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MITIGATION OF TRACTION STEER DISTURBANCE FROM DRIVER FEEDBACK TORQUE IN STEER-BY-WIRE VEHICLES

Abstract

In an exemplary embodiment, a system is provided that includes one or more sensors and one or more processors of a vehicle having a steering system. The one or more sensors are configured to obtain sensor data as to the vehicle. The one or more processors are coupled to the one or more sensors, and are configured to at least facilitate determining a likelihood of a traction steering disturbance occurring for the vehicle; and selectively adjusting resistance for a steering wheel of the steering system, in accordance with instructions that are provided via the one or more processors and that are executed via a motor that is coupled to the steering wheel.

Publication Classification

Background/Summary

INTRODUCTION

[0001] The technical field generally relates to vehicles and, more specifically, to methods and systems for controlling driver feedback torque in steering systems of vehicles.

[0002] Many vehicles today are steer-by-wire vehicles, in which a steering wheel of the vehicle is not physically connected to the wheels of the vehicle. In such vehicles, resistance may be provided for the driver via the steering wheel. However, in certain circumstances, the resistance may be affected by traction steer disturbances from driver feedback torque.

[0003] Accordingly, it is desirable to provide improved methods and systems for controlling traction steer disturbances in vehicles, such as in steer-by-wire vehicles. Furthermore, other desirable features and characteristics of the present disclosure will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and the foregoing technical field and background.

SUMMARY

[0004] In accordance with an exemplary embodiment, a method is disclosed that includes obtaining sensor data from one or more sensors of a vehicle having a steering system; determining, via one or more processors of the vehicle, a likelihood of a traction steering disturbance occurring for the vehicle; and selectively adjusting resistance for a steering wheel of the steering system, in accordance with instructions that are provided via the one or more processors and that are executed via a motor that is coupled to the steering wheel.

[0005] Also in an exemplary embodiment, the step of determining the likelihood of a traction steering disturbance occurring includes generating, via the one or more processors, scalar values for each of a plurality of parameter values from the sensor data, wherein each of the scalar values represents a respective likelihood that a respective one of the plurality of parameter values is likely to contribute to a traction steering disturbance; aggregating, via the one or more processors, the scalar values for each of the plurality of parameter values; and calculating, via the one or more processors, an aggregate measure as to the likelihood of a traction steering disturbance occurring for the vehicle, based on the aggregating of the scalar values.

[0006] Also in an exemplary embodiment, each of the scalar values has a value that is between zero and one.

[0007] Also in an exemplary embodiment, the step of aggregating the scalar values includes multiplying, via the one or more processors, the scalar values for each of the plurality of parameter values.

[0008] Also in an exemplary embodiment, the method further includes obtaining, from the sensor data, a measured steering rack load for the steering system; determining, via the one or more processors, a corrected steering rack load that is attributable to the traction steering disturbance; and determining, via the one or more processors, an adjustment to the resistance based on the corrected steering rack load; wherein the step of selectively adjusting the resistance includes implementing the adjustment via the motor that is coupled to the steering wheel in accordance with the instructions that are provided via the one or more processors.

[0009] Also in an exemplary embodiment, the method further includes determining, via the one or more processors, a traction steer induced rack force estimate, based on the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; wherein the determining of the corrected steering rack load is made using the traction steer induced rack force estimate.

[0010] Also in an exemplary embodiment, the method further includes applying, via the one or more processors, filtering based on a frequency mapping using the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; wherein the determining of the corrected steering rack load is made using both the traction steer induced rack force estimate and the filtering based on the frequency mapping.

[0011] In another exemplary embodiment, a system is provided that includes one or more sensors and one or more processors of a vehicle having a steering system. The one or more sensors are configured to obtain sensor data as to the vehicle. The one or more processors are coupled to the one or more sensors, and are configured to at least facilitate determining a likelihood of a traction steering disturbance occurring for the vehicle; and selectively adjusting resistance for a steering wheel of the steering system, in accordance with instructions that are provided via the one or more processors and that are executed via a motor that is coupled to the steering wheel.

[0012] Also in an exemplary embodiment, the one or more processors are configured to at least facilitate generating scalar values for each of a plurality of parameter values from the sensor data, wherein each of the scalar values represents a respective likelihood that a respective one of the plurality of parameter values is likely to contribute to a traction steering disturbance; aggregating the scalar values for each of the plurality of parameter values; and calculating an aggregate measure as to the likelihood of a traction steering disturbance occurring for the vehicle, based on the aggregating of the scalar values.

[0013] Also in an exemplary embodiment, each of the scalar values has a value that is between zero and one.

[0014] Also in an exemplary embodiment, the one or more processors are configured to at least facilitate aggregating the scalar values by multiplying the scalar values for each of the plurality of parameter values.

