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SYSTEM AUGMENTING PERCEPTION AND CONTROL FOR A REMOTE OPERATIVE VEHICLE USING SURROUNDING CONNECTED VEHICLES

Abstract

Systems and methods are provided for augmenting a sensor view of a vehicle. The system can determine that the vehicle needs operation assistance to complete a remote driving task. Sensor information can be requested from the vehicle. Based on the sensor information, the system can determine that the sensor information is insufficient to perform the remote driving task. The system can connect with one or more surrounding vehicles connected to the vehicle to obtain supplemental sensor information. The sensor information and the supplemental sensor information can be applied to complete the remote driving task.

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Background/Summary

TECHNICAL FIELD
[0001] The present disclosure relates generally to remote controlled driving, and in particular, some implementations may relate to the vehicle's interpretation of its environment to facilitate remote controlled driving.
DESCRIPTION OF RELATED ART
[0002] Remote driving occurs when commands to the throttle, brake, and steering are prescribed by an operator not located inside the vehicle. These commands can be relayed through wireless communication. Remote driving can serve as a fallback option for the safety of vehicle occupants. Remote driving can be used in various situations to act as a professional driver overriding the driver inside the vehicle. For instance, remote driving can be applied: when a driver intoxicated, unconscious, or incapacitated, when the vehicle is severely damaged, or when the vehicle/driver is in other distress. In testing environments, remote driving can be helpful to run crash tests without endangering any human lives. BRIEF SUMMARY OF THE DISCLOSURE
[0003] According to various embodiments of the disclosed technology, a method can comprise determining that the vehicle needs operation assistance to complete a remote driving task; requesting sensor information from the vehicle; based on the sensor information, determining that the sensor information is insufficient to perform the remote driving task; connecting with one or more surrounding vehicles connected to the vehicle; obtaining supplemental sensor information from the one or more surrounding vehicles; and applying the sensor information of the vehicle and the supplemental sensor information to complete the remote driving task.
[0004] In some embodiments, the method further comprises determining what sensor information is needed to perform the remote driving task; and requesting the needed sensor information from the one or more surrounding vehicles.
[0005] In some embodiments, applying the sensor information of the vehicle and the supplemental sensor information comprises generating a world view of an environment of the vehicle.
[0006] In some embodiments, the sensor information of the vehicle and the supplemental sensor information is received at a remote operator station configured to simulate an environment of the vehicle.
[0007] In some embodiments, the method further comprises determining what sensor information is needed to perform the remote driving task; and directing the one or more surrounding vehicles into a position where the supplemental sensor information can be generated.
[0008] In some embodiments, the remote driving task comprises a safety operation.
[0009] In some embodiments, completing the remote driving task comprises taking remote control of the vehicle from a remote operator station and executing the remote driving task.
[0010] In some embodiments, the method further comprises receiving a request from the vehicle for operation assistance.
[0011] In some embodiments, connecting with the one or more surrounding vehicles connected to the vehicle comprises communicating cooperative maneuvers for the one or more surrounding vehicles to perform to obtain the supplemental sensor information.
[0012] In some embodiments, the one or more surrounding vehicles connected to the vehicle relay maneuver-related messages to the vehicle to obtain the sensor information.

[0013] According to various embodiments of the disclosed technology, a system for augmenting a sensor view of a vehicle can comprise a processor and a memory coupled to the processor to store instructions, which when executed by the processor, causes the processor to determine that the vehicle needs operation assistance to complete a remote driving task; request sensor information from the vehicle; based on the sensor information, determine that the sensor information is insufficient to perform the remote driving task; direct one or more surrounding vehicles in a position to generate supplemental sensor information; obtain the supplemental sensor information from the one or more surrounding vehicles; and apply the sensor information of the vehicle and the supplemental sensor information to complete the remote driving task.
[0014] In some embodiments, the instructions further cause the processor to determine what sensor information is needed to perform the remote driving task; and request the needed sensor information from the one or more surrounding vehicles.
[0015] In some embodiments, the instructions further cause the processor to generate a world view of an environment of the vehicle.
[0016] In some embodiments, the remote driving task comprises a safety operation.
[0017] In some embodiments, the instructions further cause the processor to take remote control of the vehicle from a remote operator station and execute the remote driving task.
[0018] In some embodiments, the instructions further cause the processor to receive a request from the vehicle for operation assistance.
[0019] According to various embodiments of the disclosed technology, a non-transitory machine-readable medium can have instructions stored therein, which when executed by a processor, causes the processor to: determine that a vehicle needs operation assistance to complete a remote driving task; request sensor information from the vehicle; based on the sensor information, determine that the sensor information is insufficient to perform the remote driving task; connect with one or more surrounding vehicles connected to the vehicle; obtain supplemental sensor information from the one or more surrounding vehicles; take remote control of the vehicle; and execute the remote driving task based on the sensor information and the supplemental sensor information.
[0020] In some embodiments, the instructions further cause the processor to determine what sensor information is needed to perform the remote driving task and request the needed sensor information from the one or more surrounding vehicles.
[0021] In some embodiments, the instructions further cause the processor to generate a world view of an environment of the vehicle.
[0022] In some embodiments, the instructions further cause the processor to determine what sensor information is needed to perform the remote driving task and direct the one or more surrounding vehicles into a position where the supplemental sensor information can be generated.
[0023] Other features and aspects of the disclosed technology will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, which illustrate, by way of example, the features in accordance with embodiments of the disclosed technology. The summary is not intended to limit the scope of any inventions described herein, which are defined solely by the claims attached hereto.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0024] The present disclosure, in accordance with one or more various embodiments, is described in detail with reference to the following figures. The figures are provided for purposes of illustration only and merely depict typical or example embodiments.
[0025] FIG. **1** is a schematic representation of an example hybrid vehicle with which embodiments of the systems and methods disclosed herein may be implemented.

