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United States Patent	12387533
Kind Code	B2
Date of Patent	August 12, 2025
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System and method for vehicle diagnostics

Abstract

An approach for vehicle diagnostics is provided. The approach, for example, involves receiving an indication identifying a need for a diagnostic scan. The approach also involves executing the diagnostic scan by initiating a movement of a movable sensor of a vehicle mirror assembly attached to a vehicle and acquiring diagnostic data during the movement of the movable sensor. The approach further involves analyzing the diagnostic data to generate a diagnostic report and providing the diagnostic report as an output.

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Appl. No.: **17/966517**

Filed: **October 14, 2022**

Prior Publication Data

Document Identifier	Publication Date
US 20240127632 A1	Apr. 18, 2024

Publication Classification

Int. Cl.: **G07C5/08** (20060101); **G06N20/00** (20190101); **G07C5/00** (20060101)

U.S. Cl.:

CPC **G07C5/006** (20130101); **G06N20/00** (20190101); **G07C5/0808** (20130101); **G07C5/0816** (20130101);

Field of Classification Search

CPC: B60W (50/14); B60W (2556/45); B60W (2422/95); B60W (2420/403); B60W (50/0205)

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Primary Examiner: Kujundzic; Dino

Background/Summary

BACKGROUND

(1) Regular vehicle inspection is generally needed to keep vehicles in good operating order. While modern vehicles have increasingly sophisticated self-diagnostic and monitoring systems, such systems traditionally have not extended to inspections to external areas of the vehicle such as but not limited to the vehicle's body, wheels, and/tires. Historically, users have had to manually inspect these areas for wear, damage, and/or other potential problems. Accordingly, service providers and manufacturers face significant technical challenges with respect to extending automated vehicle diagnostics to all areas of a vehicle.

SOME EXAMPLE EMBODIMENTS

(2) Therefore, there is a need for improved vehicle diagnostics, e.g., particularly for external areas such as a vehicle's body, wheels, tires, and/or other areas not served by conventional diagnostic and/or monitoring systems.

(3) According to one embodiment, a method comprises receiving an indication identifying a need for a diagnostic scan. The method also comprises executing the diagnostic scan by initiating a movement of a movable sensor of a vehicle mirror assembly attached to a vehicle and acquiring diagnostic data during the movement of the movable sensor. The method further comprises analyzing the diagnostic data to generate a diagnostic report and providing the report as an output.

(4) According to another embodiment, a system comprises one or more movable sensors of a vehicle. The system also comprises a controller for directing a movement of the one or more movable sensors. The system further comprises at least one processor configured to receive an indication identifying a need for a diagnostic scan, execute the diagnostic scan by initiating the movement of the one or more movable sensors and acquiring diagnostic data during the movement of the one or more movable sensors, and analyze the diagnostic data to generate a diagnostic report.

(5) According to another embodiment, an apparatus comprises at least one processor, and at least one memory including computer program code for one or more computer programs, the at least one memory and the computer program code configured to, with the at least one processor, cause, at least in part, the apparatus to receive an indication identifying a need for a diagnostic scan. The apparatus is also caused to execute the diagnostic scan by initiating a movement of a movable sensor of a vehicle mirror assembly attached to a vehicle and acquiring diagnostic data during the movement of the movable sensor. The apparatus is further caused to analyze the diagnostic data to generate a diagnostic report and provide the report as an output.

(6) According to another embodiment, a computer-readable storage medium carries one or more sequences of one or more instructions which, when executed by one or more processors, cause, at least in part, an apparatus to receive an indication identifying a need for a diagnostic scan. The apparatus is also caused to execute the diagnostic scan by initiating a movement of a movable sensor of a vehicle mirror assembly attached to a vehicle and acquiring diagnostic data during the movement of the movable sensor. The apparatus is further caused to analyze the diagnostic data to generate a diagnostic report and provide the report as an output.

(7) According to another embodiment, an apparatus comprises means for receiving an indication identifying a need for a diagnostic scan. The apparatus also comprises means for executing the diagnostic scan by initiating a movement of a movable sensor of a vehicle mirror assembly

attached to a vehicle and acquiring diagnostic data during the movement of the movable sensor. The apparatus further comprises means for analyzing the diagnostic data to generate a diagnostic report and for providing the report as an output.

(8) In addition, for various example embodiments described herein, the following is applicable: a computer program product may be provided. For example, a computer program product comprising instructions which, when the program is executed by a computer, cause the computer to perform any one or any combination of methods (or processes) disclosed.

(9) In addition, for various example embodiments of the invention, the following is applicable: a method comprising facilitating a processing of and/or processing (1) data and/or (2) information and/or (3) at least one signal, the (1) data and/or (2) information and/or (3) at least one signal based, at least in part, on (or derived at least in part from) any one or any combination of methods (or processes) disclosed in this application as relevant to any embodiment of the invention.

(10) For various example embodiments of the invention, the following is also applicable: a method comprising facilitating access to at least one interface configured to allow access to at least one service, the at least one service configured to perform any one or any combination of network or service provider methods (or processes) disclosed in this application.

(11) For various example embodiments of the invention, the following is also applicable: a method comprising facilitating creating and/or facilitating modifying (1) at least one device user interface element and/or (2) at least one device user interface functionality, the (1) at least one device user interface element and/or (2) at least one device user interface functionality based, at least in part, on data and/or information resulting from one or any combination of methods or processes disclosed in this application as relevant to any embodiment of the invention, and/or at least one signal resulting from one or any combination of methods (or processes) disclosed in this application as relevant to any embodiment of the invention.

(12) For various example embodiments of the invention, the following is also applicable: a method comprising creating and/or modifying (1) at least one device user interface element and/or (2) at least one device user interface functionality, the (1) at least one device user interface element and/or (2) at least one device user interface functionality based at least in part on data and/or information resulting from one or any combination of methods (or processes) disclosed in this application as relevant to any embodiment of the invention, and/or at least one signal resulting from one or any combination of methods (or processes) disclosed in this application as relevant to any embodiment of the invention.

(13) Embodiments described herein refer to sensors associated with a vehicle. It is contemplated that embodiments of the invention also apply to other equipment components associated with a vehicle. Such other equipment components may include communications hardware, such as antennae or arrays, data ports, display ports, vehicle tags, displays, lighting, mirrors, tires, windshield wipers, brakes, windshield washers and the like.

(14) In various example embodiments, the methods (or processes) can be accomplished on the service provider side or on the mobile device side or in any shared way between service provider and mobile device with actions being performed on both sides.

(15) For various example embodiments, the following is applicable: An apparatus comprising means for performing a method of any of the claims.

(16) Still other aspects, features, and advantages of the invention are readily apparent from the following detailed description, simply by illustrating a number of particular embodiments and implementations, including the best mode contemplated for carrying out the invention. The invention is also capable of other and different embodiments, and its several details can be modified in various obvious respects, all without departing from the spirit and scope of the invention. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) The embodiments of the invention are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings:

(2) FIG. **1** is a diagram of system capable vehicle diagnostics based on a movable sensor, according to one example embodiment;

(3) FIG. **2** is a diagram illustrating an example of movable sensor used for vehicle diagnostics to perform as diagnostic scan on a vehicle body, according to one example embodiment;

(4) FIG. **3** is a diagram illustrating an example of controlling an opacity of a vehicle mirror assembly housing based on a field of view of a movable sensor, according to one example embodiment;

(5) FIG. **4** is a flowchart of a process for providing vehicle diagnostics using a movable sensor, according to one example embodiment;

(6) FIG. **5** is a diagram illustrating an example of movable sensor used for vehicle diagnostics to perform as diagnostic scan on vehicle tires and/or wheels, according to one example embodiment;

(7) FIGS. **6**A and **6**B are diagrams illustrating an example of sensor deployment and diagnostic scanning, according to one example embodiment;

(8) FIG. **7** is a diagram illustrating an example of training a machine learning model to predict a vehicle condition from diagnostic data, according to one example embodiment;

(9) FIG. **8** is a diagram illustrating an example vehicle diagnostic report, according to one example embodiment;

(10) FIG. **9** is a flowchart of a process for controlling a vehicle mirror assembly with a movable sensor, according to one example embodiment;

(11) FIG. **10** is a diagram of a geographic database, according to one embodiment;

(12) FIG. **11** is a diagram of hardware that can be used to implement an embodiment;

(13) FIG. **12** is a diagram of a chip set that can be used to implement an embodiment; and

(14) FIG. **13** is a diagram of a mobile terminal (e.g., handset or vehicle or part thereof) that can be used to implement an embodiment.

DESCRIPTION OF SOME EMBODIMENTS

(15) Examples of an apparatus, method, and computer program for providing a vehicle mirror assembly with movable sensor are disclosed. In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the embodiments of the invention. It is apparent, however, to one skilled in the art that the embodiments of the invention may be practiced without these specific details or with an equivalent arrangement. In other instances, well-known structures and devices are shown in block diagram form in order to avoid unnecessarily obscuring the embodiments of the invention.

(16) Reference in this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. The appearance of the phrase “in one embodiment” in various places in the specification are not necessarily all referring to the same embodiment, nor are separate or alternative embodiments mutually exclusive of other embodiments. In addition, the embodiments described herein are provided by example, and as such, “one embodiment” can also be used synonymously as “one example embodiment.” Further, the terms “a” and “an” herein do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced items. Moreover, various features are described which may be exhibited by some embodiments and not by others. Similarly, various requirements are described which may be requirements for some embodiments but not for other embodiments.

(17) FIG. **1** is a diagram of system **100** capable vehicle diagnostics based on a movable sensor **101**,

according to one example embodiment. Proper tire (e.g., tire **103**) and vehicle body (e.g., body **105**) condition ensures safe and efficient operation of a vehicle **107**. Yet, drivers often neglect or ignore the condition of their vehicles **107**, which then leads to operation inefficiencies (e.g., excessive gas consumption due to low tire pressure, reduced aerodynamics from damaged vehicle bodies **105**, etc.) or catastrophic failures (e.g., tire blowouts, corrosion, etc.). This is particularly relevant when non-catastrophic problems or imperceptible changes occur (e.g., slow tire leaks/wear, sub-surface structural body defects, corrosion, etc.). Hence, there is a need for preventing such inefficiencies and failures to safeguard road safety and reduce costly repairs/replacements. This need is particularly important for vehicles **107** that are autonomous, which may not have drivers that pay attention to the vehicle **107**. This is because vehicle tire **103**/body **105** inspections are typically done manually by mechanics, and often as a result of other vehicle troubles. Although there are some conventional sensors that can detect low tire pressure, significant technical challenges remain with respect to providing self-diagnosing technologies that can assess the condition of vehicle tires/body.

(18) To address these technical challenges, the system **100** of FIG. **1** introduces a capability to provide a self-diagnosing approach to detect vehicle tire/body issues using movable sensors **101** incorporated into a vehicle mirror assembly **109**. It is noted that although the various example embodiments described herein are discussed with respect to vehicle tire/body issues, it is contemplated that the various embodiments are also applicable to any other vehicle condition detectable from sensor or diagnostic data. In one embodiment, the approach of the various embodiments described herein capitalize on a vehicle mirror assembly **109** with movable sensors **101** that can be controlled to perform a diagnostic scan on features of the vehicle **107** to identify vehicle condition and/or related potential issues (e.g., issues with the vehicle tires **103** and/or body **105**). The movable sensor **101** provides the capability to see parts of the vehicle **107**, tires **103**, and/or body **105**, as well as the surrounding environment (e.g., by increasing its field of view) that may otherwise not be visible using a fixed sensor at the same location. This enables the system **100** to use fewer movable sensors **101** to fill gaps in sensor coverage left by traditional fixed sensors. In other words, to provide the same coverage or field of view, more traditional fixed sensors would have to be used or the available fixed sensors would have gaps in their diagnostic scans. Such gaps can present high risks, particularly for autonomous driving applications. Although more cameras/sensors can be used to fill the gaps, the use of additional sensors could have an impact on cost, space, and/or resources of the vehicle **107**.

(19) FIG. **1** illustrates in part the vehicle mirror assembly **109** from a front view **111** and a top view **113** with the top view **113** having a first variation **115***a* and a second variation **115***b* (the variations **115***a* and **115***b* are described in more detail further below). As shown in FIG. **1**, in one embodiment, the vehicle mirror assembly **109** may include: a housing **117** attachable to a vehicle **107** (e.g., as a driver-side or passenger-side mirror); a reflective surface **119** coupled to/covering an opening in the housing **117**; a movable sensor **101** contained inside a space **121** formed by the housing **117** and reflective surface **119** (e.g., variation **115***a*) or attached externally to the housing **117** with an optional cover **123** (e.g., variation **115***b*); an actuator assembly **125** configured to modify an orientation/position of the movable sensor **101** in response to control signals (e.g., sent from a controller **127**); an optional telescoping arm **129** (or any equivalent means of extension) to which the movable sensor **101** is fixed and is configured to extend the movable sensor **101** outside of the vehicle mirror assembly **109** through a portal **131** (e.g., can be automatically opened or closed by the controller **127** as needed) in the housing **117** to provide a more versatile field of view than available from fixed mounted movable sensor **101**; and a transparency control element **133** configured to selectively control the opacity/transparency of the housing **117** and/or reflective surface **119** by application of voltage, heat, light, etc. depending on the material of the housing **117** and/or reflective surface **119** to enable signals emitted or measured by the movable sensor **101** to pass through.