[0015] Also in an exemplary embodiment, the one or more processors are configured to at least facilitate obtaining, from the sensor data, a measured steering rack load for the steering system; determining a corrected steering rack load that is attributable to the traction steering disturbance; determining an adjustment to the resistance based on the corrected steering rack load; and selectively adjusting the resistance by implementing the adjustment via the motor that is coupled to the steering wheel in accordance with the instructions that are provided via the one or more processors.

[0016] Also in an exemplary embodiment, the one or more processors are configured to at least facilitate determining a traction steer induced rack force estimate, based on the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; and determining the corrected steering rack load using the traction steer induced rack force estimate.

[0017] Also in an exemplary embodiment, the one or more processors are further configured to at least facilitate applying filtering based on a frequency mapping using the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; and determining the corrected steering rack load using both the traction steer induced rack force estimate and the filtering based on the frequency mapping.

[0018] In another exemplary embodiment, a vehicle is provided that includes a steering system, one or more sensors, and one or more processors. The steering system has a steering wheel and a motor coupled thereto. The one or more sensors are configured to obtain sensor data as to the vehicle. The one or more processors are coupled to the one or more sensors, and are configured to at least facilitate determining a likelihood of a traction steering disturbance occurring for the vehicle; and selectively adjusting resistance for the steering wheel, in accordance with instructions that are provided via the one or more processors and that are executed via the motor that is coupled to the steering wheel.

[0019] Also in an exemplary embodiment, the one or more processors are configured to at least facilitate generating scalar values for each of a plurality of parameter values from the sensor data, wherein each of the scalar values represents a respective likelihood that a respective one of the plurality of parameter values is likely to contribute to a traction steering disturbance; aggregating the scalar values for each of the plurality of parameter values; and calculating an aggregate measure as to the likelihood of a traction steering disturbance occurring for the vehicle, based on the aggregating of the scalar values.

[0020] Also in an exemplary embodiment, each of the scalar values has a value that is between zero and one; and the one or more processors are configured to at least facilitate aggregating the scalar values by multiplying the scalar values for each of the plurality of parameter values.

[0021] Also in an exemplary embodiment, the steering system further includes a steering rack, and the one or more processors are configured to at least facilitate obtaining, from the sensor data, a measured steering rack load for the steering rack; determining a corrected steering rack load that is attributable to the traction steering disturbance; determining an adjustment to the resistance based on the corrected steering rack load; and selectively adjusting the resistance by implementing the adjustment via the motor that is coupled to the steering wheel in accordance with the instructions that are provided via the one or more processors.

[0022] Also in an exemplary embodiment, the one or more processors are configured to at least facilitate determining a traction steer induced rack force estimate, based on the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; and determining the corrected steering rack load using the traction steer induced rack force estimate.

[0023] Also in an exemplary embodiment, the one or more processors are further configured to at least facilitate applying filtering based on a frequency mapping using the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; and determining the corrected steering rack load using both the traction steer induced rack force estimate and the filtering based on the frequency mapping.

Description

DESCRIPTION OF THE DRAWINGS

[0024] The present disclosure will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and wherein:

[0025] FIG. **1** is a functional block diagram of a vehicle that includes a steering system and a control system for controlling the steering system, and that mitigation of traction steer disturbances in the vehicle, in accordance with exemplary embodiment; and

[0026] FIG. **2** is a flowchart of process for controlling mitigation of traction steer disturbances in vehicles, and that can be implemented in connection with the vehicle of FIG. **1**, including the steering system and the control system of FIG. **1**, and components thereof, in accordance with exemplary embodiments.

DETAILED DESCRIPTION

[0027] The following detailed description is merely exemplary in nature and is not intended to limit the disclosure or the application and uses thereof. Furthermore, there is no intention to be bound by any theory presented in the preceding background or the following detailed description.

[0028] FIG. **1** illustrates a vehicle **100**, according to an exemplary embodiment. As described in greater detail further below, the vehicle **100** includes a steering system **104**, with the vehicle **100** also having a control system **102** for controlling mitigation of traction steer disturbances in the steering system **104** that result from driver feedback in operating the vehicle **100**, as described in greater detail further below in connection with the vehicle **100** of FIG. **1** as well as the process **200** of FIG. **2**.

[0029] In various embodiments, the vehicle **100** includes an automobile. The vehicle **100** may be any one of a number of different types of automobiles, such as, for example, a sedan, a wagon, a truck, or a sport utility vehicle (SUV), and may be two-wheel drive (2WD) (i.e., rear-wheel drive or front-wheel drive), four-wheel drive (4WD) or all-wheel drive (AWD), and/or various other types of vehicles in certain embodiments. In certain embodiments, the vehicle **100** may also comprise a motorcycle or other vehicle, such as aircraft, spacecraft, watercraft, and so on, and/or one or more other types of mobile platforms (e.g., a robot and/or other mobile platform). In various

embodiments, the vehicle **100** comprises a steer-by-wire vehicle.