[0026] FIG. **2** illustrates an example architecture for augmenting a vehicle's sensor view in accordance with one embodiment of the systems and methods described herein.
[0027] FIG. **3**A illustrates an example system for augmenting a vehicle's sensor view in accordance with various embodiments.
[0028] FIG. **3**B illustrates an example system for an ego vehicle in accordance with various embodiments.
[0029] FIG. **3**C illustrates an example system for a remote operator station in accordance with various embodiments.
[0030] FIG. **3**D illustrates an example system for surrounding connected vehicles in accordance with various embodiments.
[0031] FIG. **4**A illustrates an example scenario where a vehicle can request sensor assistance, in accordance with one embodiment.
[0032] FIG. **4**B illustrates an example scenario where surrounding vehicles can augment a vehicle's sensor view, in accordance with one embodiment.
[0033] FIG. **5** illustrates an example method for augmenting a vehicle's sensor view in accordance with one embodiment.
[0034] FIG. **6** is an example computing component that may be used to implement various features of embodiments described in the present disclosure.
[0035] The figures are not exhaustive and do not limit the present disclosure to the precise form disclosed.

DETAILED DESCRIPTION

[0036] Remote driving can be used in various situations to act as a professional driver overriding or substituting for the driver inside the vehicle. Remote driving can be effectuated by a human operator located away from the “ego vehicle” (remote controlled vehicle) and/or by an automated remote driver. To accomplish remote driving, the remote operator needs to have a good understanding of the ego vehicle's environment and driving situation, which in some situations can be established by using the ego vehicle's sensor data to determine a world view of the ego vehicle. For example, motion sensors can determine the number, location, and speed of other vehicles surrounding the ego vehicle. Environmental data can determine time of day, weather conditions, and upcoming hazards. Internal sensors can monitor the ego vehicle's operating condition and maintenance needs. Just like a driver inside of a vehicle, a remote operator can use this sensor information to determine the optimal way to operate the ego vehicle. However, in some scenarios the ego vehicle may not have all of its sensors functioning to establish the proper world view. This may occur due to internal malfunctioning or other operating condition. For instance, certain sensors may not be accurate during nighttime due to the lack of available light. In these situations, the remote operator would not receive enough information about the ego vehicle's environment to remotely operate the ego vehicle. In situations where the driver inside the vehicle is incapacitated, this could greatly endanger the lives of the driver or drivers in surrounding vehicles.
[0037] Embodiments of the systems and methods disclosed herein can “augment” the ego vehicle's sensor worldview so that a remote operator can properly operate the vehicle. In particular, this system can use data from surrounding connected vehicles (SCVS) to detect that the ego vehicle needs sensory augmentation and provide that sensor augmentation to the remote operator. SCVS may have additional sensor data that the ego vehicle does not have access to or cannot access at the time. SCVS can transmit this sensor data to a remote database while the ego vehicle transmits the sensor data available to the ego vehicle. All data can be aggregated to form the world view necessary for the remote operator. The remote operator can then engage remote control of the vehicle and execute any needed safety or other driving maneuvers. Once the remote operator has completed the remote driving task, SCVS can stop sharing sensor data and the ego vehicle can return to normal operation.
[0038] The systems and methods disclosed herein may be implemented with any of a number of

different vehicles and vehicle types. For example, the systems and methods disclosed herein may be used with automobiles, trucks, motorcycles, recreational vehicles and other like on-or off-road vehicles. In addition, the principals disclosed herein may also extend to other vehicle types as well. An example hybrid electric vehicle (HEV) in which embodiments of the disclosed technology may be implemented is illustrated in FIG. **1**. Although the example described with reference to FIG. **1** is a hybrid type of vehicle, the systems and methods for augmenting the vehicle's sensor view can be implemented in other types of vehicle including gasoline-or diesel-powered vehicles, fuel-cell vehicles, electric vehicles, or other vehicles.

[0039] FIG. **1** illustrates a drive system of a vehicle **100** that may include an internal combustion engine **14** and one or more electric motors **22** (which may also serve as generators) as sources of motive power. Driving force generated by the internal combustion engine **14** and motors **22** can be transmitted to one or more wheels **34** via a torque converter **16**, a transmission **18**, a differential gear device **28**, and a pair of axles **30**.

[0040] As an HEV, vehicle **2** may be driven/powered with either or both of engine **14** and the motor(s) **22** as the drive source for travel. For example, a first travel mode may be an engine-only travel mode that only uses internal combustion engine **14** as the source of motive power. A second travel mode may be an EV travel mode that only uses the motor(s) **22** as the source of motive power. A third travel mode may be an HEV travel mode that uses engine **14** and the motor(s) **22** as the sources of motive power. In the engine-only and HEV travel modes, vehicle **100** relies on the motive force generated at least by internal combustion engine **14**, and a clutch **15** may be included to engage engine **14**. In the EV travel mode, vehicle **2** is powered by the motive force generated by motor **22** while engine **14** may be stopped and clutch **15** disengaged.

[0041] Engine **14** can be an internal combustion engine such as a gasoline, diesel or similarly powered engine in which fuel is injected into and combusted in a combustion chamber. A cooling system **12** can be provided to cool the engine **14** such as, for example, by removing excess heat from engine **14**. For example, cooling system **12** can be implemented to include a radiator, a water pump and a series of cooling channels. In operation, the water pump circulates coolant through the engine **14** to absorb excess heat from the engine. The heated coolant is circulated through the radiator to remove heat from the coolant, and the cold coolant can then be recirculated through the engine. A fan may also be included to increase the cooling capacity of the radiator. The water pump, and in some instances the fan, may operate via a direct or indirect coupling to the driveshaft of engine **14**. In other applications, either or both the water pump and the fan may be operated by electric current such as from battery **44**.

[0042] An output control circuit **14**A may be provided to control drive (output torque) of engine **14**. Output control circuit **14**A may include a throttle actuator to control an electronic throttle valve that controls fuel injection, an ignition device that controls ignition timing, and the like. Output control circuit **14**A may execute output control of engine **14** according to a command control signal(s) supplied from an electronic control unit **50**, described below. Such output control can include, for example, throttle control, fuel injection control, and ignition timing control.

[0043] Motor **22** can also be used to provide motive power in vehicle **2** and is powered electrically via a battery **44**. Battery **44** may be implemented as one or more batteries or other power storage devices including, for example, lead-acid batteries, nickel-metal hydride batteries, lithium-ion batteries, capacitive storage devices, and so on. Battery **44** may be charged by a battery charger **45** that receives energy from internal combustion engine **14**. For example, an alternator or generator may be coupled directly or indirectly to a drive shaft of internal combustion engine **14** to generate an electrical current as a result of the operation of internal combustion engine **14**. A clutch can be included to engage/disengage the battery charger **45**. Battery **44** may also be charged by motor **22** such as, for example, by regenerative braking or by coasting during which time motor **22** operate as generator.