(20) In one embodiment, a diagnostic platform **135** (e.g., a local or cloud component) alone or in combination with the controller **127** can instruct the movable sensor **101** of the vehicle mirror assembly **109** to perform a diagnostic scan of the vehicle **107**. During the diagnostic scan, the movable sensor **101** is signaled to perform a controlled sweep of (or otherwise signaled to direct its field of view to) an area of the vehicle **107** to be scanned (e.g., tires **103** and/or body **105**). During the diagnostic scan, the diagnostic platform **135** collects the sensor data captured by the movable sensor **101** as diagnostic data **137**. This diagnostic data **137** is analyzed (e.g., using predictive and/or feature detection machine learning models or algorithms) to generate a diagnostic report **139** about the condition of the area of interest on the vehicle **107**.
(21) FIG. **2** is a diagram illustrating an example of a movable sensor **101** used for vehicle diagnostics, according to one example embodiment. As shown, the vehicle **107** is equipped with a vehicle mirror assembly **109** including a movable sensor **101**. The diagnostic platform **135** initiates a diagnostic scan by instructing the controller **127** to actuate the movable sensor **101** to perform a sweep **201** that directs the field of view **203** over the vehicle body **105** (e.g., to scan the vehicle body **105** for damage). In this example, the movable sensor **101** is a camera configured to capture image data. Sensor data (e.g., image data) from the movable sensor **101** is collected as the sweep **119** is performed so that images of the vehicle body **105** is captured. The image data can then be analyzed, e.g., using computer vision and machine learning based feature detection, to identify damage to the vehicle body **105** (e.g., by analyzing the image data to determine the presence of scratches, dents, rust, and/or any other signs of damage).
(22) The vehicle diagnostic approach described herein based on movable sensors **101** provides a number of advantages, including but not limited to the ability to avoid inefficient, costly, or catastrophic issues stemming from vehicle tire/body problems. In one embodiment, the system **100** provides a self-diagnosing approach that can inform/alert users of issues with a vehicle **107**'s tires **103** and/or body **105** (or any other vehicle condition) detectable from the diagnostic data **137** collected from movable sensors **101** during a diagnostic scan enabled by the vehicle mirror assembly **109**.
(23) There are many use cases for the various embodiments described herein including but not limited to: Safety/wear checks for manual, semi-autonomous, and/or autonomous vehicles **107**; Safety/wear checks for vehicle providers (e.g., rental companies, vehicle dealers, fleet owners, etc.); and Remote monitoring of vehicles **107** in public places (e.g., places associated with high risk of damage).
(24) The various embodiments described herein also offer advantages including but not limited to: Able to detect imminent/catastrophic events and quantify their risks; and Able to detect imperceptible tire/body changes (which would inform drivers for needed service or allow companies to estimate/predict tire usage/fuel usage).
(25) In one embodiment, the unique capabilities of the vehicle mirror assembly **109** enable the various embodiments of vehicle diagnostics described herein. For example, the reflective surface **119** can be partially or semi-transparent, or a one-way mirror such that light or other target signal wavelengths can pass through the reflective surface **119** (e.g., from and/or to the movable sensor **101** mounted in the space **121** of the vehicle mirror assembly **109**). The reflective surface **119** may include a reflective coating (e.g. a metallic coating). In other embodiments, the reflective surface **119** may include a layer/coating whose opacity/transparency can be controlled by voltage (e.g., electrochromic), heat (e.g., thermochromic), or light (e.g., photochromic). By way of example, the layer/coating can include but is not limited to: (1) electrochromic devices such as electrochromic glass that changes its opacity in response to voltage; (2) polymer-dispersed liquid-crystal devices in which liquid crystals are randomly dispersed into a polymer such that the polymer appears translucent or more opaque and then appears transparent when a voltage is applied to align the liquid crystals in the polymer; (3) suspended-particle devices in which nano-particles are suspended in a liquid between or otherwise attached to glass or plastic such that when no voltage is applied the

nano-particles are arranged randomly to block light and when voltage is applied the nano-particles align to let light pass to achieve transparency; (4) micro-blinds which are composed of rolled thin metal blinds (e.g., transparent when rolled) that unroll in response to voltage to become more opaque; and (5) thermoplastics made of materials whose refractive index (and thus transparency/opacity) changes based on voltage, heat, or light. It is noted that examples above are provided by way of illustration and not as limitations. It is contemplated that any material, film, or coating whose transparency to signals of the movable sensor **101** can be used according to the various embodiments described herein.

(26) In one embodiment, the housing **117** of the vehicle mirror assembly **109** in its entirety (or a portion of it) can be completely opaque. In other embodiments, the housing **117** can include or be made of a material whose opacity/transparency can be controlled by voltage, heat, or light (e.g., similar to materials discussed with respect to embodiments of the reflective surface **119** described above). The material, for instance, may depend on the movable sensor **101** and the type of signals emitted and/or measured. For example, if the movable sensor **101** is a camera, then the material would be transparent to visible light. If the movable sensor **101** is a LiDAR sensor, then the material would be transparent to the wavelength of the laser light used by the sensor, and so on. In one embodiment, the selective opacity/transparency of the housing **117** allows for the movable sensor **101** to have a forward-looking view through the housing **117** in addition to the rear-facing view through the reflective surface **119**, thereby advantageously extending the viewing range of the movable sensor **101**. That is, the movable sensor **101** may be rotated in plane up through a full range of motion depending on sensor configuration (e.g., 180 degrees, 360 degrees, etc.) capturing forward, side, rear views, and/or any other views in between. Also, in some embodiments, the selective opacity/transparency of the housing **117** and one-way mirror of the reflective surface **119** keeps the movable sensor **101** hidden from view (e.g., resulting in less chances of theft), but allowing the movable sensor **101** to operate when in use.

(27) In one embodiment, the housing **117** can include telemetry hardware for communicating with the controller **127**. The telemetry hardware, for instance, can then relay signals from the controller **127** (e.g., signals comprising or otherwise including instructions for initiating a diagnostic scan) to other components of the vehicle mirror assembly **109** including but not limited to the movable sensor **101** (e.g., to initiate capturing sensor data during a diagnostic scan), actuator assembly **125** (e.g., to modify the orientation and/or position of the movable sensor **101**), housing **117** (e.g., to change opacity/transparency), and reflective surface **119** (e.g., to change opacity/transparency). In one embodiment, the housing **117** can include other openings (e.g., for electrical wiring/harness, mounting points to the vehicle **107**, etc.).

(28) In one embodiment, the movable sensor **101** can be any type of sensor that can be equipped or configured on or to the vehicle **107**. Examples of the movable sensor **101** include but are not limited to a camera, radar sensor, proximity sensor, optical sensor, etc. In one embodiment, the movable sensor **101** can be displaced from or mechanically coupled to the reflective surface **119**. In either case, the movable sensor **101** can be configured to either move with the movement/orientation of the reflective surface **119** or move independently from the a movement/orientation of the reflective surface **119**.

(29) The movable sensor **101** can also be mounted within the space **121** created by the housing and the reflective surface **119** (e.g., referred to as internal to the housing **117**) as illustrated in variation **115***a* of the vehicle mirror assembly **109**. In other embodiments, the movable sensor **101** can be mounted external to the housing **117** as illustrated in variation **115***b* of the vehicle mirror assembly **109**. Although the movable sensor **101** is illustrated as being mounted to the bottom the housing **117**, it is contemplated that the movable sensor **101** can be externally mounted to the housing **117** at any location including but not limited to the top, side, back, etc. If mounted externally, the movable sensor **101** can be further protected by an optional cover **123**. In one embodiment, the optional cover **123** can be made of a material that is selectively transparent or opaque to the signals

emitted or measured by the movable sensor **101**. Examples of the material are discussed above with respect to the material of the housing **117** and reflective surface **119**.
(30) In one embodiment, the actuator assembly **125** can include but is not limited to various gears (e.g. linear, helical, worm, bevel, spur, herringbone, hypoid, etc.) that can operate to move or orient the movable sensor **101**. More specifically, the actuator assembly **125** can be mechanically coupled to the movable sensor **101** and configured to move/orient the movable sensor **101** in various directions or orientations. For example, the movement or orientation of the movable sensor **101** can result in the change of a first field of view **141***a* (e.g., sensor coverage area) to a second field of view **141***b* of the movable sensor **101**. This change from the first field of view **141***a* to the second field of view **141***b* advantageously enables the movable sensor **101** to provide a greater sensor coverage area compared to an equivalent fixed or non-movable sensor. Although the movable sensor **101** is shown to rotate in a single plane, it may also be configured to orient out of plane along any axis of movement.
(31) In one embodiment, the actuator assembly **125** can also control the movement and/or orientation of the reflective surface **119**. It is noted that although the actuator assembly **125** is discussed with respect to providing movement or orientation of the movable sensor **101** using gears, it is contemplated that any equivalent assembly configured to move or orient the movable sensor **101** can be used whether or not the assembly includes gears for performing the movement or orientation. Examples of non-gear assemblies include but are not limited to pistons, belts, push rods, etc.
(32) In one embodiment, the controller **127** can control the actuator assembly **125** to result in moving or orienting the movable sensor **101** of the vehicle mirror assembly **109**. For example, the controller can generate, transmit, and/or receive various signals/data (e.g., control signals for sensor movement, images, and/or other data) related to operating the vehicle mirror assembly **109** and/or any of its components (e.g., actuator assembly **125**, movable sensor **101**, housing **117**, and/or reflective surface **119**) according to the various embodiments described herein. The controller **127**, for instance, can control housing opacity/transparency, and include the structures, hardware, circuitry, software, firmware, etc. to perform its functions.
(33) In one embodiment, the controller **127** can be incorporated into the housing **117** or external to the housing (e.g., within vehicle **107** and communicatively coupled to one or more vehicle mirror assemblies **109** equipped on the vehicle **107** via a wired or wireless connection **143**). In cases where the vehicle **107** includes multiple vehicle mirror assemblies **109** (e.g., respective vehicle mirror assemblies **109** on the driver's and passenger's sides of the vehicles **107**), each vehicle mirror assembly **109** can be associated with its own controller **127** or one controller **127** can be configured to operate the multiple vehicle mirror assemblies **109**. In some embodiments, the controller **127** can communicate with various hardware equipped in or otherwise associated with the vehicle **107** or a driver/passenger of the vehicle **107** (e.g. navigation system, heads-up display, mobile device, etc.). In addition, the controller **127** can communicate over a communication network **145** to a diagnostic platform **135**, mapping platform **147** with a geographic database **149** (e.g., storing map information, route information, etc.). In addition or alternatively, the controller **127** can have a local instance of all or a portion of the geographic database **149**. In one embodiment, the controller **127** and/or diagnostic platform **135** also have connectivity over the communication network **145** to a services platform **151** including one or more services **153** as well as connectivity to a content provider **155**. The services platform **151**, services **153**, and/or content provider **155** can provide services, applications, and/or data that the controller **127** can use to generate control signals to the vehicle mirror assembly **109** (e.g., to perform a diagnostic scan according to the various embodiments described herein).
(34) As described above, in various embodiments, the opacity/transparency of the reflective surface **119** and/or housing **117** may be selectively controlled for all or a portion of the reflective surface **119** and/or housing **117**. In addition, the controller **127** can change the orientation/position of the

