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System and method for noise localization in a vehicle

Abstract

A system for noise localization for a vehicle includes a plurality of vehicle sensors. The plurality of vehicle sensors includes at least one of a microphone, a vibration sensor, a vehicle road speed sensor, and a vehicle motor speed sensor. The system also includes a controller in electrical communication with the plurality of vehicle sensors. The controller is programmed to perform a plurality of measurements of a noise produced by a defective part of the vehicle using the plurality of vehicle sensors. The controller is further programmed to determine a location of the defective part within the vehicle based at least in part on the plurality of measurements using at least one of a machine learning based method and an analytical method. The controller is further programmed to identify the defective part of the vehicle based at least in part on the location of the defective part within the vehicle.

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Background/Summary

INTRODUCTION

(1) The present disclosure relates to systems and methods for noise localization for a vehicle, and more particularly, to systems and methods for determining a location of a defective part within a vehicle.

(2) To increase occupant awareness and convenience, vehicles may be equipped with on-board diagnostic (OBD) systems which are configured to gather and store data about the operation of vehicle systems for diagnostic purposes. OBD systems may use various sensors and data analysis techniques to gather data about the operation of vehicle systems. The data may include, for example, engine/motor performance, emissions levels, transmission performance, safety system performance, and/or the like. If abnormalities are present in the data, the OBD system may save one or more diagnostic trouble codes (DTCs), and alert vehicle occupants to take the vehicle for service. Service technicians may connect diagnostic equipment to the OBD system to read saved DTCs and further analyze data gathered by the OBD system. However, OBD systems may not account for noise and/or vibration produced by degraded, damaged, and/or defective components of the vehicle. For example, purely mechanical components without any electrical sensors in communication with the OBD system may not be monitored or diagnosed by the OBD system.

(3) Thus, while on-board diagnostic systems and methods achieve their intended purpose, there is a need for a new and improved system and method for determining a location of a defective part within a vehicle.

SUMMARY

(4) According to several aspects, a system for noise localization for a vehicle is provided. The system includes a plurality of vehicle sensors. The plurality of vehicle sensors includes at least one of a microphone, a vibration sensor, a vehicle road speed sensor, and a vehicle motor speed sensor. The system also includes a controller in electrical communication with the plurality of vehicle

sensors. The controller is programmed to perform a plurality of measurements of a noise produced by a defective part of the vehicle using the plurality of vehicle sensors. The controller is further programmed to determine a location of the defective part within the vehicle based at least in part on the plurality of measurements using at least one of a machine learning based method and an analytical method. The controller is further programmed to identify the defective part of the vehicle based at least in part on the location of the defective part within the vehicle.
(5) In another aspect of the present disclosure, to determine the location of the defective part within the vehicle using the machine learning based method, the controller is further programmed to input the plurality of measurements into a machine learning algorithm. The machine learning algorithm is configured to receive the plurality of measurements as input and produce a plurality of probabilities as output. Each of the plurality of probabilities corresponds to a probability that noises within the plurality of measurements emanate from a particular location within the vehicle. To determine the location of the defective part within the vehicle using the machine learning based method, the controller is further programmed to determine the location of the defective part within the vehicle based at least in part on the plurality of probabilities.
(6) In another aspect of the present disclosure, the plurality of vehicle sensors includes at least three vibration sensors. Each of the at least three vibration sensors are affixed to a different location in the vehicle. To perform the plurality of measurements, the controller is further programmed to perform a first plurality of vibration measurements with a first vibration sensor of the plurality of vehicle sensors. To perform the plurality of measurements, the controller is further programmed to perform a second plurality of vibration measurements with a second vibration sensor of the plurality of vehicle sensors. To perform the plurality of measurements, the controller is further programmed to perform a third plurality of vibration measurements with a third vibration sensor of the plurality of vehicle sensors.
(7) In another aspect of the present disclosure, to determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to identify a vibration event based at least in part on the first, second, and third pluralities of vibration measurements. The vibration event emanates from the location of the defective part within the vehicle. The vibration event includes at least three vibration pairs. A first vibration pair is detected in the first plurality of vibration measurements, a second vibration pair is detected in the second plurality of vibration measurements, and a third vibration pair is detected in the third plurality of vibration measurements. Each of the first, second, and third vibration pairs includes a longitudinal vibration and transversal vibration. To determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to determine a first distance between the first vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the first vibration pair and a reception time of the transversal vibration of the first vibration pair. To determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to determine a second distance between the second vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the second vibration pair and a reception time of the transversal vibration of the second vibration pair. To determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to determine a third distance between the third vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the third vibration pair and a reception time of the transversal vibration of the third vibration pair. To determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to determine the location of the defective part using trilateration based at least in part on the first distance, the second distance, and the third distance.
(8) In another aspect of the present disclosure, to identify the vibration event, the controller is further programmed to perform a spectral analysis to identify a plurality of frequencies present in

