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Methods for providing correct brake request with a stuck e-pedal

Abstract

A vehicle includes a brake-by-wire system having a brake pedal and first and second sensors. The first sensor is configured to output a first signal indicative of a position of the brake pedal and the second sensor is configured to output a second signal indicative of the position. A controller is programmed to command a braking torque based on only the first signal when a travel of the brake pedal is limited to a first range.

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Background/Summary

TECHNICAL FIELD
(1) This disclosure relates to vehicles having brake-by-wire systems.
BACKGROUND
(2) Vehicles include friction brakes located at the wheels for slowing the vehicle based on input from a brake pedal. Traditionally, a hydraulic system provided the braking force. Advances in electronics have enabled brake-by-wire systems in which the brake pedal is no longer directly connected to a hydraulic system.
SUMMARY
(3) According to one embodiment, a vehicle includes a brake-by-wire system having a brake pedal and first and second sensors. The first sensor is configured to output a first signal indicative of a position of the brake pedal and the second sensor is configured to output a second signal indicative

of the position. A controller is programmed to command a braking torque based on only the first signal when a travel of the brake pedal is limited to a first range.
(4) According to another embodiment, a vehicle includes a brake-by-wire system having a brake pedal, and first and second sensors. The first sensor is configured to output a first signal indicative of a position of the brake pedal and the second sensor being configured to output a second signal indicative of the position. A controller is in communication with the sensors and is programmed to: in response to application of the brake pedal, command a braking torque according to a baseline lookup table based on the first signal, the second signal, or both, and, in response to a discrepancy being detected in the first signal, command a braking torque according to a secondary lookup table based on the second signal only.
(5) According to yet another embodiment, a method of controlling a brake-by-wire system of a vehicle includes: in response to application of a brake pedal of a brake-by-wire system, commanding a braking torque according to a baseline lookup table based on signals of a first brake-pedal position sensor, a second brake-pedal position sensor, or both; and, in response to the brake pedal being incapable of full travel, commanding a braking torque according to a secondary lookup table based on the signal of the first brake-pedal position sensor or the signal of the second brake-pedal sensor, but not the signals of both the first brake-pedal position sensor and the second brake-pedal position sensor.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** illustrates a schematic diagram of an example electrified vehicle.
(2) FIG. **2**A illustrates an electronic brake pedal according to one example.
(3) FIG. **2**B illustrates an electronic brake pedal according to another example.
(4) FIG. **3** is a graph showing plots of brake-pedal sensor readings and the resulting brake torque command.
(5) FIG. **4** is a baseline lookup table associated with a first brake-pedal sensor.
(6) FIG. **5** is a secondary lookup table associated with a first brake-pedal sensor.
(7) FIG. **6** is a baseline lookup table associated with a second brake-pedal sensor.
(8) FIG. **7** is a secondary lookup table associated with a second brake-pedal sensor.
(9) FIG. **8** is a flow chart of an algorithm for controlling braking torque in an example brake-by-wire system.
DETAILED DESCRIPTION
(10) Embodiments of the present disclosure are described herein. It is to be understood, however, that the disclosed embodiments are merely examples and other embodiments can take various and alternative forms. The figures are not necessarily to scale; some features could be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the present invention. As those of ordinary skill in the art will understand, various features illustrated and described with reference to any one of the figures can be combined with features illustrated in one or more other figures to produce embodiments that are not explicitly illustrated or described. The combinations of features illustrated provide representative embodiments for typical applications. Various combinations and modifications of the features consistent with the teachings of this disclosure, however, could be desired for particular applications or implementations.
(11) Referring to FIG. **1**, an electrified vehicle **20** is illustrated as a fully electric vehicle but, in other embodiments, the vehicle **20** may be a hybrid-electric vehicle that includes an internal-combustion engine, or a conventionally powered vehicle that only includes an engine. The vehicle

20 is shown as being two-wheel drive (such as front-wheel drive or rear-wheel drive) but may be all-wheel drive (AWD) in other embodiments. The vehicle **20** may include a powertrain **24** including a powerplant, e.g., an electric machine **34** or an engine.