movable sensor **101** and/or reflective surface **119** based on diagnostic scan to be performed, vehicle location, target object location, vehicle part (or vehicle area/section) under scan, navigation, road information (e.g., straight, curve, hill, etc.), map information (e.g. POIs), etc. In one embodiment, the opacity/transparency and/or orientation/position can be controlled based on where the field of view of the movable sensor **101** should be directed.
(35) In some embodiments, a vehicle mirror assembly **109** can include multiple movable sensors **101**. For example, in addition to a first movable sensor **101**, the vehicle mirror assembly **109** further comprises at least one other movable sensor **101** coupled to the housing **117** or contained in the space **121** formed by the housing **117** and the reflective surface **119**. Then, the opacity or transparency of respective portions of the housing **117** and/or reflective surface **119** can be selectively controlled based on the orientation, position, and/or field of view of the respective sensors **101**. For example, in one embodiment, the vehicle mirror assembly **109** can include two cameras (i.e., two movable sensors **101**) to provide for stereoscopic vision by working in tandem to generate a three-dimensional image (e.g., for vehicle diagnostic scans). In this embodiment, different areas of the housing **117** and/or reflective surface **119** can be made transparent so that each camera can have an unobstructed field of view to the outside of the vehicle mirror assembly **109**. It is noted that the dual stereoscopic camera use case described above is provided by way of illustration and not as a limitation. It is contemplated that the vehicle mirror assembly **109** can have any number or types of movable sensors **101** that work in tandem or independently of each other to capture sensor data and provide situational awareness.
(36) FIG. **3** is a diagram illustrating an example of controlling an opacity of a vehicle mirror assembly housing **117** based on a field of view of a movable sensor **101**, according to one example embodiment. As shown, the vehicle mirror assembly **109** includes the movable sensor **101** configured to move or change orientations via the actuator assembly **125**. In an initial state, the movable sensor **101** is oriented to the face the rear of the vehicle mirror assembly **109** such that the initial field of view **301***a* is forward through the housing **117**. The housing **117** is made of a material for which selectable portions of the housing **117** can be made transparent to the movable sensor **101** (e.g., via the transparency control element **133**). For example, if the movable sensor **101** is a camera, the housing **117** is opaque to visible light and can then be made transparent to visible light. In other words, the material of the housing **117** is initially opaque to the movable sensor **101** and can be activated (e.g., via an applied voltage, heat, or light initiated by the transparency control element **133**) to become transparent to the movable sensor **101**.
(37) If the movable sensor **101** is forward facing (as in the case of field of view **301***a* that is also represented in scenario **303**), opacity of the housing **117** can be selectively controlled. That is, a portion **305** of the housing **117** can be made transparent by locally applying heat, light, or voltage (e.g. using grid-like electrical structures/leads embedded or attached to the housing interior or body). In one embodiment, as shown under scenario **303**, the portion **305** can be determined (e.g., by the controller **127**) based on a point **307** projected from the a position of the movable sensor **101** through the center of the field of view **301***a* to the surface of the housing **117**. The grid or portion **305** corresponding to the point **307** can be selected to make transparent so that the movable sensor **101** can “see” through that portion **305**. Such selective transparency/opacity advantageously reduces glare, optical interference, etc.
(38) Under scenario **309**, the movable sensor **101** is reoriented to view a new field of view **301***b* that is to the left and top of the original field of view **301***a*. In this case, the controller **127** can determine a new portion **311** of the housing **117** to make transparent. This new portion **311**, for instance, is determined by projecting a point **313** from the position of the movable sensor **101** through the center of the field of view **301***b* to the surface of the housing **117**. Heat, light, or voltage is applied to the new portion **311** to make it transparent. In addition, heat, light, or voltage is removed from the previous portion **305** to make it opaque. In this way, as the field of view of the movable sensor **101** moves around through the housing **117**, selective portions of the housing is

made transparent to provide a clear line of sight for the movable sensor **101**. The size of portion **305** or portion **311** may vary, depending upon the movable sensor **101** capabilities, as well as the distance between the movable sensor **101** and the housing **117**.

(39) Although not shown in the example of FIG. **3**, if the movable sensor **101** faces forward (e.g., looking through the reflective surface **119** of the vehicle mirror assembly **109**), light, heat, or voltage can be applied to a material or portion thereof coating or included in the reflective surface **119** to make the reflective surface **119** or portion thereof transparent to the movable sensor **101**. The opacity of the optional cover **123** may also be controlled in the same way.

(40) In one embodiment, the vehicle mirror assembly **109** in combination with the system **100** can be used to improve the safety of vehicle operation via the use of movable sensors **101**. As discussed in more detail in the various embodiments below, various aspects of the vehicle mirror assembly **109** and system **100** can be used to control the movement or orientation of the movable sensor **101** of the vehicle mirror assembly **109** to perform a vehicle diagnostic scan and/or based on vehicle location on a road, position of an object of interest around the vehicle, and/or other similar factors.

(41) FIG. **4** is a flowchart of a process **400** for providing vehicle diagnostics using a movable sensor, according to one example embodiment. In various embodiments, the diagnostic platform **135** and/or controller **127** alone or in combination with the mapping platform **147**, geographic database **149**, services platform **151**, services **153**, and/or content provider **155** may perform one or more portions of the process **300** and may be implemented in, for instance, a chip set including a processor and a memory as shown in FIG. **12** and/or other circuitry for performing one or more steps of the process **400**. As such, the diagnostic platform **103** and/or controller **127** can provide means for accomplishing various parts of the process **400**, as well as means for accomplishing embodiments of other processes described herein in conjunction with other components of the system **100**. Although the process **400** is illustrated and described as a sequence of steps, its contemplated that various embodiments of the process **400** may be performed in any order or combination and need not include all of the illustrated steps.

(42) In one embodiment, the process **400** introduces a system and method for self-diagnosing a vehicle as well as apparatuses, computer readable storage media, computer program products, etc. for providing the same. For example, in summary, one example embodiment can include but is not limited to the following: receiving an indication identifying a need for a diagnostic scan; executing diagnostic scan by controlling a movable sensor and acquiring diagnostic data; analyzing the diagnostic data; and generating a report. As another example, a system can include various elements for vehicle diagnostics including but not limited to: one or more movable sensors **101**, a controller **127** for directing the movement of the movable sensors; and at least one processor (e.g., associated with a diagnostic platform **135** or equivalent computing device) configured to receive the indication, direct the controller **127** to execute the diagnostic scan, process the diagnostic data acquired, and generate a report. Additional details of the process **400** are provided below.

(43) In step **401**, the diagnostic platform **135** receives an indication identifying a need for a diagnostic scan. In one embodiment, the indication can include any signal, process, or means to indicate that a diagnostic scan of one or more portions of the vehicle **107** (e.g., tires **103**, body **105**, etc.) is to be performed. As noted above, vehicle tires **103** and body **105** are provided by way of illustration and not as limitations. It is contemplated that the diagnostic scan can be performed to determine any condition of the vehicle **107** that can be detected or otherwise identified from the sensor data collected from the movable sensor **101** during a diagnostic scan (e.g., diagnostic data **137**). In addition, the area of interest of the vehicle **107** to which the diagnostic scan is directed can include any external (e.g., tires **103**, body **105**, etc.) or internal (e.g., vehicle interior, occupants of the vehicle, cargo, etc.) feature or part of the vehicle **107** that is visible or has line-of-sight from the movable sensors **101**.

(44) In one embodiment, the indication identifying a need for a diagnostic scan or that can trigger a diagnostic scan can include to a manual or automated signal transmitted to or otherwise detected by

the diagnostic platform **135**. For example, a manual indication can include but is not limited to when user initiates a diagnostic scan (e.g. via input into a navigation system, or application on a remote/smart device). The user, for instance, can include a driver, owner, occupant, and/or any other authorized person (e.g., fleet owner/manager in case of a rental car, vehicle inspector, mechanic, etc.).

(45) In addition or alternatively, the diagnostic platform **135**, controller **127**, and/or other vehicle **107** or system **100** component can automatically detect any configured triggering condition to identify a need for a diagnostic scan. Examples of these triggering conditions include but are not limited to one or more of the following: Fuel consumption (in)efficiency detection (e.g., fuel consumption above a threshold set by historical/current/reference/etc. conditions)—for example, if fuel consumption differs by more than a threshold value over historical fuel consumption (e.g., fuel consumption determined for a previous time period, under similar environmental conditions, etc.), current conditions (e.g., fuel consumption that should be achieved given current environmental conditions such as but not limited to weather, traffic, road type, speed, etc.), and/or reference conditions (e.g., fuel consumption estimated for the vehicle **107** by a manufacturer or other authority). Vehicle alarm activation—for example, if the vehicle **107**'s alarm system is activated, the alarm system can automatically signal diagnostic platform **135** to initiate a diagnostic scan around the perimeter of the vehicle. The diagnostic can attempt to identify the source of the alarm and/or monitor for any potential damage to the vehicle **107** from the source. In one embodiment, if the alarm is triggered based on proximity or directional sensors of the alarm system, the diagnostic scan can be directed to the part of the vehicle **107** indicated by the proximity or directional sensors. Impact/vibration detection (e.g. break-in, scratches, dents)—Similar to the car alarm activation trigger described above, the vehicle **107** may include sensors to detect when the vehicle has suffered an impact from an object (e.g., small objects such as rocks, debris, etc. as well as impacts from other vehicles, pedestrians, etc.). Example sensors can include but is not limited to accelerometers or equivalent. The same sensors can also detect when the vehicle **107** is undergoing vibration (e.g., from someone touching or bumping into the vehicle). Once an impact or vibration is detected, the vehicle system (e.g., controller **127** or equivalent) can transmit the detection to the diagnostic platform **135** to initiate a diagnostic scan. Location of the vehicle **107**—in one embodiment, a diagnostic scan can be initiated based on determining that the vehicle **107** is at a location or within a threshold proximity of the location. For example, a location sensor (e.g., GPS or equivalent) can be used to determine a location of the vehicle **107**. Any other form of localization can also be used (e.g., visual-based localization using imagery captured at a location) can be used to determine location. The vehicle **107**'s location can then be compared to a map data (e.g., stored in the geographic database **149** via the mapping platform **147**) to determine whether the vehicle **107** is at or within proximity of a location that has been configured to trigger a diagnostic scan. For instance, scan may be initiated in certain parking locations, during light traffic, etc. In another use case, the diagnostic scan with the vehicle **107** has reach a return location of a rental car, a home location of a delivery truck, a user's home garage, during light traffic, at locations with high rates of vehicle damage (e.g., from road debris, rocks, etc.), and/or the like. Nearby objects or environment—similar to the location of the vehicle **107** described above, diagnostic scans can be triggered with the vehicle **107** is within a proximity threshold of certain objects and/or environments. For example, if the vehicle **107** is within proximity of other vehicles (e.g., in a narrow parking space), a diagnostic scan can be triggered to determine potential damage (e.g., from door dings). Other examples include being near a curb when a diagnostic scan can be used to identify potential curb rash to the wheels and/or tires. In yet other examples, proximity to certain buildings, points of interest (POIs), roads, etc. can also trigger diagnostic scans. In one embodiment, the objects or environments that trigger a diagnostic scan can be determined from map data (e.g., the geographic database **149**). Navigation route entry—in one embodiment, the diagnostic platform **135** can trigger a diagnostic scan one a navigation route is entered, requested,

started, or completed in a navigation system of a vehicle **107**. For example, the navigation system of the vehicle **107** or equivalent system (e.g., navigation application executing on a mobile device of an occupant of the vehicle **107**) can transmit a request to initiate a diagnostic scan based on the status or progress of a navigation route (e.g., perform a safety check prior to departure, or upon arrival). Contextual parameter (e.g., time of day/weather)—in one embodiment, the diagnostic platform **135** can determine whether one or more contextual parameters meet criteria for initiating a diagnostic scan (e.g., inspection at specific time of day, during specific conditions, etc.). For example, after a hailstorm is detected, the diagnostic platform **135** can initiate a diagnostic scan to detect potential damage to body **105** of the vehicle **107**, or during or prior to a rainstorm, the diagnostic platform **135** can initiate a diagnostic scan to determine the condition of the vehicle **107**'s tires **103**. Periodically or based on a schedule (e.g. weekly, monthly, yearly)—in another embodiment, the diagnostic platform **105** can be configured to perform a diagnostic scan according to a preconfigured schedule or time interval.

(46) It is noted that the examples of indications for identifying a need for a diagnostic scan (e.g., conditions for triggering a diagnostic scan using a movable sensor **101**) described in the various embodiments above are provided by way of illustration and not as limitations. It is contemplated that any other indication or triggering condition (manual or automated) may be used according to the various embodiments described herein.

(47) In step **403**, after receiving an indication identifying a need for a diagnostic scan, the diagnostic platform **135** executes the diagnostic scan by interacting with the controller **127** to initiate a movement of a movable sensor **101** of a vehicle mirror assembly **109** attached to a vehicle **107** and acquiring diagnostic data **137** during the movement of the movable sensor **101**. In other words, in one embodiment, the diagnostic platform **135** initiates or executes a diagnostic scan by directing the movable sensor **101** to sweep in a controlled pattern. Sweeping, for instance, refers to specifying an area of the vehicle **107** and/or its environment over which the movable sensor **101** is moved so that its field of view is able to capture diagnostic data **137** (e.g., sensor data) of the area. In one embodiment, instead of performing a sweep, the movable sensor **101** can be moved so that its field of view is directed to a specific area of interest on or in the vehicle **107**. The type of sensor data to be collected during the diagnostic scan depends on the type of sensor(s) used in the movable sensor **101**. For example, the sensor data or diagnostic data **137** comprises image data which the movable sensor **101** is a camera. Similarly, the diagnostic data **137** can comprise other data when using other sensor types (e.g., using optical, sound, infrared, LiDAR sensors/detectors, etc.) as the movable sensor **101**.

(48) Examples of movement of the movable sensor **101** in a controlled pattern is illustrated with respect to FIG. **2** above as well as with respect to FIG. **5** below. As previously described, FIG. **2** illustrates an example sweep pattern for capturing diagnostic data **137** for the vehicle body **105** as well as its surrounding environment. Although, the example of FIG. **2** is illustrated as performing a diagnostic scan of the vehicle body **105** on the driver's side, it is contemplated that a diagnostic scan can also be performed on the right side of the vehicle (e.g., as an alternative to, concurrently with, or sequentially to the illustrated diagnostic scan of the left or driver's side).