the first, second, and third pluralities of vibration measurements. To identify the vibration event, the controller is further programmed to compare the plurality of frequencies to a range of normal operation frequencies. To identify the vibration event, the controller is further programmed to identify the vibration event in response to determining that at least one of the plurality of frequencies is outside of the range of normal operation frequencies.

(9) In another aspect of the present disclosure, to identify the vibration event, the controller is further programmed to input the first, second, and third pluralities of vibration measurements to a machine learning algorithm. The machine learning algorithm is configured to use unsupervised learning to separate the first, second, and third pluralities of vibration measurements into a normal measurement subset and an abnormal measurement subset. To identify the vibration event, the controller is further programmed to identify the vibration event based at least in part on the abnormal measurement subset.

(10) In another aspect of the present disclosure, the plurality of vehicle sensors includes at least three microphones. Each of the at least three microphones is affixed to a different location in the vehicle. To perform the plurality of measurements, the controller is further programmed to perform a first plurality of noise measurements with a first microphone of the at least three microphones. To perform the plurality of measurements, the controller is further programmed to perform a second plurality of noise measurements with a second microphone of the at least three microphones. To perform the plurality of measurements, the controller is further programmed to perform a third plurality of noise measurements with a third microphone of the at least three microphones.

(11) In another aspect of the present disclosure, to determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to identify a noise event based at least in part on the first, second, and third pluralities of noise measurements. The noise event emanates from the location of the defective part within the vehicle. To determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to determine a first possible location range of the defective part relative to the first of the at least three microphones and the second of the at least three microphones based at least in part on a first phase difference between the first plurality of noise measurements and the second plurality of noise measurements. To determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to determine a second possible location range of the defective part relative to the first of the at least three microphones and the third of the at least three microphones based at least in part on a second phase difference between the first plurality of noise measurements and the third plurality of noise measurements. To determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to determine a third possible location range of the defective part relative to the second of the at least three microphones and the third of the at least three microphones based at least in part on a third phase difference between the second plurality of noise measurements and the third plurality of noise measurements. To determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to determine the location of the defective part based at least in part on the first possible location range, the second possible location range, and the third possible location range.

(12) In another aspect of the present disclosure, the controller is further programmed to scan the location of the defective part for noise produced by the defective part using the beamforming microphone array.

(13) In another aspect of the present disclosure, the controller is further programmed to determine a possible location of the defective part within the vehicle based at least in part on the plurality of measurements using the analytical method. The controller is further programmed to determine the location of the defective part within the vehicle based at least in part on the plurality of measurements and the possible location using the machine learning based method.

(14) According to several aspects, a method for noise localization is provided. The method includes

performing a plurality of measurements of a noise produced by a defective part using a plurality of vehicle sensors. The method also includes determining a location of the defective part based at least in part on the plurality of measurements using at least one of a machine learning based method and an analytical method, and identifying the defective part based at least in part on the location of the defective part.

(15) In another aspect of the present disclosure, determining the location of the defective part using the machine learning based method further may include inputting the plurality of measurements into a machine learning algorithm. The machine learning algorithm is configured to receive the plurality of measurements as input and produce a plurality of probabilities as output. Each of the plurality of probabilities corresponds to a probability that noises within the plurality of measurements emanate from a particular location. Determining the location of the defective part using the machine learning based method further may include determining the location of the defective part based at least in part on the plurality of probabilities.

(16) In another aspect of the present disclosure, performing the plurality of measurements further may include performing a first plurality of vibration measurements with a first vibration sensor of the plurality of vehicle sensors. Performing the plurality of measurements further may include performing a second plurality of vibration measurements with a second vibration sensor of the plurality of vehicle sensors. Performing the plurality of measurements further may include performing a third plurality of vibration measurements with a third vibration sensor of the plurality of vehicle sensors.