(12) The electric machine **34** is operably coupled to driven wheels **30** and **32**. A gearbox (not shown) may be included to change a speed ratio between the electric machine **34** and the wheels **30**, **32**. The electric machine may be one or more electric machines. The electric machine **34** is capable of acting as motor to provide a positive torque to propel the vehicle **20** and is capable of acting as a generator to provide a negative torque to brake the vehicle such as via regenerative braking. The electric machine **34** may be a permanent magnet three-phase alternating current (AC) electric motor or other suitable type.

(13) The electric machine **34** is powered by one or more traction batteries, such as traction battery **36**. The traction battery **36** stores energy that can be used by the electric machine **34**. The traction battery **36** may provide a high-voltage direct current (DC) output from one or more battery cell arrays, sometimes referred to as battery cell stacks, within the traction battery **36**. The battery cell arrays include one or more battery cells. The battery cells, such as a prismatic, pouch, cylindrical, or any other type of cell, convert stored chemical energy to electrical energy. The cells may include a housing, a positive electrode (cathode), and a negative electrode (anode). An electrolyte allows ions to move between the anode and cathode during discharge, and then return during recharge. Terminals may allow current to flow out of the cell for use by the vehicle **20**. Different battery pack configurations may be available to address individual vehicle variables including packaging constraints and power requirements. The battery cells may be thermally adjusted with a thermal management system.

(14) The traction battery **36** may be electrically connected to one or more power-electronics modules through one or more contactors. The module may be electrically connected to the electric machine **34** and may provide the ability to bi-directionally transfer electrical energy between the traction battery **36** and the electric machine **34**. For example, a traction battery **36** may provide a DC voltage while the electric machine **34** may require a three-phase AC. The power-electronics module may convert the DC voltage to a three-phase AC voltage as required by the electric machines. In a generator mode, which may be during regenerative braking, the power-electronics module may convert the three-phase AC voltage from the electric machine **34** acting as a generator to the DC voltage required by the traction battery **36**.

(15) The vehicle **20** includes one or more controllers **40** in electric communication with a plurality of vehicle systems and is configured to coordinate functionality of the vehicle. The controller **40** may be a vehicle-based computing system that includes one or more controllers that communicate via a serial bus (e.g., controller area network (CAN)) or via dedicated electrical conduits. The controller **40** generally includes any number of microprocessors, ASICs, ICs, memory (e.g., FLASH, ROM, RAM, EPROM and/or EEPROM) and software code to co-act with one another to perform a series of operations. The controller **40** also includes predetermined data, or “lookup tables,” that are based on calculations and test data, and are stored within the memory. The controller **40** may communicate with other vehicle systems and controllers over one or more wired or wireless vehicle connections using common bus protocols (e.g., CAN and LIN). Used herein, any reference to “a controller” refers to one or more controllers. The controller **40** may include battery energy control module (BECM) that operates at least the traction battery, a powertrain control module (PCM) that operates at least the electric machine, and a brake control module that controls the braking system **38**.

(16) The controllers communicate with various vehicle sensors and actuators via an input/output (I/O) interface that may be implemented as a single integrated interface that provides various raw data or signal conditioning, processing, and/or conversion, short-circuit protection, and the like. Alternatively, one or more dedicated hardware or firmware chips may be used to condition and process particular signals before being supplied to the CPU. Although not explicitly illustrated,

those of ordinary skill in the art will recognize various functions or components that may be controlled by a controller within each of the subsystems identified above.

(17) The braking system **38** may be a hydraulic system, an electric system, or a combination of electric and hydraulic. The braking system **38** is a brake-by-wire system that uses pedal sensors (S.sub.1 and S.sub.2) and actuators to engage the brakes rather than a conventional direct mechanical connection between the brake pedal and the master cylinder. The pedal sensors (S.sub.1 and S.sub.2) are configured to sense movement of the brake pedal **44** and output signals. The sensors (S.sub.1 and S.sub.2) may be packaged with the brake pedal **44** as a brake-pedal assembly. The signals include data indicative of a position of the brake pedal **44**, which may be expressed as a percentage of depression or the like. The pedal sensors (S.sub.1 and S.sub.2) output this data to a braking control module of the controller(s) **40**.