[0044] Motor **22** can be powered by battery **44** to generate a motive force to move the vehicle and adjust vehicle speed. Motor **22** can also function as a generator to generate electrical power such as, for example, when coasting or braking. Battery **44** may also be used to power other electrical or electronic systems in the vehicle. Motor **22** may be connected to battery **44** via an inverter **42**. Battery **44** can include, for example, one or more batteries, capacitive storage units, or other storage reservoirs suitable for storing electrical energy that can be used to power motor **22**. When battery **44** is implemented using one or more batteries, the batteries can include, for example, nickel metal hydride batteries, lithium-ion batteries, lead acid batteries, nickel cadmium batteries, lithium-ion polymer batteries, and other types of batteries.

[0045] An electronic control unit **50** (described below) may be included and may control the electric drive components of the vehicle as well as other vehicle components. For example, electronic control unit **50** may control inverter **42**, adjust driving current supplied to motor **22**, and adjust the current received from motor **22** during regenerative coasting and breaking. As a more particular example, output torque of the motor **22** can be increased or decreased by electronic control unit **50** through the inverter **42**.

[0046] A torque converter **16** can be included to control the application of power from engine **14** and motor **22** to transmission **18**. Torque converter **16** can include a viscous fluid coupling that transfers rotational power from the motive power source to the driveshaft via the transmission. Torque converter **16** can include a conventional torque converter or a lockup torque converter. In other embodiments, a mechanical clutch can be used in place of torque converter **16**.

[0047] Clutch **15** can be included to engage and disengage engine **14** from the drivetrain of the vehicle. In the illustrated example, a crankshaft **32**, which is an output member of engine **14**, may be selectively coupled to the motor **22** and torque converter **16** via clutch **15**. Clutch **15** can be implemented as, for example, a multiple disc type hydraulic frictional engagement device whose engagement is controlled by an actuator such as a hydraulic actuator. Clutch **15** may be controlled such that its engagement state is complete engagement, slip engagement, and complete disengagement complete disengagement, depending on the pressure applied to the clutch. For example, a torque capacity of clutch **15** may be controlled according to the hydraulic pressure supplied from a hydraulic control circuit (not illustrated). When clutch **15** is engaged, power transmission is provided in the power transmission path between the crankshaft **32** and torque converter **16**. On the other hand, when clutch **15** is disengaged, motive power from engine **14** is not delivered to the torque converter **16**. In a slip engagement state, clutch **15** is engaged, and motive power is provided to torque converter **16** according to a torque capacity (transmission torque) of the clutch **15**.

[0048] As alluded to above, vehicle **100** may include an electronic control unit **50**. Electronic control unit **50** may include circuitry to control various aspects of the vehicle operation. Electronic control unit **50** may include, for example, a microcomputer that includes a one or more processing units (e.g., microprocessors), memory storage (e.g., RAM, ROM, etc.), and I/O devices. The processing units of electronic control unit **50**, execute instructions stored in memory to control one or more electrical systems or subsystems in the vehicle. Electronic control unit **50** can include a plurality of electronic control units such as, for example, an electronic engine control module, a powertrain control module, a transmission control module, a suspension control module, a body control module, and so on. As a further example, electronic control units can be included to control systems and functions such as doors and door locking, lighting, human-machine interfaces, cruise control, telematics, braking systems (e.g., ABS or ESC), battery management systems, and so on. These various control units can be implemented using two or more separate electronic control units, or using a single electronic control unit.

[0049] In the example illustrated in FIG. **1**, electronic control unit **50** receives information from a plurality of sensors included in vehicle **100**. For example, electronic control unit **50** may receive signals that indicate vehicle operating conditions or characteristics, or signals that can be used to derive vehicle operating conditions or characteristics. These may include, but are not limited to accelerator operation amount, A.sub.CC, a revolution speed, N.sub.E, of internal combustion engine **14** (engine RPM), a rotational speed, N.sub.MG, of the motor **22** (motor rotational speed), and vehicle speed, N.sub.V. These may also include torque converter **16** output, N.sub.T (e.g., output amps indicative of motor output), brake operation amount/pressure, B, battery SOC (i.e., the charged amount for battery **44** detected by an SOC sensor). Accordingly, vehicle **100** can include a plurality of sensors **52** that can be used to detect various conditions internal or external to the vehicle and provide sensed conditions to engine control unit **50** (which, again, may be implemented as one or a plurality of individual control circuits). In one embodiment, sensors **52** may be included to detect one or more conditions directly or indirectly such as, for example, fuel efficiency, E.sub.f, motor efficiency, E.sub.MG, hybrid (internal combustion engine **14**+MG **12**) efficiency, acceleration, A.sub.CC, etc.

[0050] In some embodiments, one or more of the sensors **52** may include their own processing capability to compute the results for additional information that can be provided to electronic control unit **50**. In other embodiments, one or more sensors may be data-gathering-only sensors that provide only raw data to electronic control unit **50**. In further embodiments, hybrid sensors may be included that provide a combination of raw data and processed data to electronic control unit **50**. Sensors **52** may provide an analog output or a digital output.

[0051] Sensors **52** may be included to detect not only vehicle conditions but also to detect external conditions as well. Sensors that might be used to detect external conditions can include, for example, sonar, radar, lidar or other vehicle proximity sensors, and cameras or other image sensors. Image sensors can be used to detect, for example, traffic signs indicating a current speed limit, road curvature, obstacles, and so on. Still other sensors may include those that can detect road grade. While some sensors can be used to actively detect passive environmental objects, other sensors can be included and used to detect active objects such as those objects used to implement smart roadways that may actively transmit and/or receive data or other information.

[0052] The example of FIG. **1** is provided for illustration purposes only as one example of vehicle systems with which embodiments of the disclosed technology may be implemented. One of ordinary skill in the art reading this description will understand how the disclosed embodiments can be implemented with this and other vehicle platforms.