(17) In another aspect of the present disclosure, determining the location of the defective part using the analytical method further may include identifying a vibration event based at least in part on the first, second, and third pluralities of vibration measurements. The vibration event emanates from the location of the defective part. The vibration event includes at least three vibration pairs. A first vibration pair is detected in the first plurality of vibration measurements, a second vibration pair is detected in the second plurality of vibration measurements, and a third vibration pair is detected in the third plurality of vibration measurements. Each of the first, second, and third vibration pairs includes a longitudinal vibration and transversal vibration. Determining the location of the defective part using the analytical method further may include determining a first distance between the first vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the first vibration pair and a reception time of the transversal vibration of the first vibration pair. Determining the location of the defective part using the analytical method further may include determining a second distance between the second vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the second vibration pair and a reception time of the transversal vibration of the second vibration pair. Determining the location of the defective part using the analytical method further may include determining a third distance between the third vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the third vibration pair and a reception time of the transversal vibration of the third vibration pair. Determining the location of the defective part using the analytical method further may include determining the location of the defective part using trilateration based at least in part on the first distance, the second distance, and the third distance.

(18) In another aspect of the present disclosure, identifying the vibration event further may include performing a spectral analysis to identify a plurality of frequencies present in the first, second, and third pluralities of vibration measurements. Identifying the vibration event further may include comparing the plurality of frequencies to a range of normal operation frequencies. Identifying the vibration event further may include identifying the vibration event in response to determining that at least one of the plurality of frequencies is outside of the range of normal operation frequencies.

(19) In another aspect of the present disclosure, performing the plurality of measurements further may include performing a first plurality of noise measurements with a first microphone of at least

three microphones. Performing the plurality of measurements further may include performing a second plurality of noise measurements with a second microphone of the at least three microphones. Performing the plurality of measurements further may include performing a third plurality of noise measurements with a third microphone of the at least three microphones.

(20) In another aspect of the present disclosure, determining the location of the defective part using the analytical method further may include identifying a noise event based at least in part on the first, second, and third pluralities of noise measurements. The noise event emanates from the location of the defective part. Determining the location of the defective part using the analytical method further may include determining a first possible location range of the defective part relative to the first of the at least three microphones and the second of the at least three microphones based at least in part on a first phase difference between the first plurality of noise measurements and the second plurality of noise measurements. Determining the location of the defective part using the analytical method further may include determining a second possible location range of the defective part relative to the first of the at least three microphones and the third of the at least three microphones based at least in part on a second phase difference between the first plurality of noise measurements and the third plurality of noise measurements. Determining the location of the defective part using the analytical method further may include determining a third possible location range of the defective part relative to the second of the at least three microphones and the third of the at least three microphones based at least in part on a third phase difference between the second plurality of noise measurements and the third plurality of noise measurements. Determining the location of the defective part using the analytical method further may include determining the location of the defective part based at least in part on the first possible location range, the second possible location range, and the third possible location range.

(21) According to several aspects, a system for noise localization for a vehicle is provided. The system includes a plurality of vehicle sensors. The plurality of vehicle sensors includes at least three microphones. Each of the at least three microphones is affixed to a different location in the vehicle. The system further includes a controller in electrical communication with the plurality of vehicle sensors. The controller is programmed to perform a plurality of measurements of a noise produced by a defective part of the vehicle using each of the at least three microphones. The controller is further programmed to determine a location of the defective part within the vehicle based at least in part on the plurality of measurements. The controller is further programmed to identify the defective part of the vehicle based at least in part on the location of the defective part within the vehicle.

(22) In another aspect of the present disclosure, to perform the plurality of measurements, the controller is further programmed to perform a first plurality of noise measurements with a first microphone of the at least three microphones. To perform the plurality of measurements, the controller is further programmed to perform a second plurality of noise measurements with a second microphone of the at least three microphones. To perform the plurality of measurements, the controller is further programmed to perform a third plurality of noise measurements with a third microphone of the at least three microphones.

(23) In another aspect of the present disclosure, to determine the location of the defective part within the vehicle, the controller is further programmed to identify a noise event based at least in part on the first, second, and third pluralities of noise measurements. The noise event emanates from the location of the defective part within the vehicle. To determine the location of the defective part within the vehicle, the controller is further programmed to determine a first possible location range of the defective part relative to the first of the at least three microphones and the second of the at least three microphones based at least in part on a first phase difference between the first plurality of noise measurements and the second plurality of noise measurements. To determine the location of the defective part within the vehicle, the controller is further programmed to determine a second possible location range of the defective part relative to the first of the at least three