(49) FIG. **5** is a diagram illustrating an example of movable sensor **101** used for vehicle diagnostics to perform as diagnostic scan on vehicle tires **103** and/or wheels, according to one example embodiment. As shown, the vehicle **107** is equipped with a vehicle mirror assembly **109** including a movable sensor **101**. The diagnostic platform **135** initiates a diagnostic scan by instructing the controller **127** to actuate the movable sensor **101** to bring the vehicle tire **103** into its field of view **501** (e.g., to scan the vehicle tire **103** and/or wheel for damage or wear). In this example, the movable sensor **101** is a camera configured to capture image data. Sensor data (e.g., image data) from the movable sensor **101** that depict the vehicle tire **103** and wheel is captured. The image data can then be analyzed, e.g., using computer vision and machine learning based feature detection, to identify damage or wear to the vehicle tire **103** and/or wheel as well as surrounding areas (e.g., by

analyzing the image data to determine the wear patterns, damage, etc.).
(50) In one embodiment, the movement of the movable sensor **101** can be performed as described in the various embodiment of FIGS. **1-3** above as well as FIG. **9** below. As described in some of those embodiments, the movement of the movable sensor **101** can also be accompanied by making the housing **117** and/or reflective surface **119** of the vehicle mirror assembly **109** selectively transparent so that the signals measured or emitted by the movable sensor **101** passes through the vehicle mirror assembly **109**.
(51) In one embodiment, the movement of the movable sensor **101** during the diagnostic can be accompanied by or otherwise coordinated with other actions of the vehicle **107** and/or vehicle mirror assembly **109**. For example, the diagnostic platform **135** can interact with the controller **127** to deploy the movable sensor **101** away from the vehicle **107** (e.g., to provide a better field of view of the vehicle **107**, vehicle body **105**, vehicle tires **103**, and/or its surrounding. This optional sensor deployment may consider environmental, proximity, traffic, map, and/or other factors to determine whether the sensor deployment is appropriate or needed. For example, if the vehicle **107** is located close to another vehicle or object (e.g., parked in a narrow parking spot next to another vehicle), the movable sensor **101** may not be deployed away from the vehicle **107** to reduce the risk of hitting the other vehicle with the deployed sensor. In another example, map data may indicate that the vehicle **107** is parked next to a bicycle lane and deploying the movable sensor **101** away from the vehicle **107** may encroach into the bicycle lane. As a result, the movable sensor **101** would not be deployed.
(52) FIG. **6**A is a diagram illustrating an example of deploying a movable sensor **101** away from the vehicle **107**, according to one example embodiment. As shown, in configuration **601**, the movable sensor **101** (e.g., capable of deploying away from the vehicle **107**) of the vehicle mirror assembly **109** is in its retracted or nondeployed state (e.g., movable sensor **101** is inside the space **121** of the vehicle mirror assembly **109**). For sensor deployment, configuration **601** is transformed to configuration **603**. In configuration **603**, the movable sensor **101** is in a deployed state in which the movable sensor **101** is extended outside of the vehicle mirror assembly **109** on telescoping arm **129** (e.g., through a portal **131**—not shown in FIG. **6**A) away from the vehicle **107**. In one embodiment, the distance that the movable sensor **101** is extended away from the vehicle **107** is selectable up to the maximum extended length of the telescoping arm **129**.
(53) FIG. **6**B is a diagram illustrating an example of performing a diagnostic scan after deployment of the movable sensor **110** away from the vehicle **107**, according to one example embodiment. The example of FIG. **6**B continues the example of FIG. **6**A and illustrates the movable sensor **101** in a deployed state in which it is extended at the end of the telescoping arm **129** from the vehicle mirror assembly **109**. This extended position enables the movable sensor **101** to perform a complete sweep **621** of the movable sensor **101**'s field of view **623** (e.g., imaging or any other form of diagnostic data gathering) of the vehicle **107** and/or its surrounding environment. Although the example is illustrated with the movable sensor **101** being deployed horizontally away from the vehicle **107**, it is contemplated that the movable sensor **101** may be deployed horizontally, vertically, or at an angle depending on the desired scan.
(54) In one embodiment, the diagnostic scan can include changing a feature or mode of operation of the movable sensor **101** during the scan. For example, changing the feature or mode of operation can include but is not limited to adjusting focus/zoom, opening a portal **131** in the mirror housing **117**, changing the transparency/opacity of the housing **117** and/or reflective surface **119** of the vehicle mirror assembly **109**, changing the signal frequency emitted or measured by the movable sensor **101** (e.g., hyperspectral scan), etc.
(55) In yet another embodiment, the diagnostic scan can be accompanied by or otherwise include activating/operating functions on the vehicle or providing directions/haptic feedback for operating the vehicle. The activating/operating of vehicle functions can be related to making one or more parts of the vehicle **107** (e.g., tires **103**, body **105**, etc.) more visible to the movable sensor **101**. For

example, the activating/operation of the vehicle functions can include but is not limited to turning steering wheel to make the tires **103** more visible (e.g., turning the steering wheel to the right to make the tread of the left tire more visible or conversely turning the steering wheel to the left to make the tread of the right tire more visible). Other examples include but are not limited to: moving vehicle forward/backward (e.g., to expose different parts of the tires **103**); opening/closing doors, trunks, hoods, etc.; turning off or on vehicle lights (e.g., headlights, turn signals, brake lights, interior lights, etc.); extending or retracting other sensors or components of the vehicles (e.g., other sensors, antenna, etc.). The specific function or feature of the vehicle to activate or operation can be determined based on the desired diagnostic scan and/or the target of the scan.
(56) In addition, the diagnostic scan may be performed while the vehicle **107** is moving or stationary. For example, if the vehicle **107** encounters a triggering condition or indication of a need for a diagnostic scan while traveling (e.g., hitting a pothole, encountering road debris, etc.), then the diagnostic scan can be initiated without the vehicle **107** needing to stop or remain stationary. In some cases, a desired diagnostic scan can be only performed while stationary or moving depending on the target or purpose of the scan. For example, certain vehicle conditions or issues (e.g., tire vibration or wobble above a certain speed, suspension travel, loose body panel, etc.) may only become apparent when the vehicle **107** is moving, while other conditions are apparent only when the vehicle **107** is stationary. Accordingly, in one embodiment, some diagnostic scans are configured to be performed while in motion while other diagnostic scans are configured to be performed while stationary, and yet other diagnostic scans are configured to be performed while in motion or stationary.
(57) In step **405**, after the diagnostic scan using the movable sensor **101** is completed, the diagnostic platform **135** analyzes the diagnostic data **137** to generate a diagnostic report **139**. Examples of the diagnostic data **137** resulting from the diagnostic scan include but are limited to: Image data to determine tire pressure/wear/integrity/punctures/wobble body damage (dents, scratches, corrosion) Optical (e.g. laser), sound, infrared, LiDAR data to indicate body damage/corrosion—e.g., signals reflecting off the body surface, or paint/body layers beneath the surface can be indicative of damage/corrosion. low/changes in tire pressure—e.g., a laser can be used measure the distance to the ground, which can then be used to compute the height of the vehicle. A lower-riding vehicle is indicative of lower tire pressure. Similarly, lasers can be used to determine tread depth.
(58) In one embodiment, the diagnostic platform **135** may apply various machine vision/learning algorithms (or equivalent) to analyze the collected diagnostic data **137** to determine a condition of the vehicle **107**. For example, an algorithm may be trained to identify different types of tire wear, over-inflation, under-inflation, as well as signs of puncture, etc. from images. Similarly, an algorithm may be trained to identify problems in the vehicle body that may lead to further complications, e.g., corrosion, etc.
(59) FIG. **7** is a diagram illustrating an example of training a machine learning model to predict a vehicle condition from diagnostic data **137**, according to one example embodiment. In this example, the vehicle conditions of interest tire conditions detectable from diagnostic data **137** comprises image data. To begin training, ground truth training data **701** is collected and includes a set of training images depicting various tire conditions along with their annotated ground truth labels. The tire conditions include but are not limited to visibility of a wear indicator, over-inflation, under-inflation, feathered wear, camber wear, spotty/chopped wear, diagonal wear/heel and toe wear, and local wear. The training data **701** is then used to train a machine learning model **703** (e.g., a neural network or equivalent).
(60) In one embodiment, multiple different loss functions and/or supervision schemes can be used alternatively or together to train the machine learning model **703** to determine a vehicle condition are part of analyzing the diagnostic data **137**. One example scheme is based on supervised learning. For example, in supervised learning, the diagnostic platform **135** can incorporate a learning model

(e.g., a logistic regression model, Random Forest model, and/or any equivalent model) to train the machine learning model **703** to make predictions (e.g., vehicle condition data **705**) from input features or signals (e.g., features extracted from the diagnostic data **137**). During training, the diagnostic platform **135** can feed feature sets from the training data **701** into the machine learning model **703** to make predictions using an initial set of model parameters. The diagnostic platform **135** then compares the predictions and predicted matching probability to ground truth data in the training data **701** for each training example (e.g., images labeled ground truth vehicle/tire conditions) used for training. The diagnostic platform **135** then computes an accuracy of the predictions (e.g., via a loss function) for the initial set of model parameters. If the accuracy or level of performance does not meet a threshold or configured level, the diagnostic platform **135** incrementally adjusts the model parameters (e.g., via back propagation and gradient descent) until the machine learning model **703** generates predictions at a desired or configured level of accuracy with respect to the annotated labels in the training data (e.g., the ground truth data). In other words, a “trained” machine learning model **707** has model parameters adjusted to make accurate predictions (e.g., vehicle condition predictions) with respect to the training data set. In the case of a neural network, the model paraments can include, but are not limited, to the coefficients or weights and biases assigned to each connection between neurons in the layers of the neural network.

(61) In one embodiment, the trained machine learning model **707** can then be used to process newly collected diagnostic data **137** to predict vehicle condition data **705**. The predicted vehicle condition data **705** can then be used to generate a diagnostic report **139** on the condition of the subject vehicle **107**. It is noted that although the various embodiments are discussed with respect to training the machine learning model **703** to predict vehicle tire condition from image data, it is contemplated that a similar or equivalent machine learning process can be applied to train a machine learning model to predict or classify any other type of diagnostic data **137** (e.g., optical, sound, LiDAR, infrared, etc. data) to determine any condition of the vehicle **107**, tires **103**, and/or body **105**, and/or to make predictions relating to the vehicle condition (e.g., safety risk, wear rate, impacts on performance, etc. as further described below).

(62) For example, in one embodiment, the diagnostic platform **135** may predict future issues/risk based on the diagnostic data **137** resulting from a diagnostic scan. For instance, based on a specific condition of the tires ascertained from a diagnostic scan, a risk for a catastrophic event may be determined or quantified. For example, a 10% tire wear (e.g., equivalent to 10/32″ tread depth) may correspond with 0% risk of blowout, but a 70% wear (e.g., 3/32″ tread depth) might indicate a 95% risk. Similarly, a type of body damage determined from the diagnostic data **137** may correspond to a risk (e.g., risk associated with corrosion, excessive fuel consumption, etc.).

(63) In one embodiment, the diagnostic platform **135** may use historical/reference data to identify changes in the condition of the vehicle **107**, tires **103**, and/or body **105**. For example, a current vehicle condition (e.g., tire or body condition) can be determined from a diagnostic scan and then compared against historical or reference data to identify the changes. Historical data can include vehicle condition data collected in the past for the same vehicle **107** and/or other similar vehicle types (e.g., same make, model, and trim level). Reference data can include but is not limited to specification data for the vehicle **107**, tires **103**, and/or body **105** as provided by a vehicle manufacturer, parts manufacturer, mechanic, crowd sourced data, etc.

(64) In some embodiments, the diagnostic platform **135** can execute two or more diagnostic scans taken at different times to make a prediction for wear or other problems that develop over time (e.g., via linear/non-linear interpolation, or some other wear or risk model). In other words, the diagnostic platform **135** can initiate a subject diagnostic scan at a subsequent time from the diagnostic scan (e.g., after completing an initial diagnostic scan), and then predict a vehicle problem based on the diagnostic scan and the subsequent diagnostic scan. For example, multiple diagnostic scans of the tires **103** can be taken over time to determine whether the wear rate of the tires **103** is greater or lesser than expected. Similarly, multiple diagnostic scans of the paint on the