[0030] The vehicle **100** includes a body **105** that is arranged on a chassis **108**. The body **105** substantially encloses other components of the vehicle **100**. The body **105** and the chassis **108** may jointly form a frame. The vehicle **100** also includes a plurality of wheels **110**. The wheels **110** are each rotationally coupled to the chassis **108** near a respective corner of the body **105** to facilitate movement of the vehicle **100**. In one embodiment, the vehicle **100** includes four wheels **110**, although this may vary in other embodiments (for example for trucks and certain other vehicles).

[0031] A drive system **106** is mounted on the chassis **108**, and drives the wheels **110**, for example via axles **114**. In various embodiments, the drive system **106** comprises a propulsion system that includes a motor **122** (e.g., an internal combustion engine and/or an electric motor/generator, coupled with a transmission thereof). In certain embodiments, the drive system **106** includes or is coupled to an accelerator pedal that receives inputs from a driver of the vehicle **100**. In the depicted embodiment, the axles **114** include a front axle **114(1)** and a rear axle **114(2)**.

[0032] In various embodiments, the steering system **104** provides steering for the vehicle **100**. As depicted in FIG. **1**, in various embodiments, the steering system **104** includes a steering wheel **116**, a rack system **118**, and a motor **120**. In various embodiments, a driver of the vehicle **100** controls steering via the steering wheel **116**. Also in various embodiments, inputs from the driver's engagement of the steering wheel **116** are utilized by the rack system **118** in turning the wheels **110** of the vehicle **100** to provide steering. In certain embodiments, the rack system **118** comprises a rack and pinion steering system. In addition, as mentioned above, in various embodiments, the steering system **104** comprises a steer-by-wire system, in which the steering wheel **116** is not physically connected to the wheels **110**.

[0033] Also as depicted in FIG. **1**, in various embodiments the steering system **104** also includes a motor **120** that is coupled to the steering wheel **116**. In various embodiments, the motor **120** is utilized to provide and adjust resistance for the steering wheel **116**, for example such that the steering wheel **116** performs and feels as expected for the driver. In various embodiments, the motor **120** is utilized for controlling mitigation of traction steer disturbances to the steering wheel **116** from driver feedback, in accordance with instructions provided by the control system **102** (described below).

[0034] With continued reference to FIG. **1**, in various embodiments the control system **102** controls operation of the steering system **104**. Specifically, in various embodiments, the control system **102** controls operation of the rack system **118**, including in implemented user inputs provided via the steering wheel **116** for steering of the vehicle **100**. Also in various embodiments, as noted above, the control system **102** controls mitigation of traction steer disturbances to the steering wheel **116** from driver feedback, including as described in greater detail further below in connection with the process **200** of FIG. **2**.

[0035] As depicted in FIG. **1**, in various embodiments, the control system **102** includes a sensor array **130** and a controller **140**, as described in greater detail below in accordance with an exemplary embodiment.

[0036] In various embodiments, the sensor array **130** collects data pertaining to the vehicle **100** and its components, including for detecting conditions that relate to a likelihood that traction steer disturbances may be occurring with respect to the steering wheel **116**. In various embodiments, the sensor data from the sensor array **130** is provided to the controller **140** for use in mitigating the traction steer disturbances, for example as described in greater detail further below.

[0037] In various embodiments, the sensor array **130** includes one or more rack load sensors **131**, torque sensors **132**, rotation sensors **133**, suspension sensors **134**, speed sensors **135**, throttle sensors **136**, steering wheel sensors **137**, and friction sensors **138**. In certain embodiments, the sensor array **130** may also include one or more input sensors **139**.

[0038] In various embodiments, the rack load sensors **131** measure a load on the rack system **118** of FIG. **1**.

[0039] Also in various embodiments, the torque sensors **132** measure one or more torque values for the vehicle **100**, including a propulsion torque for the front axle **114**(**1**) of the vehicle **100** in certain embodiments.

[0040] In various embodiments, the rotation sensors **133** measure a rotational speed of one or more wheels **110** of the vehicle **100**, including one or more front wheels **110** thereof.

[0041] In various embodiments, the suspension sensors **134** comprise one or more suspension and/or pitch angle sensors that obtain sensor data as to a pitch angle of the vehicle **100** and/or one or more other parameters pertaining to a suspension system of the vehicle **100**.

[0042] In addition, in various embodiments, the speed sensors **135** measure a speed of the vehicle **100** and/or information used to determine the vehicle speed (e.g., in certain embodiments, the speed sensors **135** may comprise wheel speed sensors **135** that measure wheel speed of the vehicle **100**).

