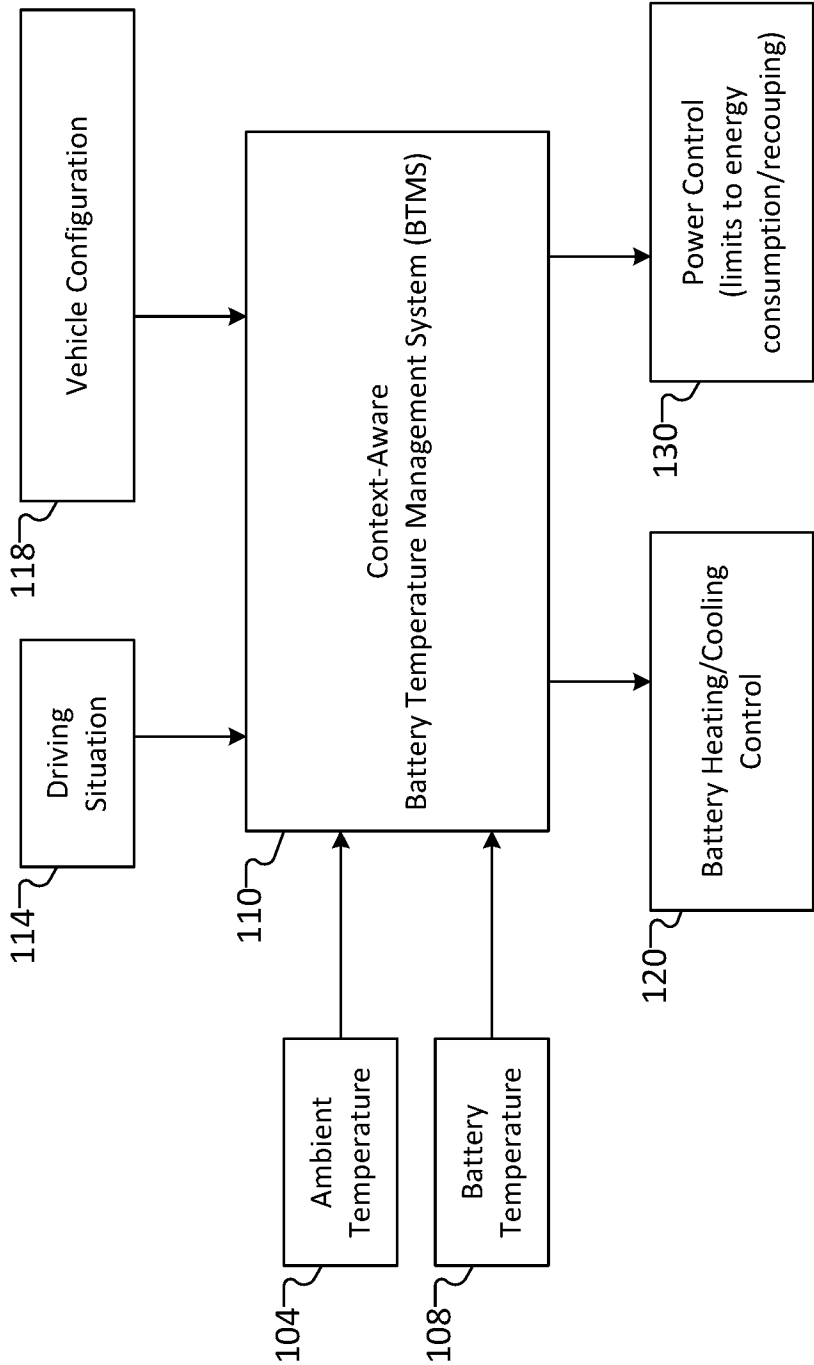


FIG. 1

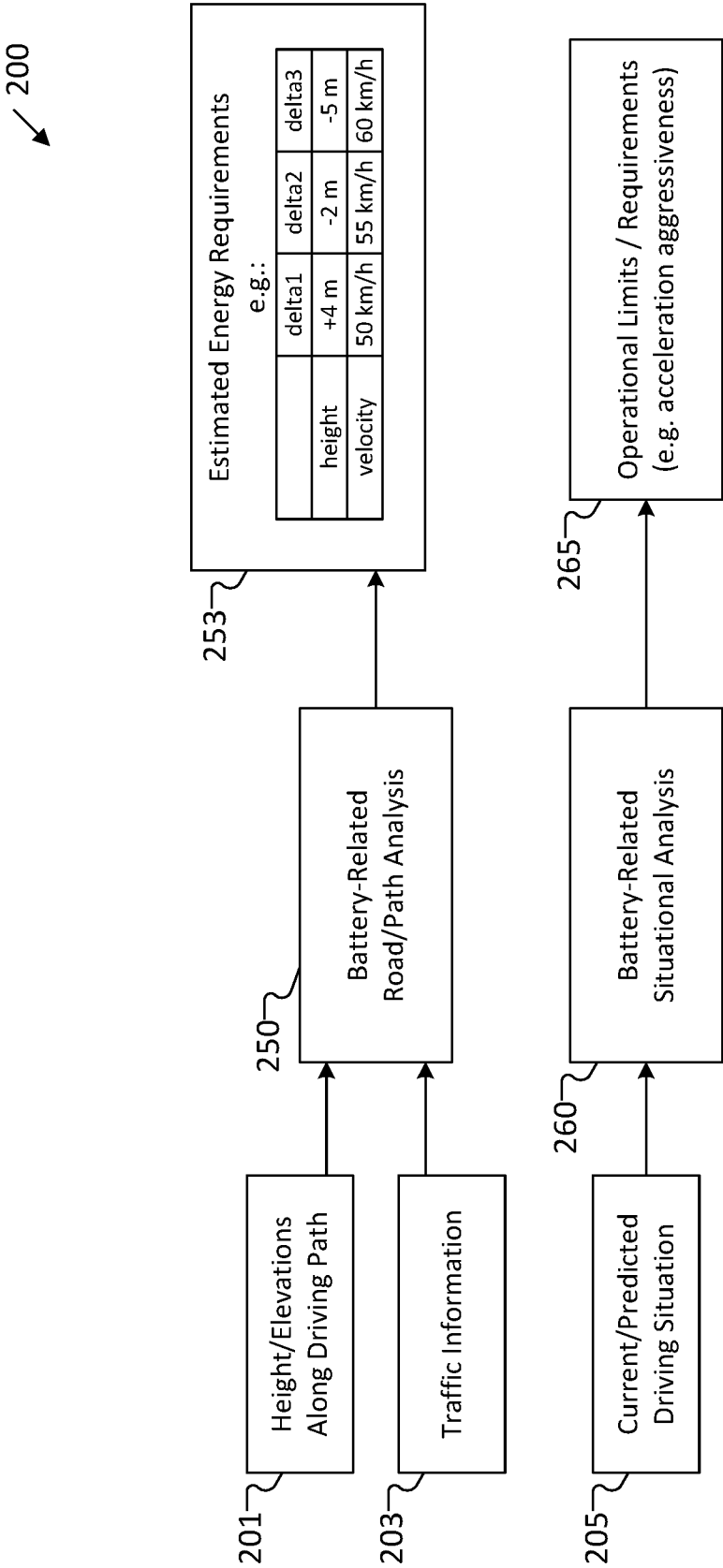