body **105** of the vehicle **107** can be performed over time to determine the progress of corrosion or sun damage.
(65) When making determinations or predictions, the diagnostic platform **135** can use various information in addition to the diagnostic data **137**. For example, map information (e.g., location, road type, traffic, construction, etc.), environment information (e.g., temperature, relative humidity, season, etc.), and vehicle information (e.g., tire tread/type, body type, etc.) can be used to predict vehicle conditions and/or related risks (e.g., tire wear or risk for catastrophic event such as tire failure). In other words, the diagnostic platform **135** can query for contextual information associated with the vehicle, an environment of the vehicle, map information associated with a location of the vehicle, or a combination thereof (e.g., for data sources such as the geographic database **149** or other data sources available from the services platform **151**, services **153**, content providers **155**, and/or other equivalent data providers).
(66) In one embodiment, as part of the analysis, the diagnostic data **137** may be pre-processed or enhanced in a variety of ways, including but not limited to spectral/color selection, filtering, masking, editing, etc. to facilitate feature extraction used during the embodiments of machine vision/learning algorithms described in the embodiments of above. In addition, various data representations can be created as inputs to the machine vision/learning algorithms or equivalent processing technique. For example, depth, height, or laser reflection measurements can be used to assemble an image, and the image can be provided as diagnostic data **137**.
(67) In one embodiment, the diagnostic platform **135** uses the vehicle condition data **705** generated from the analysis of the diagnostic data **137** to generate a diagnostic report **139** indication a condition or status of the vehicle **107**, tires **103**, body **105**, and/or any other component of the vehicle **107**. The diagnostic report **139** is an automatically generated report (e.g., by fitting the vehicle condition data **705** to one or more configured report templates) and may provide a variety of information, in any format, to different systems and/or devices (e.g. navigation system, heads-up display, mobile device, services platform **151**, services **153**, content provider **155**, mapping platform **147**, etc.). For example, the diagnostic report **139** may include elements such as but not limited to: Representations of a vehicle condition, a wheel or tire condition, a vehicle body condition, or a combination thereof such as but not limited to images/scans of body damage, tire issues, and/or any other machine detectable condition of the vehicle **107**; Recommendations for addressing the issues with the tires **103**, bod **105**, and/or any other condition of the vehicle **107**; Executable instructions determined based on the vehicle condition, wheel or tire condition, and/or any other condition of the vehicle **107** (e.g., instructions to control an autonomous vehicle to pull over, or to drive toward a specific destination, like an auto body shop); or Alerts indicating the vehicle condition, wheel or tire condition, and/or any other condition of the vehicle **107** (e.g., low tire pressure, punctured tire, presence of corrosion/damage, etc.)
(68) FIG. **8** is a diagram illustrating an example vehicle diagnostic report, according to one example embodiment. In the example of FIG. **8**, a vehicle **107** (not shown) has completed a navigation route and parked at a destination. The parking event triggers an automatic diagnostic scan using a movable sensor **101** of the vehicle **107**'s vehicle mirror assembly **109** according to the various embodiments described herein. The diagnostic scan has captured images of the tires **103** of the vehicle **107** and provided the images as diagnostic data **137** for analysis to determine a condition of the tires **103**. The diagnostic platform **135** has processed the diagnostic data **137** using a machine learning model trained to identify tire conditions and related risks.
(69) The output of the analysis of the diagnostic data **137** is presented in user interface (UI) **800** of FIG. **8**. As shown, UI **800** includes a UI element **801** that presents a representation of a tire **103** that has been determined to suffer from a vehicle condition defect (e.g., loss of tire tread from over inflation). The vehicle diagnostic report UI **800** also presents a UI element **803** that displays an alert message indicating that the “Right front tire is worn from over inflation” and the “Tire is predicted to fail within the next 500 miles.” The UI element **803** also presents recommendation

(e.g., "Replace tire immediately") and actions or instructions to be performed (e.g., "Setting a maximum travel speed to 35 mph" and "Routing to nearest service center.").

(70) If the vehicle **107** is an autonomous vehicle, the vehicle **107** can be configured to perform one or more actions automatically or otherwise presented to a driver/occupant to approve to perform. For example, in embodiments where the vehicle **107** supports autonomous or semi-autonomous mode of operation, the signals can include instructions for the vehicle **107** to take maneuvers, initiate one of the safety features described above, etc. without intervention from the driver or passenger in response to the diagnostic report **139**. In some cases, the vehicle **107** can use the signals from the system **100** to determine the mode of operation (e.g., autonomous mode, semi-autonomous mode, or manual mode) of the vehicle **107** based on the risk level estimated from the sensor data **105** of the movable sensor **101** of the vehicle mirror assembly **109**. It is contemplated that the vehicle **107** can support any number of autonomous driving modes. The vehicle **107**, for instance, can be an autonomous vehicle or highly assisted driving vehicle that is capable of sensing its environment and navigating within a road network without driver or occupant input. It is noted that autonomous vehicles and highly assisted driving vehicles are part of a spectrum of vehicle classifications that can span from no automation to fully autonomous operation. For example, the U.S. National Highway Traffic Safety Administration ("NHTSA") defines six levels of vehicle automation: Level 0 (No-Automation)—"Zero autonomy; the driver performs all driving tasks."; Level 1 (Driver Assistance)—"Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design."; Level 2 (Partial Automation)—"Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times."; Level 3 (Conditional Automation)—"Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice."; Level 4 (High Automation)—"The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle."; and Level 5 (Full Automation)—"The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle."

(71) The various embodiments described herein are applicable to vehicles that are classified in any of the levels of automation (levels 0-5) discussed above.

(72) FIG. **9** is a flowchart of a process **900** for controlling a vehicle mirror assembly **109** with a movable sensor **101** to perform a diagnostic scan, according to one example embodiment. In various embodiments, the controller **127** alone or in combination with the mapping platform **147**, geographic database **149**, services platform **151**, services **153**, and/or content provider **155** may perform one or more portions of the process **900** and may be implemented in, for instance, a chip set including a processor and a memory as shown in FIG. **12** and/or other circuitry for performing one or more steps of the process **900**. As such, the controller **127** can provide means for accomplishing various parts of the process **900**, as well as means for accomplishing embodiments of other processes described herein in conjunction with other components of the system **100**. Although the process **900** is illustrated and described as a sequence of steps, its contemplated that various embodiments of the process **900** may be performed in any order or combination and need not include all of the illustrated steps.

(73) In step **901**, the controller **127** receives (e.g., from the diagnostic platform **135**) a request to initiate a diagnostic scan of a vehicle **107**. For example, the request can be based a location of a vehicle **107**, a location of an object of interest, navigation information, map information, an orientation of a reflective surface **119** of the vehicle mirror assembly **109**, and/or any other indication for a need for the diagnostic scan as described in the various embodiments above. For example, the various triggering parameters for initiating a diagnostic scan can be determined as follows: Location of vehicle **107** to which the vehicle mirror assembly **109** is attached (e.g., as a side mirror) can be determined using a Global Navigation Satellite System (GNSS) (e.g., GPS,

GLONASS, etc.), radar, proximity, image processing and/or any other equivalent localization techniques; Location of one or more objects of interest can be determined using image processing of geotagged image data (e.g., captured from the movable sensor **101** or any other sensor of the vehicle **107**, nearby vehicles, infrastructure sensors, etc.), visual odometry, and/or other equivalent techniques; Navigation information indicating a navigation route planned for the vehicle **107** via an onboard navigation system, the mapping platform **147**, or equivalent navigation routing engine; Map information indicating map features (such as but not limited to road networks, road features, road attributes, terrain features, etc.) can be determined from the geographic database **149** (e.g., using a local instance or cloud-based instance via the mapping platform **147**); and An orientation of the reflective surface **119** can be determined from the telemetry hardware of the vehicle mirror assembly **109** or equivalent.

(74) In step **903**, the controller **127** generates a first control signal to modify an orientation, a position, or a combination thereof of a movable sensor of the vehicle mirror assembly **109** to perform the requested scan. In one embodiment, the requested diagnostic scan can be performed as a sweep over a predefined or otherwise targeted area of the vehicle **107**, tire **103**, body **105** of the vehicle, and/or its surrounding environment. Alternatively, the scan can be directed to a specific location on the vehicle **107**, tire **103**, body **105**, and/or surrounding environment. In embodiments in which the opacity/transparency of the housing **117** and/or reflective surface **119** of the vehicle mirror assembly **109** can be selectively controlled, the controller **127** can also generate a second control signal to activate a transparency of at least a portion of the housing **117** and/or reflective surface **119** to enable signals measured or emitted by the movable sensor **101** to pass through (optional step **905**). The second control signal, for instance, can be used to selectively make the housing **117** and/or reflective surface **119** transparent in coordination with the first control signal to move/orient the movable **105** or in coordination with the activation of the movable **105** to begin capturing sensor data. In some embodiments, the housing **117** and/or reflective surface **119** can be made transparent as in their entirety (e.g., as a single unit). In alternate embodiments, the selected portions of the housing **117** and/or reflective surface **119** can be selectively made transparent. For example, the second control signal may include or target a specific x-y position or elements on a grid to make transparent as described with respect to the various embodiments of FIG. **2** above.

(75) In one embodiment, the first control signal and/or second control signal can be determined based on any one or more of the following: Based on a location of the vehicle **107**—e.g., can be used to determine or anticipate viewing or sensor coverage needs (e.g., requested target of the diagnostic scan). Then depending on the anticipated viewing or sensor coverage, one or more portions of the housing **117** and/or reflective surface **119** can be made transparent so that the sensor field of view is not obstructed by the housing **117** and/or reflective surface **119**. Based on a location of one or more objects of interest to the diagnostic scan—e.g., an object such as tire **103**, body panel, etc. might not be in a current line of sight of the movable sensor **101**, and therefore would require a sensor movement or orientation adjustment. In some cases, the position and movement of the object(s) can be tracked/anticipated using the movable sensor **101** to avoid loss of visibility. Then, in embodiments supporting selective transparency, one or more portions of the housing **117** and/or reflective surface **119** can be made transparent so that the sensor field of view is not obstructed by the housing **117** and/or reflective surface **119**. Based on navigation information—e.g., an activation or movement of the movable sensor **101** to perform a diagnostic scan can be based on the status of the navigation route entered or performed for a vehicle. For example, the diagnostic scan can be triggered on based the start, end, or progress during a navigation route. In other words, the need for a diagnostic scan may be determined once a route has been entered into or calculated by a navigation system. A movement of the sensor **101** would then be activated upon starting or reaching a specific location on the navigation route. This may include analyzing the route and determining locations where diagnostic scans are to be performed (e.g., areas of the route where the vehicle **107** is likely to encounter conditions that may damage the vehicle **107**, tires **103**,

and/or body **105**). In embodiments supporting selective transparency, the controller **127** can coordinate the movements of the movable sensor **101** with a sequence of transparency activations of the housing **117** and/or reflective surface **119**. In this way, the controller **127** can also (pre)determine a sequence of transparency activations of the housing **117** and/or reflective surface **119** in coordination with sensor movements associated with a navigation route. In some embodiments, a navigation route may be modified enroute based on, for instance, updated traffic, weather, construction, destination change, etc. In such cases, the timing or location of the diagnostic scan may also be modified. Based on map information (e.g., POIs, traffic, road attributes, time of day, weather etc.) and traffic—e.g., different locations, different traffic conditions, or different times of day may trigger diagnostic scans according to the various embodiments described herein. In one embodiment, the map information may also keep a record of locations where accidents or other abnormal events have occurred before and allow trigger diagnostic scans of the vehicle **107** at those locations. Examples of other abnormal events include but are not limited to locations of previously observed debris, construction, potholes, pedestrian crossing, etc. In other words, the controller determines a proximity of the vehicle **107** to a geographic area of interest, geotagged events, and/or other map features. The control signal is then generated to modify the orientation, the position, or a combination thereof and to direct a field of view of the movable sensor to perform a diagnostic scan based on the geographic area of interest, geotagged events, map features, etc. Based on an orientation of a reflective surface **119** (e.g., a mirror) of a vehicle mirror assembly **109**—e.g., sensor movement may be locked to or made to diverge from the reflective surface **119**'s position or movement as it performs a diagnostic scan.

(76) In step **907**, the controller **127** provides the first control signal (e.g., for controlling sensor movement) to an actuator assembly **125** of the vehicle mirror assembly **109**. The actuator assembly configured to modify the orientation, the position, or a combination thereof of a movable sensor based on the control signal. In one embodiment, the control signal may specify a direction, field of view, angle, etc. to move or orient the movable sensor **101** along with signals to alter the opacity/transparency of the housing **117** and/or reflective surface **119** of the vehicle mirror assembly **109** that blocks or otherwise interferes with the movable sensor **101**'s being able to emit or measure signals from the specified direction, field of view, angle, etc.

(77) In embodiments that support selective transparency, the controller **127** provides the second control signal (e.g., for transparency activation) to a transparency control element **133** (or equivalent component) of the vehicle mirror assembly **109**. As described in the embodiments above, the second control signal can specify all or a portion housing **117** and/or reflective surface **119** to make transparent to the signals emitted or measured by the movable sensor **101**. The second control signal, for instance, can specify the target x-y position or elements on a grid corresponding to the portion of the housing **117** and/or reflective surface **119** to make transparent. The transparency control element **133** can then cause an application of voltage, heat, light, etc. to be applied to the specified portion of the housing **117** and/or reflective surface **119** to activate transparency (optional step **909**).

(78) Returning to FIG. **1**, in one embodiment, the diagnostic platform **135**, controller **127**, and/or mapping platform **147** have connectivity over the communication network **145** to the services platform **151** that provides one or more services **153**. By way of example, the services **153** may be third-party services and include mapping services, navigation services, travel planning services, notification services, social networking services, content (e.g., audio, video, images, etc.) provisioning services, application services, storage services, contextual information determination services, location-based services, information-based services (e.g., weather, traffic, news, etc.), etc. In one embodiment, the services platform **151** uses the output of the diagnostic platform **135** generated from sensor data (e.g., diagnostic data **137**) collected by one or more movable sensors **101** of the vehicle mirror assembly **109** to provide services such as navigation, mapping, other location-based services, etc.