(18) The brake system **38** may include one or more master cylinders **47** in fluid communication with a plurality of friction brakes **42** located at each of the wheels. The one or more master cylinders **47** are actuated by the controller **40** based on the data received from the pedal sensors (S.sub.1 and S.sub.2) as well as other factors. This is just one example and other types of brake-by-wire systems are contemplated, such as electro-mechanical brakes. These systems may not include a master cylinder. Modern vehicles typically have disc brakes; however, other types of friction brakes are available, such as drum brakes. In an example embodiment, each of the brakes **42** are in fluid communication with a valve body (not shown) via brake lines configured to deliver fluid pressure from the master cylinder **47** to a caliper of the brakes **42**. The valve body may include a plurality of valves configured to provide independent fluid pressure to each of the brakes **42**, such a system is commonly referred to as ABS. The braking system **38** also includes associated wheel-speed sensors **46** each located at one of the wheels. Each sensor **46** is configured to output a wheel-speed signal to the controller **40** indicative of a measured wheel speed.

(19) The vehicle **20** is configured to brake using powertrain braking (e.g., regenerative braking), friction braking, or a combination thereof depending on the powertrain of the vehicle. The brake control module includes programming for aggregating a demanded braking torque between the electric machine **34** and the friction brakes **42**. The demanded braking torque may be based on driver input, e.g., a position of the brake pedal **44**, or by the controller **40**. The aggregator may be programmed to slow the vehicle using regenerative braking whenever possible and apply the friction brakes **42** when necessary.

(20) The vehicle **20** includes an accelerator pedal **45**. The accelerator pedal **45** includes a range of travel from a released position to a fully depressed position and indeterminate positions therebetween. The released position may be considered a zero percent position and the fully depressed position may be considered a 100 percent position. Releasing the pedal may be referred to as decreasing the accelerator pedal position, and applying the pedal may be referred to as increasing the accelerator pedal position. The accelerator pedal **45** includes an associated sensor (not shown) that senses the position of the pedal **45**. The sensor is configured to output a pedal-position signal to the controller **40** that is indicative of a sensed position of the pedal **45**, i.e., an accelerator-pedal position. The accelerator pedal **45** is used by the driver to command a desired speed and torque of the vehicle. That is, the accelerator pedal **45** is used by the driver to set a driver-demanded torque. The driver-demanded torque may be a positive value or a negative value. A positive value indicates a propulsion torque, whereas a negative value indicates a braking torque. The controller **40** may be programmed to receive the accelerator pedal-position signal and determine the driver-demanded torque based on the accelerator pedal position and other factors such as vehicle speed.

(21) FIGS. **2**A and **2**B illustrate example embodiments of the of the brake pedal **44**. Referring to FIG. **2**A, a brake pedal assembly **50** of a brake-by-wire system includes a pedal **52** pivotably mounted to a support **54** of a vehicle body about a pivot axis **56**. The pedal **52** includes a foot portion **58** attached to a lever portion **60**. The foot portion **58** may be movable relative to the lever

portion **60**. For example, the foot portion **58** may be slidably received in a guide member and has a first travel **59**. Movement of the foot portion **58** relative to the lever portion **60** may be sensed by a first sensor **62**. That is, the first sensor **62** senses the first travel **59** of the brake pedal **52**. The pivoting of the lever portion **60** relative to the support **54** about the pivot axis **56** may be measured by a second sensor **64**. When the brake pedal **52** is depressed by a driver, the foot portion **58** is first depressed towards the lever portion **60**, which is still stationary. Once the foot portion **58** reaches the end of the first travel **59**, the lever portion **60** begins to rotate about the axis **56** through a second travel **66**. (In other embodiment, the lever portion **60** may begin moving before the foot portion bottoms out.) In this example, the first travel **59** is linear distance whereas the second travel is an angular distance.