[0053] FIG. **2** illustrates an example architecture for augmenting a vehicle's sensor view in accordance with one embodiment of the systems and methods described herein. Referring now to FIG. **2**, in this example, augmented sensor view system **200** includes an augmented sensor view circuit **210**, a plurality of sensors **152** and a plurality of vehicle systems **158**. Sensors **152** and vehicle systems **158** can communicate with augmented sensor view circuit **210** via a wired or wireless communication interface. Although sensors **152** and vehicle systems **158** are depicted as communicating with augmented sensor view circuit **210**, they can also communicate with each other as well as with other vehicle systems. Augmented sensor view circuit **210** can be implemented as an ECU or as part of an ECU such as, for example electronic control unit **50**. In other embodiments, augmented sensor view circuit **210** can be implemented independently of the ECU.

[0054] Augmented sensor view circuit **210** in this example includes a communication circuit **201**, a decision circuit **203** (including a processor **206** and memory **208** in this example) and a power supply **212**. Components of augmented sensor view circuit **210** are illustrated as communicating with each other via a data bus, although other communication in interfaces can be included.

[0055] Processor **206** can include one or more GPUs, CPUs, microprocessors, or any other suitable processing system. Processor **206** may include a single core or multicore processors. The memory **208** may include one or more various forms of memory or data storage (e.g., flash, RAM, etc.) that may be used to store the calibration parameters, images (analysis or historic), point parameters, instructions and variables for processor **206** as well as any other suitable information. Memory **208** can be made up of one or more modules of one or more different types of memory and may be configured to store data and other information as well as operational instructions that may be used by the processor **206** to augmented sensor view circuit **210**.

[0056] Although the example of FIG. **2** is illustrated using processor and memory circuitry, as described below with reference to circuits disclosed herein, decision circuit **203** can be implemented utilizing any form of circuitry including, for example, hardware, software, or a combination thereof. By way of further example, one or more processors, controllers, ASICs, PLAS, PALs, CPLDs, FPGAs, logical components, software routines or other mechanisms might be implemented to make up augmented sensor view circuit **210**.

[0057] Communication circuit **201** includes either or both a wireless transceiver circuit **202** with an associated antenna **205** and a wired I/O interface **204** with an associated hardwired data port (not illustrated). Communication circuit **201** can provide for V2X and/or V2V communications capabilities, allowing local augmented sensor view circuit **210** to communicate with edge devices, such as roadside unit/equipment (RSU/RSE), network cloud servers and cloud-based databases, and/or other vehicles via a network. For example, V2X communication capabilities allows surprise detection circuit **210** to communicate with edge/cloud devices, roadside infrastructure (e.g., such as roadside equipment/roadside unit, which may be a vehicle-to-infrastructure (V2I)-enabled streetlight or cameras, for example), etc. Augmented sensor view circuit **210** may also communicate with other connected vehicles over vehicle-to-vehicle (V2V) communications. For example, current driving conditions/environment data may include data relayed to the ego vehicle from, e.g., an RSE (instead of from an on-board sensor, such as sensors **252**), which can then be relayed to the augmented sensor view server.

[0058] As used herein, “connected vehicle” refers to a vehicle that is actively connected to edge devices, other vehicles, and/or a cloud server via a network through V2X, V2I, and/or V2V communications. An “unconnected vehicle” refers to a vehicle that is not actively connected. That is, for example, an unconnected vehicle may include communication circuitry capable of wireless communication (e.g., V2X, V2I, V2V, etc.), but for whatever reason is not actively connected to other vehicles and/or communication devices. For example, the capabilities may be disabled, unresponsive due to low signal quality, etc. Further, an unconnected vehicle, in some embodiments, may be incapable of such communication, for example, in a case where the vehicle does not have the hardware/software providing such capabilities installed therein.

[0059] As this example illustrates, communications with augmented sensor view circuit **210** can include either or both wired and wireless communications circuits **201**. Wireless transceiver circuit **202** can include a transmitter and a receiver (not shown) to allow wireless communications via any of a number of communication protocols such as, for example, WiFi, Bluetooth, near field communications (NFC), Zigbee, and any of a number of other wireless communication protocols whether standardized, proprietary, open, point-to-point, networked or otherwise. Antenna **205** is coupled to wireless transceiver circuit **202** and is used by wireless transceiver circuit **202** to transmit radio signals wirelessly to wireless equipment with which it is connected and to receive radio signals as well. These RF signals can include information of almost any sort that is sent or received by augmented sensor view circuit **210** to/from other entities such as sensors **152** and vehicle systems **158**.

[0060] Wired I/O interface **204** can include a transmitter and a receiver (not shown) for hardwired communications with other devices. For example, wired I/O interface **204** can provide a hardwired interface to other components, including sensors **152** and vehicle systems **158**. Wired I/O interface **204** can communicate with other devices using Ethernet or any of a number of other wired communication protocols whether standardized, proprietary, open, point-to-point, networked or otherwise.

[0061] Power supply **212** can include one or more of a battery or batteries (such as, e.g., Li-ion, Li-Polymer, NiMH, NiCd, NiZn, and NiH.sub.2, to name a few, whether rechargeable or primary batteries,), a power connector (e.g., to connect to vehicle supplied power, etc.), an energy harvester (e.g., solar cells, piezoelectric system, etc.), or it can include any other suitable power supply.

[0062] Sensors **152** can include, for example, sensors **52** such as those described above with reference to the example of FIG. **1**. Sensors **152** can include additional sensors that may or may not otherwise be included on a standard vehicle **10** with which augmented sensor view system **200** is implemented. In the illustrated example, sensors **152** include vehicle acceleration sensors **212**, vehicle speed sensors **214**, wheelspin sensors **216** (e.g., one for each wheel), a tire pressure monitoring system (TPMS) **220**, accelerometers such as a 3-axis accelerometer **222** to detect roll, pitch and yaw of the vehicle, vehicle clearance sensors **224**, left-right and front-rear slip ratio sensors **226**, and environmental sensors **228** (e.g., to detect salinity or other environmental conditions). Additional sensors **232** can also be included as may be appropriate for a given implementation of augmented sensor view system **200**.

[0063] Vehicle systems **158** can include any of a number of different vehicle components or subsystems used to control or monitor various aspects of the vehicle and its performance. In this example, the vehicle systems **158** include a GPS or other vehicle positioning system **272**; torque splitters **274** that can control distribution of power among the vehicle wheels such as, for example, by controlling front/rear and left/right torque split; engine control circuits **276** to control the operation of engine (e.g. Internal combustion engine **14**); cooling systems **278** to provide cooling for the motors, power electronics, the engine, or other vehicle systems; suspension system **280** such as, for example, an adjustable-height air suspension system, or an adjustable-damping suspension system; and other vehicle systems **282**.