microphones and the third of the at least three microphones based at least in part on a second phase difference between the first plurality of noise measurements and the third plurality of noise measurements. To determine the location of the defective part within the vehicle, the controller is further programmed to determine a third possible location range of the defective part relative to the second of the at least three microphones and the third of the at least three microphones based at least in part on a third phase difference between the second plurality of noise measurements and the third plurality of noise measurements. To determine the location of the defective part within the vehicle, the controller is further programmed to determine the location of the defective part based at least in part on the first possible location range, the second possible location range, and the third possible location range.
(24) Further areas of applicability will become apparent from the description provided herein. It should be understood that the description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The drawings described herein are for illustration purposes only and are not intended to limit the scope of the present disclosure in any way.
(2) FIG. **1** is a schematic diagram of a system for noise localization for a vehicle, according to an exemplary embodiment;
(3) FIG. **2** is a schematic diagram of a first embodiment of the system for noise localization for a vehicle, according to an exemplary embodiment;
(4) FIG. **3** is a schematic diagram of a second embodiment of the system for noise localization for a vehicle, according to an exemplary embodiment;
(5) FIG. **4** is a flowchart of a method for noise localization, according to an exemplary embodiment;
(6) FIG. **5** is a flowchart of a first embodiment of a method for determining a location of a defective part, according to an exemplary embodiment;
(7) FIG. **6** is a flowchart of a second embodiment of a method for determining a location of a defective part, according to an exemplary embodiment;
(8) FIG. **7** is a flowchart of a first embodiment of a method for identifying a vibration event, according to an exemplary embodiment;
(9) FIG. **8** is a flowchart of a second embodiment of a method for identifying a vibration event, according to an exemplary embodiment; and
(10) FIG. **9** is a flowchart of a third embodiment of a method for determining a location of a defective part, according to an exemplary embodiment.
DETAILED DESCRIPTION
(11) The following description is merely exemplary in nature and is not intended to limit the present disclosure, application, or uses.
(12) Upon degradation, malfunction, and/or failure, electrical and/or mechanical components of vehicles may produce abnormal vibrations and/or noises. Service technicians may evaluate abnormal noises produced by the vehicle as part of a diagnostic process. However, some noises and/or vibrations are imperceptible to the human senses, due to, for example, volume and/or frequency levels. Additionally, locating a defective part which is a source of abnormal noise and/or vibration in a complex vehicle system may be challenging, especially if the abnormal noise and/or vibration is produced predominately when the vehicle is in motion. Accordingly, the present disclosure provides a new and improved system and method to locate a defective part within a vehicle which is producing abnormal noise and/or vibration.