FIG. 2

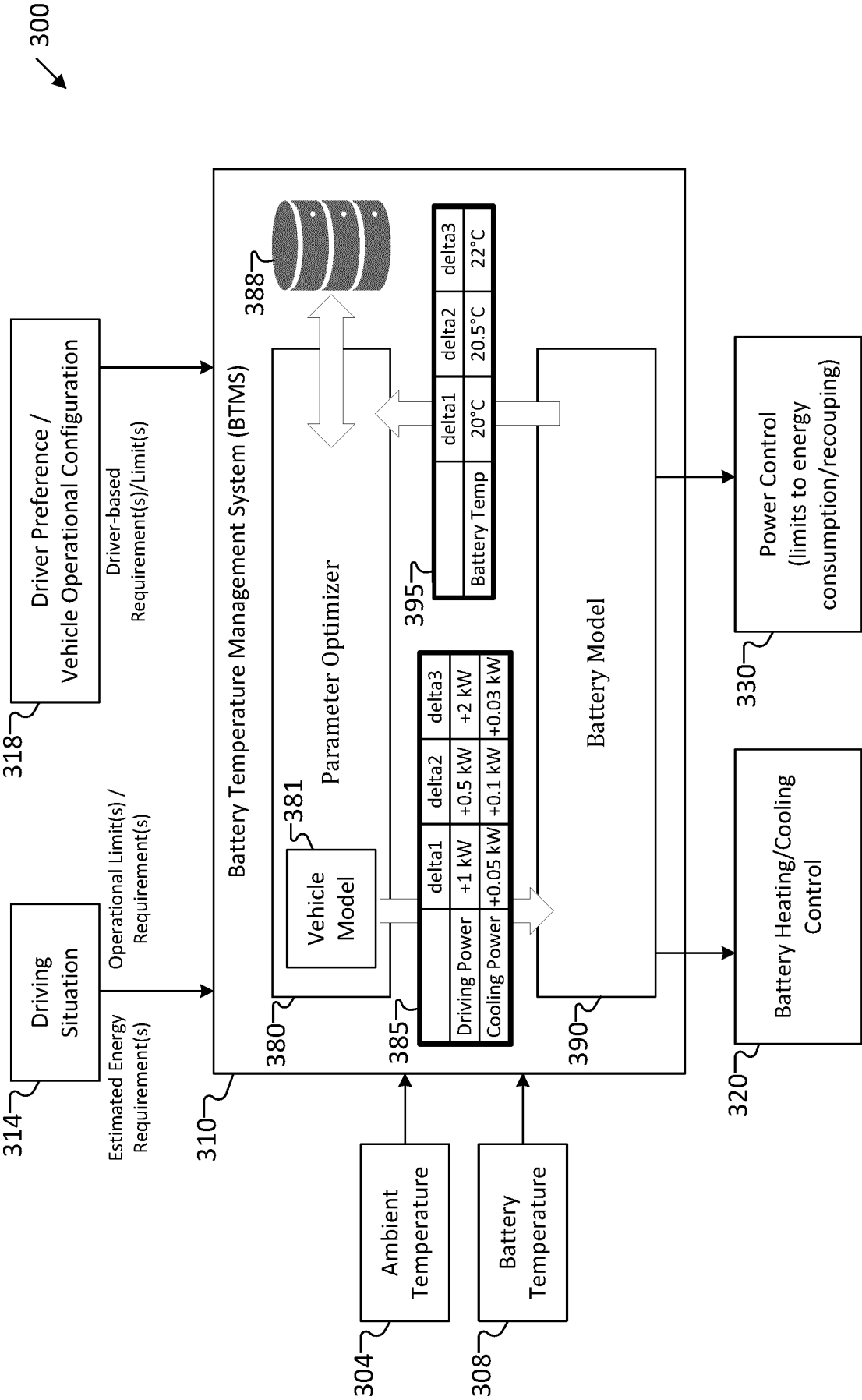


FIG. 3