[0064] During operation, augmented sensor view circuit **210** can receive information from various vehicle sensors to determine whether the vehicle requires an augmented sensor view. Communication circuit **201** can be used to transmit and receive information between augmented sensor view circuit **210** and sensors **152**, and augmented sensor view circuit **210** and vehicle systems **158**. Also, sensors **152** may communicate with vehicle systems **158** directly or indirectly (e.g., via communication circuit **201** or otherwise).

[0065] In various embodiments, augmented sensor view circuit **210** can be configured to receive data and other information from sensors **152** that is used in determining whether to augment the vehicle's sensor view. Additionally, augmented sensor view circuit **210** can be used to send an activation signal or other activation information to various vehicle systems **158** as part of augmenting the sensor view. For example, as described in more detail below, augmented sensor view circuit **210** can be used to send signals to one or more of: torque splitters **274** to control front/rear torque split and left/right torque split; motor controllers **276** to, for example, control motor torque, motor speed of the various motors in the system; ICE control circuit **276** to, for example, control power to engine **14** (e.g., to shut down the engine so all power goes to the rear motors, to ensure the engine is running to charge the batteries or allow more power to flow to the motors); cooling system (e.g., **278** to increase cooling system flow for one or more motors and their associated electronics); suspension system **280** (e.g., to increase ground clearance such as by increasing the ride height using the air suspension). The decision regarding what action to take via these various vehicle systems **158** can be made based on the information detected by sensors **152**. Examples of this are described in more detail below.

[0066] FIGS. **3**A-**3**D illustrate an example system for augmenting an ego vehicle's world view. Turning to FIGS. **3**A and **3**B, ego vehicle **300** may comprise sensors **302**, wireless transmitter **304**, requested view processing module **306**, actuators **308**, electronic control units **310**, and wireless receiver **312**. As described above in FIG. **2**, sensors **302** can comprise any sensors to generate a view of the ego vehicle's environment (e.g., sensors **152**, motion sensors, video or audio cameras, or any other available sensor). Sensors **302** can send fused sensor data and corresponding metadata to wireless transmitter **304**. Wireless transmitter **304** can transmit the fused sensor data and metadata to remote operator station **350**, described further below with reference to FIG. **3**C. Wireless transmitter **304** and wireless receiver **312** can correspond to wireless transceiver circuit

202 as described above in FIG. **2**. Remote operator station **350** can transmit a request for the ego vehicle's world view through the available sensor data. This request can be received at requested view processing module **306**, which can determine that sensor data needs to be transmitted to remote operator station **350**. Requested view processing module **306** can forward this request to sensors **302**, which in turn can transmit fused sensor data and metadata to wireless transmitter **304**. Wireless transmitter **304** can forward this data to remote operator station **350** in response to the request for sensor data.

[0067] Once remote operator station **350** has established a sufficient world view, remote operator station **350** can transmit driving commands to be received at wireless receiver **312**. Wireless receiver **312** can forward these commands to electronic control units **310**. Electronic control units **310** can be any vehicle electronic control unit (e.g., electronic control unit **50** of FIG. **1**) able to receive lower driving commands and designate upper driving commands to actuators **308**. Here, lower driving commands can refer to throttle position, brake pedal position, steering angle, engine fuel rate. Upper driving commands can refer to a trajectory prescribed to the teleoperated vehicle. Actuators **308** and electronic control units **310** can execute the driving commands as dictated by the remote operator station to complete the remote driving task.

[0068] Turning to FIGS. **3**A and **3**D, SCV **320** can comprise sensors **322**, wireless transmitter **324**, requested view processing module **326**, and wireless receiver **328**. Sensors **322** can comprise similar sensor data to that of sensors **302**; however, sensors **322** can incorporate additional sensor data deemed to be missing from the ego vehicle's world view. As with sensors **302**, sensors **322** can transmit fused sensor data and metadata to wireless transmitter **324**, which can transmit the sensor data to remote operator station **350**. As described further below with reference to FIGS. **3**C, **4**, and **5**, remote operator station **350** can transmit a request for augmented sensor data to SCV **320**. This request can be received at wireless transmitter **328**, which can forward the request to requested view processing module **326**. Requested view processing module **326** can be similar to requested view processing module **306**; however, the augmentation request can include requests for sensor data outside of that available to ego vehicle **300**. This request can be forwarded to sensors **322** to be transmitted to remote operator station **350**.

[0069] Turning to FIGS. **3**A and **3**C, remote operator station **350** can be any remote operator station including automated facilities and/or live human operators. Remote operator station **350** can be located anywhere to achieve wide access to various ego vehicles and corresponding SCVS. Remote operator station **350** can include simulation and animation module **352**, necessity module **354**, and wireless transmitter **356**. Simulation and animation module **352** can receive sensor data from sensors **302** and sensors **322** to generate the augmented world view. First, simulation and animation module **352** can receive sensor data from sensors **302**. Simulation and animation module **352** can generate a partial worldview from solely the ego vehicle's sensor data. At necessity module **304**, remote operator station **350** can determine that the partial worldview is incomplete due to insufficient sensor data. Necessity module **304** can determine what sensor data is needed to complete the world view. Necessity module **304** can then generate an augmentation request to be forwarded to SCV **320**. Wireless transmitter **356** can forward this request. As described above, once SCV **320** receives the augmentation request, SCV **320** can provide the appropriate sensor data to simulation and animation module **352**. Simulation and animation module **352** can complete the sensor world view with the aggregated sensor data. Once the world view is complete, necessity module **354** can determine that no additional sensor data is necessary. Remote operator station **350** can then transmit driving commands via wireless transmitter **356** back to ego vehicle **300** to complete the remote driving task. Alternatively, if the world view is still incomplete, necessity module **304** can generate additional augmentation requests to be forwarded to additional SCVS as is necessary to complete the world view. Remote operator station **350** can continue evaluating the sensor world view until remote driving is accessible.