(13) Referring to FIG. **1**, a system for noise localization for a vehicle is illustrated and generally indicated by reference number **10**. The system **10** is shown with an exemplary vehicle **12**. While a passenger vehicle is illustrated, it should be appreciated that the vehicle **12** may be any type of vehicle without departing from the scope of the present disclosure. The system **10** generally includes a controller **14** and a plurality of vehicle sensors **16**.
(14) The controller **14** is used to implement a method **100** for noise localization, as will be described below. The controller **14** includes at least one processor **18** and a non-transitory computer readable storage device or media **20**. The processor **18** may be a custom made or commercially available processor, a central processing unit (CPU), a graphics processing unit (GPU), an auxiliary processor among several processors associated with the controller **14**, a semiconductor-based microprocessor (in the form of a microchip or chip set), a macroprocessor, a combination thereof, or generally a device for executing instructions. The computer readable storage device or media **20** may include volatile and nonvolatile storage in read-only memory (ROM), random-access memory (RAM), and keep-alive memory (KAM), for example. KAM is a persistent or non-volatile memory that may be used to store various operating variables while the processor **18** is powered down. The computer-readable storage device or media **20** may be implemented using a number of memory devices such as PROMs (programmable read-only memory), EPROMs (electrically PROM), EEPROMs (electrically erasable PROM), flash memory, or another electric, magnetic, optical, or combination memory devices capable of storing data, some of which represent executable instructions, used by the controller **14** to control various systems of the vehicle **12**. The controller **14** may also consist of multiple controllers which are in electrical communication with each other. The controller **14** may be inter-connected with additional systems and/or controllers of the vehicle **12**, allowing the controller **14** to access data such as, for example, speed, acceleration, braking, and steering angle of the vehicle **12**.
(15) The controller **14** is in electrical communication with the plurality of vehicle sensors **16**. In an exemplary embodiment, the electrical communication is established using, for example, a CAN network, a FLEXRAY network, a local area network (e.g., WiFi, ethernet, and the like), a serial peripheral interface (SPI) network, or the like. It should be understood that various additional wired and wireless techniques and communication protocols for communicating with the controller **14** are within the scope of the present disclosure.
(16) The plurality of vehicle sensors **16** are used to detect and measure vibrational and/or sound waves produced by a defective part **22** within the vehicle **12**. In the scope of the present disclosure, the defective part **22** is a mechanical and/or electrical component which requires service. The defective part **22** may include, for example, a suspension component (e.g., a tie rod, a shock, a strut, and/or the like), an engine component (e.g., an ignition coil, a crankshaft, a timing chain, and/or the like), a transmission component, an electric drivetrain component (e.g., an electric motor), and/or the like. Due to a deteriorated state of the defective part **22**, the defective part **22** may produce noise and/or vibration during operation which may be detected by the plurality of vehicle sensors **16**.
(17) Referring to FIG. **2**, a first exemplary embodiment **10***a* of the system **10** is shown. In the first exemplary embodiment **10***a*, the plurality of vehicle sensors **16** includes at least a first vibration sensor **24***a*, a second vibration sensor **24***b*, and a third vibration sensor **24***c*.
(18) The first vibration sensor **24***a*, the second vibration sensor **24***b*, and the third vibration sensor **24***c* are used to detect vibrations produced by the defective part **22** and transmitted through a structure of the vehicle **12**. In an exemplary embodiment, the first vibration sensor **24***a*, the second vibration sensor **24***b*, and the third vibration sensor **24***c* are affixed to different locations within the vehicle **12**.
(19) In a non-limiting example, the first vibration sensor **24***a* is affixed near a front portion of the vehicle **12** (e.g., in an engine bay of the vehicle **12**). The second vibration sensor **24***b* is affixed near a middle of the portion of the vehicle **12** (e.g., on a frame of the vehicle **12** in a passenger

compartment of the vehicle **12**). The third vibration sensor **24***c* is affixed near a rear portion of the vehicle **12** (e.g., in a cargo area of the vehicle **12**). In an exemplary embodiment, the first vibration sensor **24***a*, the second vibration sensor **24***b*, and the third vibration sensor **24***c* are fixedly bonded to structural components of the vehicle **12** (e.g., a frame of the vehicle **12**, a body pillar of the vehicle **12**, and/or the like), such that vibrations are effectively transmitted to the first vibration sensor **24***a*, the second vibration sensor **24***b*, and the third vibration sensor **24***c*.

(20) In an exemplary embodiment, the first vibration sensor **24***a*, the second vibration sensor **24***b*, and the third vibration sensor **24***c* can measure and distinguish between transversal vibrations and longitudinal vibrations. In the scope of the present disclosure, transversal vibrations are vibrations which displace particles of a medium transmitting the transversal vibration perpendicular to a direction of travel of the transversal vibration wave in the medium. Longitudinal vibrations are vibrations which displace particles of a medium transmitting the longitudinal vibration parallel to a direction of travel of the longitudinal vibration wave in the medium. Transversal and longitudinal vibrations travel at different speeds. In an exemplary embodiment, the first vibration sensor **24***a*, the second vibration sensor **24***b*, and the third vibration sensor **24***c* are accelerometers. It should be understood that the first vibration sensor **24***a*, the second vibration sensor **24***b*, and the third vibration sensor **24***c* may be any sensors capable of detecting and measuring transversal vibrations and longitudinal vibrations. In some embodiments, the first vibration sensor **24***a*, the second vibration sensor **24***b*, and the third vibration sensor **24***c* may each further include a microphone.

(21) Referring to FIG. **3**, a second exemplary embodiment **10***b* of the system **10** is shown. In the second exemplary embodiment **10***b*, the plurality of vehicle sensors **16** includes at least a first microphone **26***a*, a second microphone **26***b*, and a third microphone **26***c*.

(22) The first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c* are used to detect noises produced by the defective part **22**. In an exemplary embodiment, the first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c* are affixed to different locations within the vehicle **12**.

(23) In a non-limiting example, the first microphone **26***a* is affixed near a front portion of the vehicle **12** (e.g., in an engine bay of the vehicle **12**). The second microphone **26***b* is affixed near a middle of the portion of the vehicle **12** (e.g., on a frame of the vehicle **12** in a passenger compartment of the vehicle **12**). The third microphone **26***c* is affixed near a rear portion of the vehicle **12** (e.g., in a cargo area of the vehicle **12**).