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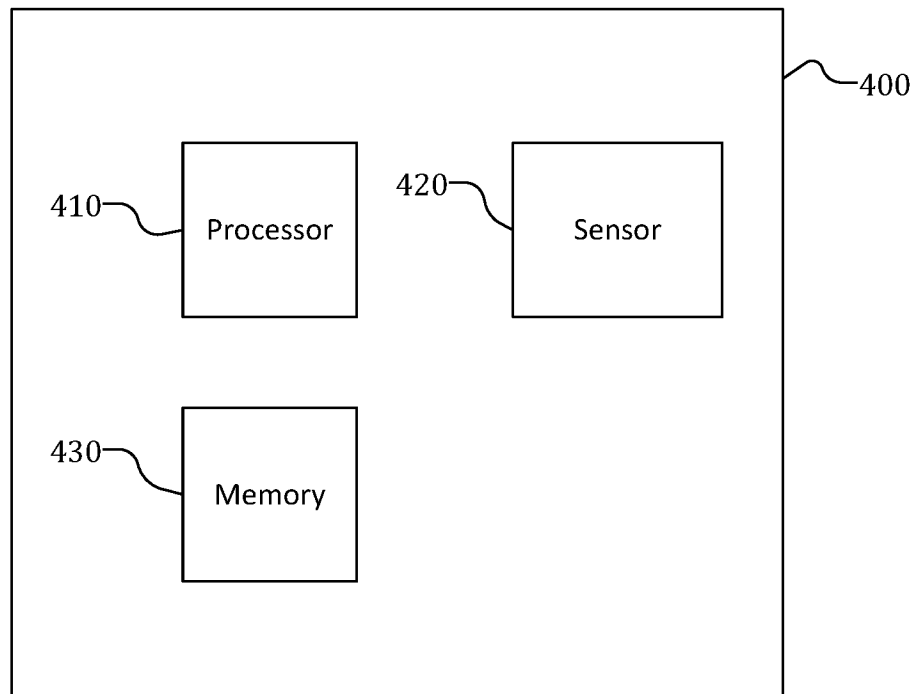