[0043] In various embodiments, the throttle sensors **136** measure or detect a position of a throttle of the vehicle **100** (e.g., of the propulsion system **106**).

[0044] In various embodiments, the steering wheel sensors **137** obtain sensor data as to the steering wheel **116** of the vehicle **100**, including as to an angle and a velocity of the steering wheel **116**.

[0045] Also in certain embodiments, the friction sensors **138** comprise one or more sensors that measure or detect sensor data that pertains to and/or that can be used to calculate a road friction coefficient for a road or path on which the vehicle **100** is travelling.

[0046] In various embodiments, the input sensors **139** include one or more sensors that measure or detect inputs provided by a driver of the vehicle **100**. In various embodiments, the input sensors **139** are coupled to a steering wheel, accelerator pedal, brake pedal, and other instruments of the vehicle **100**, and are configured to measure or detect the driver's engagement thereof.

[0047] In various embodiments, the controller **140** is coupled to the sensor array **130** and receives sensor data therefrom. In various embodiments, the controller **140** is further coupled to the steering system **104**, and in certain embodiments one or more of (and, in certain embodiments, to the drive system **106** and/or other systems of the vehicle **100**). In various embodiments, the controller **140** controls the steering system **104** (including mitigation of traction steer disturbances) based on sensor data, including as described further below in connection with the process **200** of FIG. **2**.

[0048] In various embodiments, the controller **140** comprises a computer system (also referred to herein as computer system **140**). In various embodiments, the controller **140** (and, in certain embodiments, the control system **102** itself) is disposed within the body **105** of the vehicle **100**. In one embodiment, the control system **102** is mounted on the chassis **108**. In certain embodiments, the controller **140** and/or control system **102** and/or one or more components thereof may be disposed outside the body **105**, for example on a remote server, in the cloud, or the like.

[0049] It will be appreciated that the controller **140** may otherwise differ from the embodiment depicted in FIG. **1**. For example, the controller **140** may be coupled to or may otherwise utilize one or more remote computer systems and/or other control systems, for example as part of one or more of the above-identified vehicle **100** devices and systems.

[0050] In the depicted embodiment, the computer system of the controller **140** includes a processor **142**, a memory **144**, an interface **146**, a storage device **148**, and a bus **150**. The processor **142** performs the computation and control functions of the controller **140**, and may comprise any type of processor or multiple processors, single integrated circuits such as a microprocessor, or any suitable number of integrated circuit devices and/or circuit boards working in cooperation to accomplish the functions of a processing unit. During operation, the processor **142** executes one or more programs **152** contained within the memory **144** and, as such, controls the general operation of the controller **140** and the computer system of the controller **140**, generally in executing the processes described herein, such as the process **200** of FIG. **2** and described further below in connection therewith.

[0051] The memory **144** can be any type of suitable memory, including various types of non-transitory computer readable storage medium. In certain examples, the memory **144** is located on

and/or co-located on the same computer chip as the processor **142**. In the depicted embodiment, the memory **144** stores the above-referenced program **152** along with stored values **154** (e.g., look-up tables, thresholds, and/or other values with respect to traction steer disturbances and their relationship pertaining to the sensor data).

[0052] The interface **146** allows communication to the computer system of the controller **140**, for example from a system driver and/or another computer system, and can be implemented using any suitable method and apparatus. In one embodiment, the interface **146** obtains the various data from the sensor array **130**, among other possible data sources. The interface **146** can include one or more network interfaces to communicate with other systems or components. The interface **146** may also include one or more network interfaces to communicate with technicians, and/or one or more storage interfaces to connect to storage apparatuses, such as the storage device **148**.

[0053] The storage device **148** can be any suitable type of storage apparatus, including various different types of direct access storage and/or other memory devices. In one exemplary embodiment, the storage device **148** comprises a program product from which memory **144** can receive a program **152** that executes one or more embodiments of one or more processes of the present disclosure, such as the steps of the process **200** of FIG. **2** and described further below in connection therewith. In another exemplary embodiment, the program product may be directly stored in and/or otherwise accessed by the memory **144** and/or a disk (e.g., disk **156**), such as that referenced below.

[0054] The bus **150** serves to transmit programs, data, status and other information or signals between the various components of the computer system of the controller **140**. The bus **150** can be any suitable physical or logical means of connecting computer systems and components. This includes, but is not limited to, direct hard-wired connections, fiber optics, infrared and wireless bus technologies. During operation, the program **152** is stored in the memory **144** and executed by the processor **142**.