[0070] FIGS. **4**A and **4**B illustrate an example driving scenario where an augmented sensor view can be generated and applied. Referring to FIG. **4**A, step **410**, ego vehicle **400** may be driving on a two-lane highway. Ego vehicle **400** may be any connected automated vehicle that can communicate with remote operator station **406**. Illustrated on this highway are SCVS **402** that can communicate with remote operator station **406**, and several unconnected vehicles. At step **410**, ego vehicle **400** may send a “SOS” signal to remote operator station **406**, requesting assistance in remote operation. As mentioned above, this assistance can be requested in various situations, such as when the ego driver is incapacitated, or the driver/vehicle is in other distress. As described above, the remote operator can determine the emergency scenario and the needed sensor data to complete the remote driving task. Remote operator center **406** can communicate the proposed remote driving task to ego vehicle **400**, which can accept the request for remote control. In this case, ego vehicle **400** may be approaching hazard vehicle **404**, which may be braking or stopped in the highway, indicated by red taillights.

[0071] In the example of step **410**, the system may require a short-range radar, long-range radar, and one or more cameras in order to produce a minimum risk maneuver in response to hazard vehicle **404**, such as pulling over to the shoulder, slowing down the vehicle, and/or effectuating a lane change. As described above in FIGS. **3**A-**3**D, the remote operator center can access ego vehicle **400**′s short-range radar and cameras. Remote operator center **406** can determine that the ego vehicle does not have long-range radar accessible to complete the world view. At step **420**, the remote operator can transmit the augmentation request to SCVS **402**. As illustrated at step **420**, one of the SCVS has access to long-range radar. Remote operator center **406** can send a request for the long-range radar data stream. In some embodiments, remote operator center **406** can request an assisting maneuver from the SCVS so that they augment the data until ego vehicle **400** slows down sufficiently not to need the sensor augmentation. An assisting maneuver can include moving the SCV into a good location such that the SCV's sensor data corresponds to the ego vehicle's world view. Once the SCVS accept the request for sensor data and the request for the assisting maneuver, SCVS **402** can communicate the additional sensor data to remote operator center **406** to complete the world view. Concurrently, ego vehicle **400** can begin transmitting its short-range radar data and camera streams.

[0072] Referring to FIG. **4**B, at step **430**, remote operator center **406** can initiate remote control of ego vehicle **400** by sending commands and getting a stream of sensor data from ego vehicle **400**. Optionally, remote operator center **406** can send maneuver messages to SCVS **402** to be positioned in a way that best augments the ego vehicle's sensors. Here, maneuver messages can refer to the general class of wireless messages exchanged among road users, and between road users and infrastructure. Each message can contain the future trajectory (or possible future trajectories) of the transmitting road user. Specific examples of such messages are the Maneuver Coordination Message (MCM) and the Maneuver Sharing Coordination Message (MSCM). Remote operator center **406** can request maneuvers from SCVS **402** based on the automation capabilities of SCVS **402** and the acceptance of the maneuver requests.

[0073] At step **440**, remote operator center **406** can successfully guide ego vehicle **400** onto the shoulder of the road. Remote operator center **406** can send a “remote operation finished notification” to both ego vehicle **400** and SCVS **402**. In some embodiments, remote operator center **406** can determine that it does not require additional assistance from SCVS **402** and release the vehicles from automated driving. SCVS **402** can stop streaming sensor data to the remote operator and can stop allowing for assisting maneuvers.

[0074] The scenario described in FIGS. **4**A and **4**B can be altered depending on the emergency and/or capabilities of the surrounding vehicles and environment. For example, in some embodiments, ego vehicle **400** may not reliably communicate with remote operator center **406** but can only send an SOS signal, alerting that it requires assistance. This could be due to the fact that its data communication module (cellular modem) is malfunctioning. In this case, remote operator center **406** can send maneuver messages (MM) to ego vehicle **400**, i.e., via a roadside unit that can communicate with the ego vehicle via standardized V2V communication. As the suggested maneuver is executed, the roadside unit can continue to send maneuver messages. The ego vehicle can continue to confirm its ability to perform the maneuver via response maneuver messages. When ego vehicle **400** finishes the requested maneuver, it can send a status message saying that the remote operation is finished.

[0075] In some embodiments, remote operator center **406** may not have an available roadside unit, so it cannot relay the maneuver message directly to ego vehicle **400** with the suggested maneuvering. In this case, remote operator center **406** can send a control message to SCVS **402** to be relayed to ego vehicle **400**. For instance, when remote operator center **406** communicates with ego vehicle **400**, vehicle may traditionally accept remote control by means of a message, start streaming sensor information, or may follow commands given by remote operator center **406**. If there is sufficient delay before ego vehicle **400** executes any of the above, remote operator center **406** may engage in "cooperative maneuvering mode." After determining that the only way to control ego vehicle **400** is through controlling SCVS **402**, remote operator center **406** can send a request to control SCVS **402**. If SCVS **402** are automated, these vehicles can cooperate with ego vehicle **400** in the subsequent maneuver. If neither SCV is automated, these vehicles can relay specific commands sent by the remote operator or relay the entire suggested minimal risk maneuver by a complete trajectory. Relaying specific commands instead of the entire trajectory may be beneficial in certain situations. For example, specific commands may allow for finer specification of ego vehicle **400**′s minimal risk maneuver. However, in some situations, the latency in transmitting multiple specific commands separately may be high, as a large amount of data may need to be relayed from remote operator center **406**. Once the maneuver is finished, ego vehicle **400** can send a notification that the remote operation is finished. The message can be sent first to SCVS **402** and then relayed to remote operator center **406**. As described in FIGS. **4**A and **4**B, remote operator center **406** can release SCVS **402** and stop accepting the additional sensory data.

[0076] FIG. **5** illustrates an example method in accordance with the systems described above. At block **502**, the system can determine that the vehicle needs operation assistance to complete a remote driving task. As described above, the ego vehicle may send a "SOS" signal to a remote operator station, requesting assistance in remote operation. This assistance can be requested in various situations, such as when the ego driver is incapacitated, or the driver/vehicle is in other distress. As described above, the remote operator can determine the emergency scenario and the needed sensor data to complete the remote driving task.

[0077] At block **504**, the system can request sensor data from the ego vehicle. As described above, sensor data can include any sensors needed to generate a view of the ego vehicle's environment (e.g., sensors **152**, motion sensors, video or audio cameras, or any other available sensor). Fused sensor data and corresponding metadata can be transmitted to generate the sensor worldview.