FIG. 4

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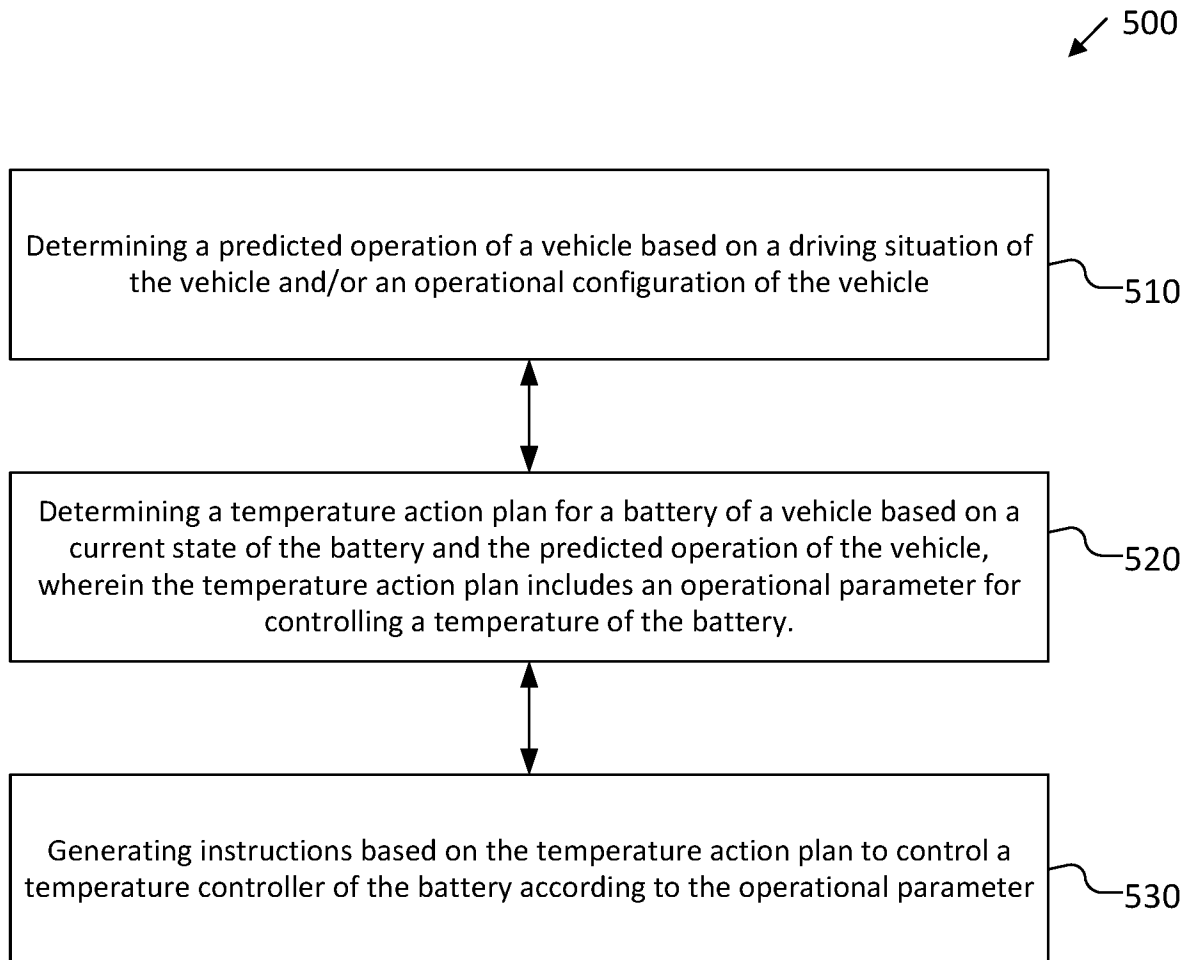


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2023/079778

A. CLASSIFICATION OF SUBJECT MATTER

INV. B60L58/25 B60L58/26 B60L58/27 H01M10/613 H01M10/615
H01M10/625

ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60L H01M

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2023/001824 A1 (SHAOTRAN ETHAN [US]) 5 January 2023 (2023-01-05) figures 1-10 paragraphs [0035] - [0072] -----	1-25
X	JP 2019 176691 A (DENSO CORP) 10 October 2019 (2019-10-10) figures 8-10 paragraphs [0033] - [0037], [0043] - [0047], [0051], [0080] - [0100] -----	1-25
A	US 2020/160619 A1 (WANG ZHI HU [CN] ET AL) 21 May 2020 (2020-05-21) figures 3-5 paragraphs [0040] - [0060] -----	1-25



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

10 January 2024

Date of mailing of the international search report

23/01/2024

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2023/079778

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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