(79) In one embodiment, the services platform **151** and/or mapping platform **147** may be a platform with multiple interconnected components and may include multiple servers, intelligent networking devices, computing devices, components, and corresponding software for providing a runaway vehicle detection system. In addition, it is noted that the services platform **151** and/or mapping platform **147** may be a separate entity of the system **100** or included within the local components of the vehicle **107** or controller **127**.
(80) In one embodiment, content providers **155** may provide content or data (e.g., including geographic data, sensor data, etc.) to the geographic database **149**, the mapping platform **147**, the services platform **151**, the services **153**, and/or the controller **127**. The content provided may be any type of content, such as sensor data, map content, textual content, audio content, video content, image content, etc. In one embodiment, the content providers **155** may provide content that may aid in controlling the movement/orientation of the movable sensor **101** and/or using the sensor data collected by the movable sensor **101**. In one embodiment, the content providers **155** may also store content associated with the geographic database **149**, mapping platform **147**, services platform **151**, services **153**, and/or controller **127**. In another embodiment, the content providers **155** may manage access to a central repository of data, and offer a consistent, standard interface to data, such as a repository of the geographic database **149**.
(81) By way of example, the controller **127** can be any type of embedded system, processor, mobile terminal, fixed terminal, or portable terminal including a built-in navigation system, a personal navigation device, mobile handset, station, unit, device, multimedia computer, multimedia tablet, Internet node, communicator, desktop computer, laptop computer, notebook computer, netbook computer, tablet computer, personal communication system (PCS) device, personal digital assistants (PDAs), audio/video player, digital camera/camcorder, positioning device, fitness device, television receiver, radio broadcast receiver, electronic book device, game device, or any combination thereof, including the accessories and peripherals of these devices, or any combination thereof. In one embodiment, the controller **127** may be associated with the vehicle mirror assembly **109** or vehicle **107** or be a component part of the vehicle mirror assembly **109** or vehicle **107**.
(82) In one embodiment, the vehicle mirror assembly **109** are configured with various movable sensors **101** for generating or collecting sensor data, related geographic/map data, etc. In one embodiment, the sensed data represent sensor data associated with a geographic location or coordinates at which the sensor data was collected. By way of example, the sensors may include a camera/image sensor, proximity sensors, a radar system, a LiDAR system, a global positioning sensor for gathering location data (e.g., GPS), a network detection sensor for detecting wireless signals or receivers for different short-range communications (e.g., Bluetooth, Wi-Fi, Li-Fi, near field communication (NFC) etc.), temporal information sensors, an audio recorder for gathering audio data, velocity sensors, and the like.
(83) Other examples of movable sensors **101** of the vehicle mirror assembly **109** may include light sensors, orientation sensors augmented with height sensors and acceleration sensors (e.g., an accelerometer can measure acceleration and can be used to determine orientation of the vehicle), tilt sensors to detect the degree of incline or decline of the vehicle along a path of travel, moisture sensors, pressure sensors, etc. In a further example embodiment, the movable sensors **101** may detect the relative distance of the vehicle from a physical divider, a lane or roadway, the presence of other vehicles, pedestrians, traffic lights, potholes and any other objects, or a combination thereof. In one scenario, the sensors **101** may detect weather data, traffic information, or a combination thereof. In one embodiment, the vehicle **107** may include GPS or other satellite-based receivers to obtain geographic coordinates from satellites for determining current location and time. Further, the location can be determined by visual odometry, triangulation systems such as A-GPS, Cell of Origin, or other location extrapolation technologies. In yet another embodiment, the vehicle can include equivalent sensors that are not movable and can be used in combination with the movable sensors **101** to determine risk and/or determine an optimal orientation or movement of the

mobile sensors **101** according to various embodiments described herein.

(84) In one embodiment, the communication network **145** of system **100** includes one or more networks such as a data network, a wireless network, a telephony network, or any combination thereof. It is contemplated that the data network may be any local area network (LAN), metropolitan area network (MAN), wide area network (WAN), a public data network (e.g., the Internet), short range wireless network, or any other suitable packet-switched network, such as a commercially owned, proprietary packet-switched network, e.g., a proprietary cable or fiber-optic network, and the like, or any combination thereof. In addition, the wireless network may be, for example, a cellular network and may employ various technologies including enhanced data rates for global evolution (EDGE), general packet radio service (GPRS), global system for mobile communications (GSM), Internet protocol multimedia subsystem (IMS), universal mobile telecommunications system (UMTS), etc., as well as any other suitable wireless medium, e.g., worldwide interoperability for microwave access (WiMAX), 5G New Radio, Long Term Evolution (LTE) networks, code division multiple access (CDMA), wideband code division multiple access (WCDMA), wireless fidelity (Wi-Fi), wireless LAN (WLAN), Bluetooth®, Internet Protocol (IP) data casting, satellite, mobile ad-hoc network (MANET), and the like, or any combination thereof.

(85) By way of example, the diagnostic platform **135**, controller **127**, mapping platform **147**, services platform **151**, services **153**, vehicle **107**, and/or content providers **155** communicate with each other and other components of the system **100** using well known, new or still developing protocols. In this context, a protocol includes a set of rules defining how the network nodes within the communication network **145** interact with each other based on information sent over the communication links. The protocols are effective at different layers of operation within each node, from generating and receiving physical signals of various types, to selecting a link for transferring those signals, to the format of information indicated by those signals, to identifying which software application executing on a computer system sends or receives the information. The conceptually different layers of protocols for exchanging information over a network are described in the Open Systems Interconnection (OSI) Reference Model.

(86) Communications between the network nodes are typically effected by exchanging discrete packets of data. Each packet typically comprises (1) header information associated with a particular protocol, and (2) payload information that follows the header information and contains information that may be processed independently of that particular protocol. In some protocols, the packet includes (3) trailer information following the payload and indicating the end of the payload information. The header includes information such as the source of the packet, its destination, the length of the payload, and other properties used by the protocol. Often, the data in the payload for the particular protocol includes a header and payload for a different protocol associated with a different, higher layer of the OSI Reference Model. The header for a particular protocol typically indicates a type for the next protocol contained in its payload. The higher layer protocol is said to be encapsulated in the lower layer protocol. The headers included in a packet traversing multiple heterogeneous networks, such as the Internet, typically include a physical (layer 1) header, a datalink (layer 2) header, an internetwork (layer 3) header and a transport (layer 4) header, and various application (layer 5, layer 6 and layer 7) headers as defined by the OSI Reference Model.

(87) FIG. **10** is a diagram of a geographic database, according to one embodiment. In one embodiment, the geographic database **149** includes geographic data **1001** used for (or configured to be compiled to be used for) mapping and/or navigation-related services. In one embodiment, geographic features (e.g., two-dimensional or three-dimensional features) are represented using polygons (e.g., two-dimensional features) or polygon extrusions (e.g., three-dimensional features). For example, the edges of the polygons correspond to the boundaries or edges of the respective geographic feature. In the case of a building, a two-dimensional polygon can be used to represent a footprint of the building, and a three-dimensional polygon extrusion can be used to represent the three-dimensional surfaces of the building. It is contemplated that although various embodiments

are discussed with respect to two-dimensional polygons, it is contemplated that the embodiments are also applicable to three-dimensional polygon extrusions. Accordingly, the terms polygons and polygon extrusions as used herein can be used interchangeably.
(88) In one embodiment, the following terminology applies to the representation of geographic features in the geographic database **149**.
(89) "Node"—A point that terminates a link.
(90) "Line segment"—A straight line connecting two points.
(91) "Link" (or "edge")—A contiguous, non-branching string of one or more line segments terminating in a node at each end.
(92) "Shape point"—A point along a link between two nodes (e.g., used to alter a shape of the link without defining new nodes).
(93) "Oriented link"—A link that has a starting node (referred to as the "reference node") and an ending node (referred to as the "non reference node").
(94) "Simple polygon"—An interior area of an outer boundary formed by a string of oriented links that begins and ends in one node. In one embodiment, a simple polygon does not cross itself.
(95) "Polygon"—An area bounded by an outer boundary and none or at least one interior boundary (e.g., a hole or island). In one embodiment, a polygon is constructed from one outer simple polygon and none or at least one inner simple polygon. A polygon is simple if it just consists of one simple polygon, or complex if it has at least one inner simple polygon.
(96) In one embodiment, the geographic database **149** follows certain conventions. For example, links do not cross themselves and do not cross each other except at a node. Also, there are no duplicated shape points, nodes, or links. Two links that connect each other have a common node. In the geographic database **149**, overlapping geographic features are represented by overlapping polygons. When polygons overlap, the boundary of one polygon crosses the boundary of the other polygon. In the geographic database **149**, the location at which the boundary of one polygon intersects they boundary of another polygon is represented by a node. In one embodiment, a node may be used to represent other locations along the boundary of a polygon than a location at which the boundary of the polygon intersects the boundary of another polygon. In one embodiment, a shape point is not used to represent a point at which the boundary of a polygon intersects the boundary of another polygon.
(97) As shown, the geographic database **149** includes node data records **1003**, road segment or link data records **1005**, POI data records **1007**, diagnostic data records **1009**, other records **1011**, and indexes **1013**, for example. More, fewer, or different data records can be provided. In one embodiment, additional data records (not shown) can include cartographic ("carto") data records, routing data, and maneuver data. In one embodiment, the indexes **1013** may improve the speed of data retrieval operations in the geographic database **149**. In one embodiment, the indexes **1013** may be used to quickly locate data without having to search every row in the geographic database **149** every time it is accessed. For example, in one embodiment, the indexes **1013** can be a spatial index of the polygon points associated with stored feature polygons.
(98) In exemplary embodiments, the road segment data records **1005** are links or segments representing roads, streets, or paths, as can be used in the calculated route or recorded route information for determination of one or more personalized routes. The node data records **1003** are end points corresponding to the respective links or segments of the road segment data records **1005**. The road link data records **1005** and the node data records **1003** represent a road network, such as used by vehicles, cars, and/or other entities. Alternatively, the geographic database **149** can contain path segment and node data records or other data that represent pedestrian paths or areas in addition to or instead of the vehicle road record data, for example.
(99) The road/link segments and nodes can be associated with attributes, such as geographic coordinates, street names, address ranges, speed limits, turn restrictions at intersections, and other navigation related attributes, as well as POIs, such as gasoline stations, hotels, restaurants,

museums, stadiums, offices, automobile dealerships, auto repair shops, buildings, stores, parks, other road adjacent objects/features, etc. In one embodiment, the stored attributes or data can include two-dimensional and/or three-dimensional representations of object geometries corresponding to road adjacent object, buildings, features, etc. These object representations and their location data can be used by the system **100** to control one or more vehicle mirror assemblies **109** to keep the objects within the field of view of their respective movable sensors **101**. For example, the stored object representations and locations can be used to compute a line of sight between the sensors **101** of the vehicle mirror assemblies **109** and the different objects (e.g., to determine sensor movements and/or transparency activations according to the various embodiments described herein). The geographic database **149** can include data about the POIs and their respective locations in the POI data records **1007**. The geographic database **149** can also include data about places, such as cities, towns, or other communities, and other geographic features, such as bodies of water, mountain ranges, etc. Such place or feature data can be part of the POI data records **1007** or can be associated with POIs or POI data records **1007** (such as a data point used for displaying or representing a position of a city). In one embodiment, the geographic database **149** can also store the locations where incidents, accidents, and/or any other events that the system **100** can monitor and direct sensor movements and/or transparency activations towards.

(100) In one embodiment, the geographic database **149** can also include diagnostic data records **1009** for storing the data used for performing diagnostic scans, performing orientation/movement of the movable sensors **101**, sensor data collected from the sensor data, risk assessment data resulting from the analysis of the sensor data, optimal orientation or sequences of orientations determine for a given road or map feature, and/or any other data used or generated by the diagnostic platform **135**, controller **127**, mapping platform **147**, services platform **151**, services **153**, and/or content provider **155** according to the various embodiments described herein. In one embodiment, the diagnostic data records **1009** (e.g., data indicating an optimal movement or orientation of a movable sensor **101**) can be associated with one or more of the node records **1503**, road segment records **1005**, and/or POI data records **1007**; or portions thereof (e.g., smaller or different segments than indicated in the road segment records **1005**, individual lanes of the road segments, etc.) to provide recommend orientations or fields of views for the movable sensor **101** at a given location.

(101) In one embodiment, the geographic database **149** can be maintained by the content provider **155** in association with the mapping platform **147** (e.g., a map developer). The map developer can collect geographic data to generate and enhance the geographic database **149**. There can be different ways used by the map developer to collect data. These ways can include obtaining data from other sources, such as municipalities or respective geographic authorities. In addition, the map developer can employ field personnel to travel by vehicle along roads throughout the geographic region to observe features (e.g., runaway vehicle events, runaway vehicle safety locations, etc.) and/or record information about them, for example. Also, remote sensing, such as aerial or satellite photography, can be used.

(102) In one embodiment, the geographic database **149** include high resolution or high definition (HD) mapping data that provide centimeter-level or better accuracy of map features. For example, the geographic database **149** can be based on Light Detection and Ranging (LiDAR) or equivalent technology to collect billions of 3D points and model road surfaces and other map features down to the number lanes and their widths. In one embodiment, the HD mapping data capture and store details such as the slope and curvature of the road, lane markings, roadside objects such as sign posts, including what the signage denotes. In one embodiment, the HD mapping data can also include locations and two-dimensional and/or three-dimensional representations of objects that can be monitored by the movable sensors **101** of the vehicle mirror assemblies **109**. As discussed above, the locations and representation enable the system **100** to compute line-of-sight data between sensors **101**/vehicle mirror assemblies **109**/vehicles **107** and the objects/map features of

interest to control sensor movement and/or transparency activations of the housing **117** and/or reflective surface **119**. By way of example, the HD mapping data also enable highly automated vehicles to precisely localize themselves on the road, and to determine road attributes (e.g., learned speed limit values) to at high accuracy levels.