[0055] It will be appreciated that while this exemplary embodiment is described in the context of a fully functioning computer system, those skilled in the art will recognize that the mechanisms of the present disclosure are capable of being distributed as a program product with one or more types of non-transitory computer-readable signal bearing media used to store the program and the instructions thereof and carry out the distribution thereof, such as a non-transitory computer readable medium bearing the program and containing computer instructions stored therein for causing a computer processor (such as the processor **142**) to perform and execute the program.

[0056] FIG. **2** is a flowchart of process **200** for controlling mitigation of traction steer disturbances from driver feedback, in accordance with exemplary embodiments. The process **200** can be implemented in connection with the vehicle **100** of FIG. **1**, including the steering system **104** and the control system **102** of FIG. **1**, and components thereof, in accordance with exemplary embodiments.

[0057] As depicted in FIG. **2**, the process **200** begins at step **202**. In one embodiment, the process **200** begins when the vehicle **100** is or has been operated, for example during or after a current vehicle drive. In one embodiment, the steps of the process **200** are performed continuously once the process **200** begins.

[0058] Sensor data is obtained at step **204**. In various embodiments, sensor data pertaining to the vehicle is obtained via each of the sensors of the sensor array **130** of FIG. **1**. In certain embodiments, the sensor data of step **204** includes the following, among other possible types of sensor data: (i) rack load sensor data from one or more rack load sensors **131** as to a measure a load on the rack system **118** of FIG. **1**; (ii) torque sensor data from one or more torque sensors **132**, including a propulsion torque for the front axle **114(1)** of the vehicle **100**; (iii) rotational sensor data from one or more rotation sensors **133**, including a rotational speed of one or more front wheels **110** of the vehicle **100**; (iv) suspension data from one or more suspension sensors **134** pertaining to a pitch angle of the vehicle **100** and/or one or more other parameters pertaining to a

suspension system of the vehicle **100**; (v) speed sensor data from one or more speed sensors **135** as to a measure a speed of the vehicle **100** and/or information used to determine the vehicle speed (e.g., wheel speed); (vi) throttle sensor data from one or more throttle sensors **136** as to a position of a throttle of the vehicle **100** (e.g., of the propulsion system **106**); (vii) steering wheel angle sensor data from one or more steering wheel sensors **137** as to an angle or angular position of the steering wheel **116**; (viii) steering wheel velocity sensor data from one or more steering wheel sensors **137** as to a velocity of the steering wheel **116**; and (ix) friction sensor data from one or more friction sensors **138**, including as to a road friction coefficient for a road or path on which the vehicle **100** is travelling. In certain embodiments, additional sensor data may also be obtained via one or more input sensors **139**, and for example may pertain to inputs provided by a driver of the vehicle **100**, such as via a steering wheel, accelerator pedal, brake pedal, and other instruments of the vehicle **100**.

[0059] In various embodiments, the sensor data of step **204** is translated (e.g., as denoted in FIG. **2** as a combined step **206**). Specifically, in various embodiments, during combined step **206**, each of the particular types of sensor data (e.g., as reflected in each respective type of sensor data signals) are translated into respective scalar values, as a representation of how likely each type of sensor data (or associated parameter) is likely to contribute to a traction steering condition for the steering wheel **116**. In various embodiments, this is performed by a processor (such as the processor **142** of FIG. **1**).

[0060] Specifically, as part of the combined step **206**, in various embodiments: (i) a steering rack load **208** from the rack load sensor data is translated into a rack load scalar **210** (also referred to as K.sub.10 in FIG. **2**); (ii) a front axle propulsion torque **212** from the torque sensor data is translated into a propulsion torque scalar **214** (also referred to as K.sub.1 in FIG. **2**); (iii) a front axle torque rate of change **216** is calculated from the front axle propulsion torque **212** and is translated into a propulsion torque rate of change scalar **218** (also referred to as K.sub.2 in FIG. **2**); (iv) a front wheel rotational delta (or change) **220** from the rotational sensor data is translated into a rotational delta scalar **222** (also referred to as K.sub.3 in FIG. **2**); (v) a vehicle suspension pitch angle **224** from the suspension data is translated into a pitch angle scalar **226** (also referred to as K.sub.4 in FIG. **2**); (vi) a vehicle speed **228** from the speed sensor data is translated into a vehicle speed scalar **230** (also referred to as K.sub.5 in FIG. **2**); (vii) a throttle position **232** from the throttle sensor data is translated into a throttle scalar **234** (also referred to as K.sub.6 in FIG. **2**); (viii) a steering wheel angle **236** from the steering wheel angle sensor data is translated into a steering wheel angle scalar **238** (also referred to as K.sub.7 in FIG. **2**); (ix) a steering wheel velocity **240** from the steering wheel velocity sensor data is translated into a steering wheel velocity scalar **242** (also referred to as K.sub.8 in FIG. **2**); and (x) a road friction coefficient **244** from the road friction sensor data is translated into a road friction coefficient scalar **246** (also referred to as K.sub.9 in FIG. **2**).