(22) Referring to FIG. **2**B, another brake pedal assembly **70** includes a pedal **71** having lever portion **72** pivotally connected to a support **74** about a pivot axis **76**. A foot portion **78** is rigidly attached to the lever portion **72**. The brake pedal assembly **70** is an example of a dual-angle ePedal in which both the first sensor and the second sensor measure angles of movement. The pedal assembly **70** includes an intermediate member **80** that is pivotally attached about the pivot axis **76**. A first linkage **82** connects between the lever portion **72** and the intermediate member **80**. A second linkage **84** connects between the intermediate member **80** and the support **74**. The pedal **71** is designed to move in two phases: During the first phase, the lever portion **72** rotates through its travel (a first travel **86**) while the intermediary member **80** remains stationary. At the end of the first travel **86**, the lever portion **72** begins to drive the intermediary member **80** towards the support **74** through a second range of travel **88**. (In other embodiments, the intermediary member **80** may begin moving before the lever portion reaches the end of the first travel **86**.)

(23) The first sensor **90** measures the angle (a) between the lever portion **72** and the intermediate member **80**. The second sensor **92** measures the angle (B) between the support **74** and the intermediate member **80**. When the pedal **71** is depressed from full release, the lever portion **72** moves towards the intermediate member **80**, which is stationary at this point. Here, movement of the pedal is sensed only by the first sensor **90**. As the driver further depresses the pedal, the intermediate member **80** begins to pivot and the pedal movement is sensed by the second sensor **92** (in some implementations both the sensors **90**/**92** will measure pedal movement during this phase of movement).

(24) FIG. **3** illustrates plots of first sensor data **100**, second sensor data **102**, and requested brake torque **104** during a braking event of the vehicle in which the brake pedal assembly is functioning normally. As shown in the graph, the first sensor **100** senses the initial movement of the brake pedal and the second sensor **102** senses the final movement of the brake pedal. In this example, the first and second sensors have significant overlap during an intermediate portion of pedal travel. The braking torque **104** is based on the data from the first and second sensors. In this example, the braking torque **104** is mostly based on readings from the first sensor **100** during the first half brake pedal travel. Similarly, the braking torque **104** is mostly based on readings from the second sensor **102** during the second half of brake pedal travel.

(25) If one or more movable portions of the brake pedal becomes mechanically stuck or one or more of the sensors becomes inoperable or inaccurate, the data being received by the controller may no longer be accurate. This may result in a non-optimal braking torque command **104** and/or result in abrupt steps in the braking torque **104** rather than the smooth continuum shown in FIG. **3**. For example, if the controller is not properly receiving the S.sub.1 signal, the controller may command less braking torque during the first half of pedal travel and then abruptly jump to a higher braking torque once the second sensor becomes dominant. The below-described controls provide redundancy to ensure a smooth braking torque curve.

(26) The controller **40** may include memory that stores mapping or lookup tables and arbitration logic that outputs a desired braking torque **104** based at least on data from the first sensor, the second sensor, both, and/or potentially other factors. FIG. **4** illustrates a simplified example (for the

purposes of description) of a baseline lookup table **110**. In this example, the first sensor S.sub.1 measures the first travel of the pedal. FIG. **5** illustrates a simplified example (for the purposes of description) of a secondary lookup table **112** that is used when a discrepancy is sensed with regards to the second sensor S.sub.2 (S.sub.1 is still functioning normally). In comparing these lookup tables, it can be seen that the pedal outputs contribution is increased for the secondary lookup table **112** to account for the inaccurate information being received from the second sensor S.sub.2. By using the secondary lookup table, 100 percent of the pedal contribution can come from S.sub.1 so that full braking torque can be commanded without an accurate signal from the second sensor S.sub.2.

(27) FIGS. **6** and **7** show baseline and secondary brake-torque lookup tables for sensor S.sub.2. FIG. **6** illustrates a simplified example (for the purposes of description) of a baseline lookup table **114**. In this example, the first sensor S.sub.1 measures the first travel of the pedal. FIG. **7** illustrates a simplified example (for the purposes of description) of a secondary lookup table **116** that is used when a discrepancy is sensed with regards to the second sensor S.sub.1 (S.sub.2 is still functioning normally). In comparing these lookup tables, it can be seen that the pedal outputs contribution is initially decreased for the secondary lookup table **116** to account for the inaccurate information being received from the second sensor S.sub.1. By using the secondary lookup table, an abrupt spike in braking torque does not occur while still providing full braking torque based only on the second sensor S.sub.2.