[0078] At block **506**, the system can determine the sensor information is insufficient to complete the driving task. As described above, a simulation and animation module can generate a partial worldview from solely the ego vehicle's sensor data. A necessity module can determine that the partial worldview is incomplete due to insufficient sensor data. This necessity module can determine what sensor data is needed to complete the world view. The necessity module can then generate an augmentation request to be forwarded to surrounding connected vehicles.

[0079] At blocks **508** and **510**, the system can connect with surrounding vehicles connected with the ego vehicle (SCVS) and obtain sensor information from the SCVS. As described above, once an SCV receives the augmentation request, the SCV can provide the appropriate sensor data to the simulation and animation module. A simulation and animation module can complete the sensor world view with the aggregated sensor data. Once the world view is complete, the necessity module can determine that no additional sensor data is necessary. Alternatively, if the world view is still incomplete, the necessity module can generate additional augmentation requests to be forwarded to additional SCVS as is necessary to complete the world view. The sensor world view can be continuously evaluated until remote driving is accessible. At block **512**, the system can apply the sensor information of the ego vehicle and the sensor information of the surrounding vehicles to complete the remote driving task.

[0080] As used herein, the terms circuit and component might describe a given unit of functionality that can be performed in accordance with one or more embodiments of the present application. As used herein, a component might be implemented utilizing any form of hardware, software, or a combination thereof. For example, one or more processors, controllers, ASICs, PLAS, PALs, CPLDs, FPGAs, logical components, software routines or other mechanisms might be implemented to make up a component. Various components described herein may be implemented as discrete components or described functions and features can be shared in part or in total among one or more components. In other words, as would be apparent to one of ordinary skill in the art after reading this description, the various features and functionality described herein may be implemented in any given application. They can be implemented in one or more separate or shared components in various combinations and permutations. Although various features or functional elements may be individually described or claimed as separate components, it should be understood that these features/functionalities can be shared among one or more common software and hardware elements. Such a description shall not require or imply that separate hardware or software components are used to implement such features or functionality.

[0081] Where components are implemented in whole or in part using software, these software elements can be implemented to operate with a computing or processing component capable of carrying out the functionality described with respect thereto. One such example computing component is shown in FIG. **5**. Various embodiments are described in terms of this example-computing component **600**. After reading this description, it will become apparent to a person skilled in the relevant art how to implement the application using other computing components or architectures.

[0082] Referring now to FIG. **5**, computing component **600** may represent, for example, computing or processing capabilities found within a self-adjusting display, desktop, laptop, notebook, and tablet computers. They may be found in hand-held computing devices (tablets, PDA's, smart phones, cell phones, palmtops, etc.). They may be found in workstations or other devices with displays, servers, or any other type of special-purpose or general-purpose computing devices as may be desirable or appropriate for a given application or environment. Computing component **600** might also represent computing capabilities embedded within or otherwise available to a given device. For example, a computing component might be found in other electronic devices such as, for example, portable computing devices, and other electronic devices that might include some form of processing capability.

[0083] Computing component **600** might include, for example, one or more processors, controllers, control components, or other processing devices. Processor **604** might be implemented using a general-purpose or special-purpose processing engine such as, for example, a microprocessor, controller, or other control logic. Processor **604** may be connected to a bus **602**. However, any communication medium can be used to facilitate interaction with other components of computing component **600** or to communicate externally.

[0084] Computing component **600** might also include one or more memory components, simply referred to herein as main memory **608**. For example, random access memory (RAM) or other dynamic memory, might be used for storing information and instructions to be executed by processor **604**. Main memory **608** might also be used for storing temporary variables or other intermediate information during execution of instructions to be executed by processor **604**. Computing component **600** might likewise include a read only memory (“ROM”) or other static storage device coupled to bus **602** for storing static information and instructions for processor **604**.

[0085] The computing component **600** might also include one or more various forms of information storage mechanism **610**, which might include, for example, a media drive **612** and a

storage unit interface **620**. The media drive **612** might include a drive or other mechanism to support fixed or removable storage media **614**. For example, a hard disk drive, a solid-state drive, a magnetic tape drive, an optical drive, a compact disc (CD) or digital video disc (DVD) drive (R or RW), or other removable or fixed media drive might be provided. Storage media **614** might include, for example, a hard disk, an integrated circuit assembly, magnetic tape, cartridge, optical disk, a CD or DVD. Storage media **614** may be any other fixed or removable medium that is read by, written to or accessed by media drive **612**. As these examples illustrate, the storage media **614** can include a computer usable storage medium having stored therein computer software or data.
[0086] In alternative embodiments, information storage mechanism **610** might include other similar instrumentalities for allowing computer programs or other instructions or data to be loaded into computing component **600**. Such instrumentalities might include, for example, a fixed or removable storage unit **622** and an interface **620**. Examples of such storage units **622** and interfaces **620** can include a program cartridge and cartridge interface, a removable memory (for example, a flash memory or other removable memory component) and memory slot. Other examples may include a PCMCIA slot and card, and other fixed or removable storage units **622** and interfaces **620** that allow software and data to be transferred from storage unit **622** to computing component **600**.
[0087] Computing component **600** might also include a communications interface **624**. Communications interface **624** might be used to allow software and data to be transferred between computing component **600** and external devices. Examples of communications interface **624** might include a modem or softmodem, a network interface (such as Ethernet, network interface card, IEEE 802.XX or other interface). Other examples include a communications port (such as for example, a USB port, IR port, RS232 port Bluetooth® interface, or other port), or other communications interface. Software/data transferred via communications interface **624** may be carried on signals, which can be electronic, electromagnetic (which includes optical) or other signals capable of being exchanged by a given communications interface **624**. These signals might be provided to communications interface **624** via a channel **628**. Channel **628** might carry signals and might be implemented using a wired or wireless communication medium. Some examples of a channel might include a phone line, a cellular link, an RF link, an optical link, a network interface, a local or wide area network, and other wired or wireless communications channels.
[0088] In this document, the terms “computer program medium” and “computer usable medium” are used to generally refer to transitory or non-transitory media. Such media may be, e.g., memory **608**, storage unit **620**, media **614**, and channel **628**. These and other various forms of computer program media or computer usable media may be involved in carrying one or more sequences of one or more instructions to a processing device for execution. Such instructions embodied on the medium, are generally referred to as “computer program code” or a “computer program product” (which may be grouped in the form of computer programs or other groupings). When executed, such instructions might enable the computing component **600** to perform features or functions of the present application as discussed herein.
[0089] It should be understood that the various features, aspects and functionality described in one or more of the individual embodiments are not limited in their applicability to the particular embodiment with which they are described. Instead, they can be applied, alone or in various combinations, to one or more other embodiments, whether or not such embodiments are described and whether or not such features are presented as being a part of a described embodiment. Thus, the breadth and scope of the present application should not be limited by any of the above-described exemplary embodiments.
[0090] Terms and phrases used in this document, and variations thereof, unless otherwise expressly stated, should be construed as open ended as opposed to limiting. As examples of the foregoing, the term “including” should be read as meaning “including, without limitation” or the like. The term “example” is used to provide exemplary instances of the item in discussion, not an exhaustive or limiting list thereof. The terms “a” or “an” should be read as meaning “at least one,” “one or more”