[0061] In various embodiments, each of the respective scalar values **210**, **214**, **218**, **222**, **226**, **230**, **234**, **238**, **242**, and **246** is based on the current respective corresponding parameter values **208**, **212**, **216**, **220**, **224**, **228**, **232**, **236**, **240**, and **244** in combination with prior or historical data pertaining to such parameter values in relation to traction steer events (e.g., in certain embodiments pertaining to the same vehicle **100** and/or pertaining to other vehicles, such as may be obtained in or from vehicle manufacturer data, published data, shared data between different vehicles, and so on). Also in certain embodiments, the prior or historical data is stored in the memory **144** of FIG. **1** as stored values **154** therein, for example that may include functions, look-up tables, and/or other data representations.

[0062] Also in various embodiments, each of the scalar values **210**, **214**, **218**, **222**, **226**, **230**, **234**, **238**, **242**, and **246** has a respective value that is between zero and one. Also in various embodiments, the closer the scalar value is to zero ("0") for a particular parameter, the less likelihood that the particular parameter is contributing to a traction steer disturbance (e.g., with a value of zero meaning that there is certainty or near certainty that a current value of the particular

parameter is not causing a traction steer disturbance). Conversely, also in various embodiments, the closer the scalar value is to one ("1") for a particular parameter, the greater is the likelihood that the particular parameter is contributing to a traction steer disturbance (e.g., with a value of one meaning that there is certainty or near certainty that a current value of the particular parameter is causing a traction steer disturbance).

[0063] In various embodiments, the respective scalar values are aggregated (step **248**). Specifically, in various embodiments, the scalar values **210**, **214**, **218**, **222**, **226**, **230**, **234**, **238**, **242**, and **246** are multiplied together, thereby generating a product **249**. In various embodiments, the product **249** may also be referred to as a traction steer likelihood indication (TSLI) **249**.

[0064] As depicted in FIG. **2**, in various embodiments, a traction steer induced rack force estimate is determined (step **250**). In various embodiment, during step **250**, the traction steer induced rack force represents an amount of rack force that is attributed to a traction steer disturbance. In various embodiments, during step **250**, the traction steer induced rack force is determined by a processor (such as the processor **142** of FIG. **1**) based on the TSLI **249** along with the rack load **208**.

[0065] Also in various embodiments, the traction steer induced rack force of step **250** also corresponds to a rack force offset **257** (e.g., that can be utilized to correct or mitigate the traction steer in certain embodiments). In various embodiments, the rack force offset **257** corresponds to a torque that can be applied by the motor **120** to the steering wheel **116** that is equal and opposite to an amount of resistance torque that is coming from the drive torque forces that are creating the rack force, in order to thereby mitigate the traction steer for the steering wheel **116**.

[0066] In addition, in various embodiments, the TSLI **249** from step **248** is also utilized for cutoff frequency mapping (step **252**). Specifically, in various embodiments, when traction steer is deemed to be likely to occur, a cutoff frequency is selected for filtering of the sensor data (particularly the rack load sensor data) that is dependent on the likelihood as to whether traction steer is occurring or about to occur. In various embodiments, this is performed via a processor, such as the processor **142** of FIG. **1**. Also in various embodiments, step **252** results in the selection of a particular optimized cutoff frequency "f.sub.c" **253** (as depicted in FIG. **2**) that is dependent upon the TSLI **249**.

[0067] In various embodiments, filtering is applied (step **254**). Specifically, in various embodiments, during step **254**, filtering is applied to the measure values of steering rack load **208** based on the optimized cutoff frequency "f.sub.c" **253** of step **252**. In various embodiments, the filtering is performed in a manner such that the sensor data (particularly the rack load sensor data) is sufficiently filtered so as to remove any portion of the rack load data that is attributable to force due to drive torque, to thereby also mitigate the traction steer disturbance. In various embodiments, this is performed by a processor, such as the processor **142** of FIG. **1**. Also in various embodiments, a variable digital filter is utilized for the cutoff frequency mapping. In certain embodiments, the variable digital filter comprises a first order, low pass filter. In one exemplary embodiment, the variable digital filter comprises a three hertz (3 HZ) low pass filter; however, this may vary in other embodiments. In various embodiments, the filtering of step **254** yields, as an output thereof, a filtered steering rack load **256**.

[0068] In various embodiments, the rack force offset **257** (from step **250**) and the filtered steering rack load **256** (from step **254**) are aggregated in step **258**. Specifically, in various embodiments, during step **258**, the rack force offset **257** and the filtered steering rack load **256** are added together. Also in various embodiments, this is performed via a processor, such as the processor **142** of FIG. **1**.