(28) The controller may be programmed to utilize the baseline lookup table(s) when it is determined that the pedal is operating normally. That is, the pedal is mechanically sound and the sensors are outputting accurate information. If the controller determines that one or more portions of the pedal are stuck and inhibiting proper movement of the pedal through its various ranges of travel, or one or more of the sensors are outputting inaccurate information, the secondary lookup table(s) are used to account for the issue and provide redundancy. For example, the controller may be programmed to command a braking torque based on only the first signal when a travel of the brake pedal is limited to a first range and/or command the braking torque based on only the second signal when the travel of the brake pedal is limited to a second range.

(29) Control logic or functions performed by controller **40** may be represented by flow charts or similar diagrams in one or more figures. These figures provide representative control strategies and/or logic that may be implemented using one or more processing strategies such as event-driven, interrupt-driven, multi-tasking, multi-threading, and the like. As such, various steps or functions illustrated may be performed in the sequence illustrated, in parallel, or in some cases omitted. Although not always explicitly illustrated, one of ordinary skill in the art will recognize that one or more of the illustrated steps or functions may be repeatedly performed depending upon the particular processing strategy being used. Similarly, the order of processing is not necessarily required to achieve the features and advantages described herein, but is provided for case of illustration and description. The control logic may be implemented primarily in software executed by a microprocessor-based vehicle, engine, and/or powertrain controller, such as controller **40**. Of course, the control logic may be implemented in software, hardware, or a combination of software and hardware in one or more controllers depending upon the particular application. When implemented in software, the control logic may be provided in one or more computer-readable storage devices or media having stored data representing code or instructions executed by a computer to control the vehicle or its subsystems. The computer-readable storage devices or media may include one or more of a number of known physical devices which utilize electric, magnetic, and/or optical storage to keep executable instructions and associated calibration information, operating variables, and the like.

(30) FIG. **8** is a flowchart **200** of an algorithm for controlling a brake-by-wire system. At operation **202**, the pedal is depressed by the driver to initiate a braking event. At operation **204**, the controller receives data from the pedal sensors S.sub.1, S.sub.2, or both. At operation **206**, the controller

determines whether or not a mechanical impediment or and in accurate pedal sensor is detected. If no, the pedal assembly is operating normally, and the baseline lookup table(s) are used to determine the driver-demanded braking torque at operation **208**. If the received sensor data indicates an issue with the brake pedal or sensors, control passes to operation **210** and the controller uses the secondary lookup table(s) to determine the driver-demanded braking torque.

(31) When the secondary tables are used, the controller may be programmed to command a braking torque based on only the first signal when a travel of the brake pedal is limited to a first range or to command the braking torque based on only the second signal when the travel of the brake pedal is limited to a second range. Additionally or alternatively, the controller also be programmed in response to a discrepancy being detected in the first signal, command a braking torque according to a secondary lookup table based on the second signal only and/or in response to a discrepancy being detected in the second signal, command another braking torque according to another secondary lookup table based on the first signal only.

(32) The controller may determine a discrepancy in the sensor data by comparing the sensor data to expected values. If the sensor data does not match the expected values, this is indicative of a discrepancy. Alternatively, the control may compare pedal movements of the first travel to the second travel. For example, if S.sub.1 data is increasing while the S.sub.2 data is static, that is indicative of a discrepancy. In yet another example, the controller flags a discrepancy responsive to S.sub.1 or S.sub.2 being unable to reach its maximum value. These are just some examples and are not an exhaustive list of ways for detecting anomalies in brake pedal operation.

(33) While exemplary embodiments are described above, it is not intended that these embodiments describe all possible forms encompassed by the claims. The words used in the specification are words of description rather than limitation, and it is understood that various changes can be made without departing from the spirit and scope of the disclosure. As previously described, the features of various embodiments can be combined to form further embodiments of the invention that may not be explicitly described or illustrated. While various embodiments could have been described as providing advantages or being preferred over other embodiments or prior art implementations with respect to one or more desired characteristics, those of ordinary skill in the art recognize that one or more features or characteristics can be compromised to achieve desired overall system attributes, which depend on the specific application and implementation. These attributes can include, but are not limited to strength, durability, marketability, appearance, packaging, size, serviceability, weight, manufacturability, ease of assembly, etc. As such, embodiments described as less desirable than other embodiments or prior art implementations with respect to one or more characteristics are not outside the scope of the disclosure and can be desirable for particular applications.