or the like; and adjectives such as “conventional,” “traditional,” “normal,” “standard,” “known.” Terms of similar meaning should not be construed as limiting the item described to a given time period or to an item available as of a given time. Instead, they should be read to encompass conventional, traditional, normal, or standard technologies that may be available or known now or at any time in the future. Where this document refers to technologies that would be apparent or known to one of ordinary skill in the art, such technologies encompass those apparent or known to the skilled artisan now or at any time in the future.
[0091] The presence of broadening words and phrases such as “one or more,” “at least,” “but not limited to” or other like phrases in some instances shall not be read to mean that the narrower case is intended or required in instances where such broadening phrases may be absent. The use of the term “component” does not imply that the aspects or functionality described or claimed as part of the component are all configured in a common package. Indeed, any or all of the various aspects of a component, whether control logic or other components, can be combined in a single package or separately maintained and can further be distributed in multiple groupings or packages or across multiple locations.
[0092] Additionally, the various embodiments set forth herein are described in terms of exemplary block diagrams, flow charts and other illustrations. As will become apparent to one of ordinary skill in the art after reading this document, the illustrated embodiments and their various alternatives can be implemented without confinement to the illustrated examples. For example, block diagrams and their accompanying description should not be construed as mandating a particular architecture or configuration.

Claims

1. A method for augmenting a sensor view of a vehicle, comprising: determining that the vehicle needs operation assistance to complete a remote driving task; requesting sensor information from the vehicle; based on the sensor information, determining that the sensor information is insufficient to perform the remote driving task; connecting with one or more surrounding vehicles connected to the vehicle; obtaining supplemental sensor information from the one or more surrounding vehicles; and applying the sensor information of the vehicle and the supplemental sensor information to complete the remote driving task.
2. The method of claim 1, further comprising: determining what sensor information is needed to perform the remote driving task; and requesting the needed sensor information from the one or more surrounding vehicles.
3. The method of claim 1, wherein applying the sensor information of the vehicle and the supplemental sensor information comprises generating a world view of an environment of the vehicle.
4. The method of claim 1, wherein the sensor information of the vehicle and the supplemental sensor information is received at a remote operator station configured to simulate an environment of the vehicle.
5. The method of claim 1, further comprising: determining what sensor information is needed to perform the remote driving task; and directing the one or more surrounding vehicles into a position where the supplemental sensor information can be generated.
6. The method of claim 1, wherein the remote driving task comprises a safety operation.
7. The method of claim 1, wherein completing the remote driving task comprises taking remote control of the vehicle from a remote operator station and executing the remote driving task.
8. The method of claim 1, further comprising receiving a request from the vehicle for operation assistance.
9. The method of claim 1, wherein connecting with the one or more surrounding vehicles connected to the vehicle comprises communicating cooperative maneuvers for the one or more

surrounding vehicles to perform to obtain the supplemental sensor information.

10. The method of claim 1, wherein the one or more surrounding vehicles connected to the vehicle relay maneuver-related messages to the vehicle to obtain the sensor information.

11. A system for augmenting a sensor view of a vehicle, comprising: a processor; and a memory coupled to the processor to store instructions, which when executed by the processor, cause the processor to: determine that the vehicle needs operation assistance to complete a remote driving task; request sensor information from the vehicle; based on the sensor information, determine that the sensor information is insufficient to perform the remote driving task; direct one or more surrounding vehicles in a position to generate supplemental sensor information; obtain the supplemental sensor information from the one or more surrounding vehicles; and apply the sensor information of the vehicle and the supplemental sensor information to complete the remote driving task.

12. The system of claim 11, wherein the instructions further cause the processor to: determine what sensor information is needed to perform the remote driving task; and request the needed sensor information from the one or more surrounding vehicles.

13. The system of claim 11, wherein the instructions further cause the processor to generate a world view of an environment of the vehicle.

14. The system of claim 11, wherein the remote driving task comprises a safety operation.

15. The system of claim 11, wherein the instructions further cause the processor to take remote control of the vehicle from a remote operator station and execute the remote driving task.

16. The system of claim 11, wherein the instructions further cause the processor to receive a request from the vehicle for operation assistance.

17. A non-transitory machine-readable medium having instructions stored therein, which when executed by a processor, cause the processor to: determine that a vehicle needs operation assistance to complete a remote driving task; request sensor information from the vehicle; based on the sensor information, determine that the sensor information is insufficient to perform the remote driving task; connect with one or more surrounding vehicles connected to the vehicle; obtain supplemental sensor information from the one or more surrounding vehicles; take remote control of the vehicle; and execute the remote driving task based on the sensor information and the supplemental sensor information.

18. The non-transitory machine-readable medium of claim 15, wherein the instructions further cause the processor to: determine what sensor information is needed to perform the remote driving task; and request the needed sensor information from the one or more surrounding vehicles.

19. The non-transitory machine-readable medium of claim 15, wherein the instructions further cause the processor to generate a world view of an environment of the vehicle.

20. The non-transitory machine-readable medium of claim 15, wherein the instructions further cause the processor to: determine what sensor information is needed to perform the remote driving task; and direct the one or more surrounding vehicles into a position where the supplemental sensor information can be generated.