(103) In one embodiment, the geographic database **149** is stored as a hierarchical or multilevel tile-based projection or structure. More specifically, in one embodiment, the geographic database **149** may be defined according to a normalized Mercator projection. Other projections may be used. By way of example, the map tile grid of a Mercator or similar projection is a multilevel grid. Each cell or tile in a level of the map tile grid is divisible into the same number of tiles of that same level of grid. In other words, the initial level of the map tile grid (e.g., a level at the lowest zoom level) is divisible into four cells or rectangles. Each of those cells are in turn divisible into four cells, and so on until the highest zoom or resolution level of the projection is reached.

(104) In one embodiment, the map tile grid may be numbered in a systematic fashion to define a tile identifier (tile ID). For example, the top left tile may be numbered 00, the top right tile may be numbered 01, the bottom left tile may be numbered 10, and the bottom right tile may be numbered 11. In one embodiment, each cell is divided into four rectangles and numbered by concatenating the parent tile ID and the new tile position. A variety of numbering schemes also is possible. Any number of levels with increasingly smaller geographic areas may represent the map tile grid. Any level (n) of the map tile grid has 2(n+1) cells. Accordingly, any tile of the level (n) has a geographic area of A/2(n+1) where A is the total geographic area of the world or the total area of the map tile grid **10**. Because of the numbering system, the exact position of any tile in any level of the map tile grid or projection may be uniquely determined from the tile ID.

(105) In one embodiment, the system **100** may identify a tile by a quadkey determined based on the tile ID of a tile of the map tile grid. The quadkey, for example, is a one-dimensional array including numerical values. In one embodiment, the quadkey may be calculated or determined by interleaving the bits of the row and column coordinates of a tile in the grid at a specific level. The interleaved bits may be converted to a predetermined base number (e.g., base **10**, base **4**, hexadecimal). In one example, leading zeroes are inserted or retained regardless of the level of the map tile grid in order to maintain a constant length for the one-dimensional array of the quadkey. In another example, the length of the one-dimensional array of the quadkey may indicate the corresponding level within the map tile grid **10**. In one embodiment, the quadkey is an example of the hash or encoding scheme of the respective geographical coordinates of a geographical data point that can be used to identify a tile in which the geographical data point is located.

(106) The geographic database **149** can be a master geographic database stored in a format that facilitates updating, maintenance, and development. For example, the master geographic database or data in the master geographic database can be in an Oracle spatial format or other spatial format, such as for development or production purposes. The Oracle spatial format or development/production database can be compiled into a delivery format, such as a geographic data files (GDF) format. The data in the production and/or delivery formats can be compiled or further compiled to form geographic database products or databases, which can be used in end user navigation devices or systems.

(107) For example, geographic data is compiled (such as into a platform specification format (PSF) format) to organize and/or configure the data for performing navigation-related functions and/or services, such as route calculation, route guidance, map display, speed calculation, distance and travel time functions, and other functions, by a navigation device, such as by the vehicle **107**, for example. The navigation-related functions can correspond to vehicle navigation, pedestrian navigation, or other types of navigation. The compilation to produce the end user databases can be performed by a party or entity separate from the map developer. For example, a customer of the map developer, such as a navigation device developer or other end user device developer, can perform compilation on a received geographic database in a delivery format to produce one or

more compiled navigation databases.

(108) The processes described herein for providing vehicle diagnostics using a vehicle mirror assembly **109** with a movable sensor **101** may be advantageously implemented via software, hardware (e.g., general processor, Digital Signal Processing (DSP) chip, an Application Specific Integrated Circuit (ASIC), Field Programmable Gate Arrays (FPGAs), etc.), firmware or a combination thereof. Such exemplary hardware for performing the described functions is detailed below.

(109) Additionally, as used herein, the term ‘circuitry’ may refer to (a) hardware-only circuit implementations (for example, implementations in analog circuitry and/or digital circuitry); (b) combinations of circuits and computer program product(s) comprising software and/or firmware instructions stored on one or more computer readable memories that work together to cause an apparatus to perform one or more functions described herein; and (c) circuits, such as, for example, a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation even if the software or firmware is not physically present. This definition of ‘circuitry’ applies to all uses of this term herein, including in any claims. As a further example, as used herein, the term ‘circuitry’ also includes an implementation comprising one or more processors and/or portion(s) thereof and accompanying software and/or firmware. As another example, the term ‘circuitry’ as used herein also includes, for example, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in a server, a cellular device, other network device, and/or other computing device.

(110) FIG. **11** illustrates a computer system **1100** upon which an embodiment of the invention may be implemented. Computer system **1100** is programmed (e.g., via computer program code or instructions) to provide vehicle diagnostic functions associated with a vehicle mirror assembly **109** with a movable sensor **101** as described herein and includes a communication mechanism such as a bus **1110** for passing information between other internal and external components of the computer system **1100**. Information (also called data) is represented as a physical expression of a measurable phenomenon, typically electric voltages, but including, in other embodiments, such phenomena as magnetic, electromagnetic, pressure, chemical, biological, molecular, atomic, sub-atomic and quantum interactions. For example, north and south magnetic fields, or a zero and non-zero electric voltage, represent two states (0, 1) of a binary digit (bit). Other phenomena can represent digits of a higher base. A superposition of multiple simultaneous quantum states before measurement represents a quantum bit (qubit). A sequence of one or more digits constitutes digital data that is used to represent a number or code for a character. In some embodiments, information called analog data is represented by a near continuum of measurable values within a particular range.

(111) A bus **1110** includes one or more parallel conductors of information so that information is transferred quickly among devices coupled to the bus **1110**. One or more processors **1102** for processing information are coupled with the bus **1110**.

(112) A processor **1102** performs a set of operations on information as specified by computer program code related to providing vehicle diagnostic functions associated with a vehicle mirror assembly **109** with a movable sensor **101**. The computer program code is a set of instructions or statements providing instructions for the operation of the processor and/or the computer system to perform specified functions. The code, for example, may be written in a computer programming language that is compiled into a native instruction set of the processor. The code may also be written directly using the native instruction set (e.g., machine language). The set of operations include bringing information in from the bus **1110** and placing information on the bus **1110**. The set of operations also typically include comparing two or more units of information, shifting positions of units of information, and combining two or more units of information, such as by addition or multiplication or logical operations like OR, exclusive OR (XOR), and AND. Each operation of the set of operations that can be performed by the processor is represented to the processor by information called instructions, such as an operation code of one or more digits. A sequence of

operations to be executed by the processor **1102**, such as a sequence of operation codes, constitute processor instructions, also called computer system instructions or, simply, computer instructions. Processors may be implemented as mechanical, electrical, magnetic, optical, chemical or quantum components, among others, alone or in combination.

(113) Computer system **1100** also includes a memory **1104** coupled to bus **1110**. The memory **1104**, such as a random access memory (RAM) or other dynamic storage device, stores information including processor instructions for providing vehicle diagnostics using a vehicle mirror assembly **109** with a movable sensor **101**. Dynamic memory allows information stored therein to be changed by the computer system **1100**. RAM allows a unit of information stored at a location called a memory address to be stored and retrieved independently of information at neighboring addresses. The memory **1104** is also used by the processor **1102** to store temporary values during execution of processor instructions. The computer system **1100** also includes a read only memory (ROM) **1106** or other static storage device coupled to the bus **1110** for storing static information, including instructions, that is not changed by the computer system **1100**. Some memory is composed of volatile storage that loses the information stored thereon when power is lost. Also coupled to bus **1110** is a non-volatile (persistent) storage device **1108**, such as a magnetic disk, optical disk, or flash card, for storing information, including instructions, that persists even when the computer system **1100** is turned off or otherwise loses power.

(114) Information, including instructions for providing vehicle diagnostics using a vehicle mirror assembly **109** with a movable sensor **101**, is provided to the bus **1110** for use by the processor from an external input device **1112**, such as a keyboard containing alphanumeric keys operated by a human user, or a sensor. A sensor detects conditions in its vicinity and transforms those detections into physical expression compatible with the measurable phenomenon used to represent information in computer system **1100**. Other external devices coupled to bus **1110**, used primarily for interacting with humans, include a display device **1114**, such as a cathode ray tube (CRT) or a liquid crystal display (LCD), or plasma screen or printer for presenting text or images, and a pointing device **1116**, such as a mouse or a trackball or cursor direction keys, or motion sensor, for controlling a position of a small cursor image presented on the display **1114** and issuing commands associated with graphical elements presented on the display **1114**. In some embodiments, for example, in embodiments in which the computer system **1100** performs all functions automatically without human input, one or more of external input device **1112**, display device **1114** and pointing device **1116** is omitted.

(115) In the illustrated embodiment, special purpose hardware, such as an application specific integrated circuit (ASIC) **1120**, is coupled to bus **1110**. The special purpose hardware is configured to perform operations not performed by processor **1102** quickly enough for special purposes. Examples of application specific ICs include graphics accelerator cards for generating images for display **1114**, cryptographic boards for encrypting and decrypting messages sent over a network, speech recognition, and interfaces to special external devices, such as robotic arms and medical scanning equipment that repeatedly perform some complex sequence of operations that are more efficiently implemented in hardware.

(116) Computer system **1100** also includes one or more instances of a communications interface **1170** coupled to bus **1110**. Communication interface **1170** provides a one-way or two-way communication coupling to a variety of external devices that operate with their own processors, such as printers, scanners, and external disks. In general the coupling is with a network link **1178** that is connected to a local network **1180** to which a variety of external devices with their own processors are connected. For example, communication interface **1170** may be a parallel port or a serial port or a universal serial bus (USB) port on a personal computer. In some embodiments, communications interface **1170** is an integrated services digital network (ISDN) card or a digital subscriber line (DSL) card or a telephone modem that provides an information communication connection to a corresponding type of telephone line. In some embodiments, a communication

interface **1170** is a cable modem that converts signals on bus **1110** into signals for a communication connection over a coaxial cable or into optical signals for a communication connection over a fiber optic cable. As another example, communications interface **1170** may be a local area network (LAN) card to provide a data communication connection to a compatible LAN, such as Ethernet. Wireless links may also be implemented. For wireless links, the communications interface **1170** sends or receives or both sends and receives electrical, acoustic, or electromagnetic signals, including infrared and optical signals, that carry information streams, such as digital data. For example, in wireless handheld devices, such as mobile telephones like cell phones, the communications interface **1170** includes a radio band electromagnetic transmitter and receiver called a radio transceiver. In certain embodiments, the communications interface **1170** enables connection to the communication network **145** for providing vehicle diagnostic functions associated with a vehicle mirror assembly **109** with a movable sensor **101**.
(117) The term computer-readable medium is used herein to refer to any medium that participates in providing information to processor **1102**, including instructions for execution. Such a medium may take many forms, including, but not limited to, non-volatile media, volatile media, and transmission media. Non-volatile media include, for example, optical or magnetic disks, such as storage device **1108**. Volatile media include, for example, dynamic memory **1104**.
(118) Transmission media include, for example, coaxial cables, copper wire, fiber optic cables, and carrier waves that travel through space without wires or cables, such as acoustic waves and electromagnetic waves, including radio, optical and infrared waves. Signals include man-made transient variations in amplitude, frequency, phase, polarization or other physical properties transmitted through the transmission media. Common forms of computer-readable media include, for example, a floppy disk, a flexible disk, hard disk, magnetic tape, any other magnetic medium, a CD-ROM, CDRW, DVD, any other optical medium, punch cards, paper tape, optical mark sheets, any other physical medium with patterns of holes or other optically recognizable indicia, a RAM, a PROM, an EPROM, a FLASH-EPROM, any other memory chip or cartridge, a carrier wave, or any other medium from which a computer can read.
(119) Network link **1178** typically provides information communication using transmission media through one or more networks to other devices that use or process the information. For example, network link **1178** may provide a connection through local network **1180** to a host computer **1182** or to equipment **1184** operated by an Internet Service Provider (ISP). ISP equipment **1184** in turn provides data communication services through the public, world-wide packet-switching communication network of networks now commonly referred to as the Internet **1190**.
(120) A computer called a server host **1192** connected to the Internet hosts a process that provides a service in response to information received over the Internet. For example, server host **1192** hosts a process that provides information representing video data for presentation at display **1114**. It is contemplated that the components of system can be deployed in various configurations within other computer systems, e.g., host **1182** and server **1192**.
(121) FIG. **12** illustrates a chip set **1200** upon which an embodiment of the invention may be implemented. Chip set **1200** is programmed to provide vehicle diagnostic functions associated with a vehicle mirror assembly **109** with a movable sensor **101** as described herein and includes, for instance, the processor and memory components described with respect to FIG. **11** incorporated in one or more physical packages (e.g., chips). By way of example, a physical package includes an arrangement of one or more materials, components, and/or wires on a structural assembly (e.g., a baseboard) to provide one or more characteristics such as physical strength, conservation of size, and/or limitation of electrical interaction. It is contemplated that in certain embodiments the chip set can be implemented in a single chip.
(122) In one embodiment, the chip set **1200** includes a communication mechanism such as a bus **1201** for passing information among the components of the chip set **1200**. A processor **1203** has connectivity to the bus **1201** to execute instructions and process information stored in, for example,

a memory **1205**. The processor **1203** may include one or more processing cores with each core configured to perform independently. A multi-core processor enables multiprocessing within a single physical package. Examples of a multi-core processor include two, four, eight, or greater numbers of processing cores. Alternatively or in addition, the processor **1203** may include one or more microprocessors configured in tandem via the bus **1201** to enable independent execution of instructions, pipelining, and multithreading. The processor **1203** may also be accompanied with one or more specialized components to perform certain processing functions and tasks such as one or more digital signal processors (DSP) **1207**, or one or more application-specific integrated circuits (ASIC) **1209**. A DSP **1207** typically is configured to process real-world signals (e.g., sound) in real time independently of the processor **1203**. Similarly, an ASIC **1209** can be configured to performed specialized functions not easily performed by a general purposed processor. Other specialized components to aid in performing the inventive functions described herein include one or more field programmable gate arrays (FPGA) (not shown), one or more controllers (not shown), or one or more other special-purpose computer chips.