[0069] In various embodiments, the summation of step **258** yields, as its calculated result, a traction steering corrected rack load **260**. In various embodiments, the traction steering corrected rack load **260** represents a modified or updated rack load value after the removal, from that force value, any forces that are due to traction steer disturbances (e.g., due to propulsion torque and/or related feedback). In various embodiments, this is performed via one or more processor (such as the

processor **142** of FIG. **1**).

[0070] In various embodiments, a resistance adjustment is determined (step **262**). Specifically, in various embodiments, during step **262**, the traction steering corrected rack load is utilized in determining an appropriate adjustment to be made to the resistance that is provided to the steering wheel **116** of FIG. **1** via the motor **120** of FIG. **1**. In various embodiments, the adjustment is determined via a processor (such as the processor **142** of FIG. **1**, and/or one or more separate processors, for example of the motor **120** and/or steering system **104** of FIG. **1**). Also in various embodiments, the adjustment is determined in a manner such that the resulting adjustment to the resistance on the steering wheel **116** will be equal to, and/or will appear to the driver as being equal to, the resistance on the steering wheel **116** that would have been provided originally in the absence of the traction steer disturbance.

[0071] Also in various embodiments, adjusted resistance is provided (step **264**). In various embodiments, adjusted resistance is provided for the steering wheel **116** in implementing the determined adjustment of step **264**. In various embodiments, the adjusted resistance is automatically implemented via the motor **120** in adjusting resistance to the steering wheel **116** in accordance with and execution of instructions provided to the motor **120** via one or more processors (such as the processor **142** of FIG. **1**). Accordingly, in various embodiments, as a result the driver experiences an appropriate level of resistance from the steering wheel **116** based on current operating conditions and parameters pertaining to the vehicle **100** and the roadway, but without the unwanted traction steering disturbance. In other words, in various embodiments, the steering will feel more consistent with what the driver is expecting.

[0072] In various embodiments, the process **200** then terminates at step **265**.

[0073] Accordingly, methods, systems, and vehicles are provided for controlling mitigation of traction steer disturbances for the steering wheel of vehicles. In various embodiments, sensor data is utilized to determine a likelihood that a traction steer disturbance is occurring or about to occur for the steering wheel, and resistance for the steering wheel is adjusted accordingly to mitigate the traction steer disturbances for the steering wheel as experienced by the driver of the vehicle, utilizing a motor that is coupled to the steering wheel and that is controlled in accordance with instructions that are provided by a processor of a control system and that are based on the sensor data.

[0074] It will be appreciated that the systems, vehicles, and methods may vary from those depicted in the Figures and described herein. For example, the vehicle **100** of FIG. **1**, the control system **102**, and steering system **104** thereof, and/or components thereof of FIG. **1** may vary in different embodiments. It will similarly be appreciated that the steps of the process **200** may differ from that depicted in FIG. **2**, and/or that various steps of the process **200** may occur concurrently and/or in a different order than that depicted in FIG. **2**.

[0075] While at least one exemplary embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the disclosure in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing the exemplary embodiment or exemplary embodiments. It should be understood that various changes can be made in the function and arrangement of elements without departing from the scope of the disclosure as set forth in the appended claims and the legal equivalents thereof.

Claims

1. A method comprising: obtaining sensor data from one or more sensors of a vehicle having a steering system; determining, via one or more processors of the vehicle, a likelihood of a traction

steering disturbance occurring for the vehicle; and selectively adjusting resistance for a steering wheel of the steering system, in accordance with instructions that are provided via the one or more processors and that are executed via a motor that is coupled to the steering wheel.

2. The method of claim 1, wherein the step of determining the likelihood of a traction steering disturbance occurring comprises: generating, via the one or more processors, scalar values for each of a plurality of parameter values from the sensor data, wherein each of the scalar values represents a respective likelihood that a respective one of the plurality of parameter values is likely to contribute to a traction steering disturbance; aggregating, via the one or more processors, the scalar values for each of the plurality of parameter values; and calculating, via the one or more processors, an aggregate measure as to the likelihood of a traction steering disturbance occurring for the vehicle, based on the aggregating of the scalar values.

3. The method of claim 2, wherein each of the scalar values has a value that is between zero and one.

4. The method of claim 2, wherein the step of aggregating the scalar values comprises multiplying, via the one or more processors, the scalar values for each of the plurality of parameter values.

5. The method of claim 1, further comprising: obtaining, from the sensor data, a measured steering rack load for the steering system; determining, via the one or more processors, a corrected steering rack load that is attributable to the traction steering disturbance; and determining, via the one or more processors, an adjustment to the resistance based on the corrected steering rack load; wherein the step of selectively adjusting the resistance comprises implementing the adjustment via the motor that is coupled to the steering wheel in accordance with the instructions that are provided via the one or more processors.