Claims

1. A vehicle comprising: a brake-by-wire system including a brake pedal assembly, the brake pedal assembly having a brake pedal and first and second sensors that each sense movement of the brake pedal, the first sensor being configured to output a first signal indicative of a position of the brake pedal and the second sensor being configured to output a second signal indicative of the position of the brake pedal; and a controller programmed to command a braking torque based on only the first signal when a travel of the brake pedal is limited to a first range.
2. The vehicle of claim 1, wherein the controller is further programmed to command the braking torque based on both the first and second signals when the travel of the brake pedal is not impeded.
3. The vehicle of claim 1, wherein the controller is further programmed to command the braking torque based on only the second signal when the travel of the brake pedal is limited to a second range.
4. The vehicle of claim 3, wherein the first and second ranges do not overlap.
5. The vehicle of claim 1, wherein the first sensor is configured to sense movement of the brake

pedal within the first range but not the second range, and the second sensor is configured to sense movement of the brake pedal within the second range but not the first range.

6. The vehicle of claim 1, wherein the first sensor senses angular position of the brake pedal.

7. The vehicle of claim 6, wherein the second sensor senses linear movement of the brake pedal or pressure applied to the brake pedal.

8. The vehicle of claim 6, wherein the second sensor senses angular position of the brake pedal.

9. A vehicle comprising: a brake-by-wire system including a brake pedal, and first and second sensors, the first sensor being configured to output a first signal indicative of a position of the brake pedal and the second sensor being configured to output a second signal indicative of the position; and a controller in communication with the sensors, the controller being programmed to: in response to application of the brake pedal, command a braking torque according to a baseline lookup table based on the first signal, the second signal, or both, and in response to a discrepancy being detected in the first signal, command a braking torque according to a secondary lookup table based on the second signal only.

10. The vehicle of claim 9, wherein the controller is further programmed to, in response to a discrepancy being detected in the second signal, command another braking torque according to another secondary lookup table based on the first signal only.

11. The vehicle of claim 9, wherein the first sensor measures a first range of travel of the brake pedal, and the second sensor measures a second range of travel of the brake pedal.

12. The vehicle of claim 9, wherein the secondary lookup table is associated with the other of the first and second signals.

13. The vehicle of claim 12, wherein, for a same value of the second signal, the baseline lookup table and the secondary lookup table output different values of braking torque.

14. The vehicle of claim 12 further comprising memory associated with the controller and storing thereon the baseline lookup table, the secondary lookup table, and another secondary lookup table associated the first signal.

15. The vehicle of claim 9, wherein the first sensor senses angular position of the brake pedal and the second sensor senses pressure applied to the brake pedal or linear movement of the brake pedal.

16. A method of controlling a brake-by-wire system of a vehicle, the method comprising: in response to application of a brake pedal of a brake-by-wire system, commanding a braking torque according to a baseline lookup table based on signals of a first brake-pedal position sensor, a second brake-pedal position sensor, or both; and in response to the brake pedal being incapable of full travel, commanding a braking torque according to a secondary lookup table based on the signal of the first brake-pedal position sensor or the signal of the second brake-pedal sensor, but not the signals of both the first brake-pedal position sensor and the second brake-pedal position sensor.

17. The method of claim 16, wherein the first sensor measures a first range of travel of the brake pedal, and the second sensor measures a second range of travel of the brake pedal.

18. The method of claim 16, wherein, for a same value of the first sensor, the baseline lookup table and the secondary lookup table output different values of braking torque.

19. The method of claim 16, wherein, for a same value of the first sensor, the baseline lookup table outputs a first value of braking torque and the secondary lookup table outputs a second, larger value of braking torque.

20. The vehicle of claim 9 further comprising a brake pedal assembly that includes the brake pedal, the first sensor, and the second sensor, wherein the first and second sensors are configured to sense movement of the brake pedal.