(123) The processor **1203** and accompanying components have connectivity to the memory **1205** via the bus **1201**. The memory **1205** includes both dynamic memory (e.g., RAM, magnetic disk, writable optical disk, etc.) and static memory (e.g., ROM, CD-ROM, etc.) for storing executable instructions that when executed perform the inventive steps described herein to provide vehicle diagnostic functions associated with a vehicle mirror assembly **109** with a movable sensor **101**. The memory **1205** also stores the data associated with or generated by the execution of the inventive steps.

(124) FIG. **13** is a diagram of exemplary components of a mobile terminal (e.g., handset) capable of operating in the system of FIG. **1**, according to one embodiment. Generally, a radio receiver is often defined in terms of front-end and back-end characteristics. The front-end of the receiver encompasses all of the Radio Frequency (RF) circuitry whereas the back-end encompasses all of the base-band processing circuitry. Pertinent internal components of the telephone include a Main Control Unit (MCU) **1303**, a Digital Signal Processor (DSP) **1305**, and a receiver/transmitter unit including a microphone gain control unit and a speaker gain control unit. A main display unit **1307** provides a display to the user in support of various applications and mobile station functions that offer automatic contact matching. An audio function circuitry **1309** includes a microphone **1311** and microphone amplifier that amplifies the speech signal output from the microphone **1311**. The amplified speech signal output from the microphone **1311** is fed to a coder/decoder (CODEC) **1313**.

(125) A radio section **1315** amplifies power and converts frequency in order to communicate with a base station, which is included in a mobile communication system, via antenna **1317**. The power amplifier (PA) **1319** and the transmitter/modulation circuitry are operationally responsive to the MCU **1303**, with an output from the PA **1319** coupled to the duplexer **1321** or circulator or antenna switch, as known in the art. The PA **1319** also couples to a battery interface and power control unit **1320**.

(126) In use, a user of mobile station **1301** speaks into the microphone **1311** and his or her voice along with any detected background noise is converted into an analog voltage. The analog voltage is then converted into a digital signal through the Analog to Digital Converter (ADC) **1323**. The control unit **1303** routes the digital signal into the DSP **1305** for processing therein, such as speech encoding, channel encoding, encrypting, and interleaving. In one embodiment, the processed voice signals are encoded, by units not separately shown, using a cellular transmission protocol such as global evolution (EDGE), general packet radio service (GPRS), global system for mobile communications (GSM), Internet protocol multimedia subsystem (IMS), universal mobile telecommunications system (UMTS), etc., as well as any other suitable wireless medium, e.g., microwave access (WiMAX), Long Term Evolution (LTE) networks, 5G New Radio networks, code division multiple access (CDMA), wireless fidelity (WiFi), satellite, and the like.

(127) The encoded signals are then routed to an equalizer **1325** for compensation of any frequency-dependent impairments that occur during transmission though the air such as phase and amplitude distortion. After equalizing the bit stream, the modulator **1327** combines the signal with a RF signal generated in the RF interface **1329**. The modulator **1327** generates a sine wave by way of frequency or phase modulation. In order to prepare the signal for transmission, an up-converter **1331** combines the sine wave output from the modulator **1327** with another sine wave generated by a synthesizer **1333** to achieve the desired frequency of transmission. The signal is then sent through a PA **1319** to increase the signal to an appropriate power level. In practical systems, the PA **1319** acts as a variable gain amplifier whose gain is controlled by the DSP **1305** from information received from a network base station. The signal is then filtered within the duplexer **1321** and optionally sent to an antenna coupler **1335** to match impedances to provide maximum power transfer. Finally, the signal is transmitted via antenna **1317** to a local base station. An automatic gain control (AGC) can be supplied to control the gain of the final stages of the receiver. The signals may be forwarded from there to a remote telephone which may be another cellular telephone, other mobile phone or a landline connected to a Public Switched Telephone Network (PSTN), or other telephony networks.
(128) Voice signals transmitted to the mobile station **1301** are received via antenna **1317** and immediately amplified by a low noise amplifier (LNA) **1337**. A down-converter **1339** lowers the carrier frequency while the demodulator **1341** strips away the RF leaving only a digital bit stream. The signal then goes through the equalizer **1325** and is processed by the DSP **1305**. A Digital to Analog Converter (DAC) **1343** converts the signal and the resulting output is transmitted to the user through the speaker **1345**, all under control of a Main Control Unit (MCU) **1303**—which can be implemented as a Central Processing Unit (CPU) (not shown).
(129) The MCU **1303** receives various signals including input signals from the keyboard **1347**. The keyboard **1347** and/or the MCU **1303** in combination with other user input components (e.g., the microphone **1311**) comprise a user interface circuitry for managing user input. The MCU **1303** runs a user interface software to facilitate user control of at least some functions of the mobile station **1301** to provide vehicle diagnostic functions associated with a vehicle mirror assembly **109** with a movable sensor **101**. The MCU **1303** also delivers a display command and a switch command to the display **1307** and to the speech output switching controller, respectively. Further, the MCU **1303** exchanges information with the DSP **1305** and can access an optionally incorporated SIM card **1349** and a memory **1351**. In addition, the MCU **1303** executes various control functions required of the station. The DSP **1305** may, depending upon the implementation, perform any of a variety of conventional digital processing functions on the voice signals. Additionally, DSP **1305** determines the background noise level of the local environment from the signals detected by microphone **1311** and sets the gain of microphone **1311** to a level selected to compensate for the natural tendency of the user of the mobile station **1301**.
(130) The CODEC **1313** includes the ADC **1323** and DAC **1343**. The memory **1351** stores various data including call incoming tone data and is capable of storing other data including music data received via, e.g., the global Internet. The software module could reside in RAM memory, flash memory, registers, or any other form of writable computer-readable storage medium known in the art including non-transitory computer-readable storage medium. For example, the memory device **1351** may be, but not limited to, a single memory, CD, DVD, ROM, RAM, EEPROM, optical storage, or any other non-volatile or non-transitory storage medium capable of storing digital data.
(131) An optionally incorporated SIM card **1349** carries, for instance, important information, such as the cellular phone number, the carrier supplying service, subscription details, and security information. The SIM card **1349** serves primarily to identify the mobile station **1301** on a radio network. The card **1349** also contains a memory for storing a personal telephone number registry, text messages, and user specific mobile station settings.
(132) While the invention has been described in connection with a number of embodiments and

implementations, the invention is not so limited but covers various obvious modifications and equivalent arrangements, which fall within the purview of the appended claims. Although features of the invention are expressed in certain combinations among the claims, it is contemplated that these features can be arranged in any combination and order.

Claims

1. A method comprising: receiving an indication identifying a need for a diagnostic scan; executing the diagnostic scan by initiating a movement of a movable sensor of a vehicle mirror assembly attached to a vehicle and acquiring diagnostic data during the movement of the movable sensor by repositioning the movable sensor from inside the vehicle mirror assembly to outside the vehicle mirror assembly through a portal of the vehicle mirror assembly; analyzing the diagnostic data to generate a diagnostic report; and providing the diagnostic report as an output.
2. The method of claim 1, wherein the indication comprises at least one of: a fuel consumption of the vehicle; an activation of an alarm of the vehicle; an impact or a vibration of the vehicle; a location of the vehicle; an object detected within a proximity threshold of the vehicle; a navigation route of the vehicle; a contextual parameter; or a schedule.
3. The method of claim 1, wherein the movement includes at least one of: a sweep of the movable sensor in a controlled pattern; a deployment of the movable sensor away from the vehicle; or a change in a feature or mode of operation of the movable sensor.
4. The method of claim 1, further comprising performing at least one of: activating or operating a function on the vehicle during the diagnostic data; or providing directions or feedback for operating the vehicle during the diagnostic scan.
5. The method of claim 1, wherein the analyzing of the diagnostic data comprises processing the diagnostic data to determine a wheel or tire condition, a vehicle body condition, or a combination thereof; and wherein the diagnostic report relates to the wheel or tire condition, the vehicle body condition, or a combination thereof.
6. The method of claim 1, wherein the analyzing of the diagnostic data comprises applying a machine vision or a machine learning algorithm on the diagnostic data to detect a vehicle condition.
7. The method of claim 1, wherein the analyzing of the diagnostic data comprises using historical or reference data to identify a change in a vehicle condition based on the diagnostic data.
8. The method of claim 1, further comprising: predicting a risk to the vehicle based on the diagnostic scan.
9. The method of claim 1, further comprising: initiating a subsequent diagnostic scan at a subsequent time from the diagnostic scan; and predicting a vehicle problem based on the diagnostic scan and the subsequent diagnostic scan.
10. The method of claim 1, further comprising: querying for contextual information associated with the vehicle, an environment of the vehicle, map information associated with a location of the vehicle, or a combination thereof, wherein the analyzing of the diagnostic data is further based on the contextual information.
11. The method of claim 1, wherein the diagnostic report includes at least one of: a representation of a vehicle condition, a wheel or tire condition, or a combination thereof determined based on the diagnostic scan; a recommendation for addressing the vehicle condition, the wheel or tire condition, or a combination thereof; an executable instruction based on the vehicle condition, the wheel or tire condition, or a combination thereof; or an alert indicating the vehicle condition, the wheel or tire condition, or a combination thereof.
12. The method of claim 1, wherein the diagnostic data includes image data, optical data, sound data, infrared data, LiDAR data, or a combination thereof.
13. The method of claim 1, wherein the vehicle mirror assembly comprises: a housing attachable to the vehicle; a reflective surface coupled to the housing covering an opening of the housing; the

movable sensor coupled to the housing or contained in a space formed by the housing the reflective surface; and an actuator assembly configured to modify an orientation, a position, or a combination thereof of the movable sensor in response to a control signal.

14. A system comprising: one or more movable sensors of a vehicle; a controller for directing a movement of the one or more movable sensors; and at least one processor configured to: receive an indication identifying a need for a diagnostic scan; execute the diagnostic scan by initiating the movement of the one or more movable sensors and acquiring diagnostic data during the movement of the one or more movable sensors, wherein the movement of the one or more movable sensors includes repositioning at least one of the one or more movable sensors from inside the vehicle mirror assembly to outside the vehicle mirror assembly through a portal of the vehicle mirror assembly; and analyzing the diagnostic data to generate a diagnostic report.

15. The system of claim 14, wherein the indication comprises at least one of: a fuel consumption of the vehicle; an activation of an alarm of the vehicle; an impact or a vibration of the vehicle; a location of the vehicle; an object detected within a proximity threshold of the vehicle; a navigation route of the vehicle; a contextual parameter; or a schedule.

16. The system of claim 14, wherein the movement includes at least one of: a sweep of the one or more movable sensors in a controlled pattern; a deployment of the one or more movable sensors away from the vehicle; or a change in a feature or mode of operation of the movable sensor.

17. The system of claim 14, wherein the controller is further configured to perform at least one of: activating or operating a function on the vehicle during the diagnostic data; or providing directions or feedback for operating the vehicle during the diagnostic scan.

18. A non-transitory computer-readable storage medium carrying one or more sequences of one or more instructions which, when executed by one or more processors, cause an apparatus to perform: receiving an indication identifying a need for a diagnostic scan; executing the diagnostic scan by initiating a movement of a movable sensor of a vehicle mirror assembly attached to a vehicle and acquiring diagnostic data during the movement of the movable sensor, wherein the movement of the movable sensor repositions the movable sensor from inside the vehicle mirror assembly to outside the vehicle mirror assembly through a portal of the vehicle mirror assembly; analyzing the diagnostic data to generate a diagnostic report; and providing the diagnostic report as an output.

19. The non-transitory computer-readable storage medium of claim 18, wherein the indication comprises at least one of: a fuel consumption of the vehicle; an activation of an alarm of the vehicle; an impact or a vibration of the vehicle; a location of the vehicle; an object detected within a proximity threshold of the vehicle; a navigation route of the vehicle; a contextual parameter; or a schedule.

20. The non-transitory computer-readable storage medium of claim 18, wherein the movement includes at least one of: a sweep of the movable sensor in a controlled pattern; a deployment of the movable sensor away from the vehicle; or a change in a feature or mode of operation of the movable sensor.