6. The method of claim 5, further comprising: determining, via the one or more processors, a traction steer induced rack force estimate, based on the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; wherein the determining of the corrected steering rack load is made using the traction steer induced rack force estimate.

7. The method of claim 6, further comprising: applying, via the one or more processors, filtering based on a frequency mapping using the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; wherein the determining of the corrected steering rack load is made using both the traction steer induced rack force estimate and the filtering based on the frequency mapping.

8. A system comprising: one or more sensors of a vehicle having a steering system, the one or more sensors configured to obtain sensor data as to the vehicle; and one or more processors of the vehicle that are coupled to the one or more sensors and that are configured to at least facilitate: determining a likelihood of a traction steering disturbance occurring for the vehicle; and selectively adjusting resistance for a steering wheel of the steering system, in accordance with instructions that are provided via the one or more processors and that are executed via a motor that is coupled to the steering wheel.

9. The system of claim 8, wherein the one or more processors are configured to at least facilitate: generating scalar values for each of a plurality of parameter values from the sensor data, wherein each of the scalar values represents a respective likelihood that a respective one of the plurality of parameter values is likely to contribute to a traction steering disturbance; aggregating the scalar values for each of the plurality of parameter values; and calculating an aggregate measure as to the likelihood of a traction steering disturbance occurring for the vehicle, based on the aggregating of the scalar values.

10. The system of claim 9, wherein each of the scalar values has a value that is between zero and one.

11. The system of claim 9, wherein the one or more processors are configured to at least facilitate aggregating the scalar values by multiplying the scalar values for each of the plurality of parameter values.

12. The system of claim 8, wherein the one or more processors are configured to at least facilitate: obtaining, from the sensor data, a measured steering rack load for the steering system; determining a corrected steering rack load that is attributable to the traction steering disturbance; determining an adjustment to the resistance based on the corrected steering rack load; and selectively adjusting the resistance by implementing the adjustment via the motor that is coupled to the steering wheel in accordance with the instructions that are provided via the one or more processors.

13. The system of claim 12, wherein the one or more processors are configured to at least facilitate: determining a traction steer induced rack force estimate, based on the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; and determining the corrected steering rack load using the traction steer induced rack force estimate.

14. The system of claim 13, wherein the one or more processors are further configured to at least facilitate: applying filtering based on a frequency mapping using the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; and determining the corrected steering rack load using both the traction steer induced rack force estimate and the filtering based on the frequency mapping.

15. A vehicle comprising: a steering system having a steering wheel and a motor coupled thereto; one or more sensors configured to obtain sensor data as to the vehicle; and one or more processors that are coupled to the one or more sensors and that is configured to at least facilitate: determining a likelihood of a traction steering disturbance occurring for the vehicle; and selectively adjusting resistance for the steering wheel, in accordance with instructions that are provided via the one or more processors and that are executed via the motor that is coupled to the steering wheel.

16. The vehicle of claim 15, wherein the one or more processors are configured to at least facilitate: generating scalar values for each of a plurality of parameter values from the sensor data, wherein each of the scalar values represents a respective likelihood that a respective one of the plurality of parameter values is likely to contribute to a traction steering disturbance; aggregating the scalar values for each of the plurality of parameter values; and calculating an aggregate measure as to the likelihood of a traction steering disturbance occurring for the vehicle, based on the aggregating of the scalar values.

17. The vehicle of claim 16, wherein: each of the scalar values has a value that is between zero and one; and the one or more processors are configured to at least facilitate aggregating the scalar values by multiplying the scalar values for each of the plurality of parameter values.

18. The vehicle of claim 15, wherein the steering system further includes a steering rack, and the one or more processors are configured to at least facilitate: obtaining, from the sensor data, a measured steering rack load for the steering rack; determining a corrected steering rack load that is attributable to the traction steering disturbance; determining an adjustment to the resistance based on the corrected steering rack load; and selectively adjusting the resistance by implementing the adjustment via the motor that is coupled to the steering wheel in accordance with the instructions that are provided via the one or more processors.

19. The vehicle of claim 18, wherein the one or more processors are configured to at least facilitate: determining a traction steer induced rack force estimate, based on the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; and determining the corrected steering rack load using the traction steer induced rack force estimate.

20. The vehicle of claim 19, wherein the one or more processors are further configured to at least facilitate: applying filtering based on a frequency mapping using the measured steering rack load and the likelihood of a traction steering disturbance occurring for the vehicle; and determining the corrected steering rack load using both the traction steer induced rack force estimate and the filtering based on the frequency mapping.