(24) In an exemplary embodiment, each of the first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c* includes at least one microphone. Based on differences in time of arrival and/or power level of received noises between the first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c*, a direction of the location of the defective part **22** relative to each of the first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c* may be determined.

(25) For a given one of the first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c*, a direction of the location of the defective part **22** may be ambiguous if the defective part **22** is located in a particular region (sometimes referred to as the cone of confusion **30**) relative to the given pair of microphones. An axis of the cone of confusion **30** lies along an axis between the pair of microphones. Noises emanating from a location along a circumference of a circular conical slice of the cone of confusion **30** may not be unambiguously located by two microphones in some instances. This is because, for noises emanating from a location along a circumference of a circular conical slice of the cone of confusion **30**, there is no difference in time of arrival or power level between signals received by any two of the first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c*. Therefore, in the second exemplary embodiment **10***b*, the plurality of vehicle sensors **16** includes three microphones (i.e., the first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c*) such that the defective part **22** may be accurately located.

(26) In a non-limiting example, the each of the first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c* includes at least one microelectromechanical systems (MEMS) microphone (e.g., a microphone having a pressure-sensitive diaphragm etched directly into a silicon wafer). It should be understood that additional types of microphones which are configured to convert acoustic waves to electrical signals (e.g., digital and/or analog electrical signals) are included in the scope of the present disclosure.
(27) In an exemplary embodiment, one or more of the first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c* may include a beamforming microphone array. In the scope of the present disclosure, "beamforming" refers to the process of forming a directional beam of sensitivity toward a desired noise source while suppressing noise and interference from other directions. In a non-limiting example, the beamforming microphone array uses signal processing algorithms to analyze signals received from individual microphones and selectively combine them to create the directional beam of sensitivity. As will be discussed in greater detail below, once a probable location of the defective part **22** has been established, the beamforming microphone array may be used to scan the probable location to confirm and/or increase the accuracy of the determination of the location of the defective part **22**.
(28) It should be understood that in both the first exemplary embodiment **10***a* and the second exemplary embodiment **10***b*, the plurality of vehicle sensors **16** further includes sensors to determine performance data about the vehicle **12**. In an exemplary embodiment, the plurality of vehicle sensors **16** further includes at least one of a motor speed sensor, a motor torque sensor, a road speed sensor, an electric drive motor voltage and/or current sensor, an accelerator pedal position sensor, a coolant temperature sensor, a cooling fan speed sensor, and a transmission oil temperature sensor.
(29) In another exemplary embodiment, the plurality of vehicle sensors **16** further includes sensors to determine information about the environment within the vehicle **12**, such as, for example, a seat occupancy sensor, a cabin air temperature sensor, a cabin motion detection sensor, a cabin camera, a cabin microphone, and/or the like.
(30) In another exemplary embodiment, the plurality of vehicle sensors **16** further includes sensors to determine information about the environment surrounding the vehicle **12**, for example, an ambient air temperature sensor, a barometric pressure sensor, and/or a photo and/or video camera which is positioned to view an environment in front of the vehicle **12**.
(31) Referring to FIG. **4**, a flowchart of the method **100** for noise localization is shown. The method **100** begins at block **102** and proceeds to block **104**. At block **104**, the controller **14** performs a plurality of measurements using the plurality of vehicle sensors **16** and determines a location of the defective part **22**, as will be discussed in greater detail below. After block **104**, the method **100** proceeds to block **106**.
(32) At block **106**, the controller **14** identifies the defective part **22** based at least in part on the location of the defective part **22** determined at block **104**. In an exemplary embodiment, the controller **14** uses a lookup table (LUT) stored in the media **20** of the controller **14** to identify the defective part **22**. The LUT has a key column (i.e., a key column for the location of the defective part **22**) and one value column (i.e., a name of the defective part **22**, a part number of the defective part **22**, and/or the like). In an exemplary embodiment, the LUT includes a plurality of rows, each of the plurality of rows mapping a unique location in the key column to a value in the value column (i.e., the identity of the defective part **22**). The LUT is stored in the media **20** of the controller **14**. In an exemplary embodiment, the plurality of rows of the LUT are predetermined. In another exemplary embodiment, the plurality of rows of the LUT may be modified by the occupant, using, for example, a human-interface device. In yet another exemplary embodiment, the plurality of rows of the LUT may be updated over-the-air (OTA). It should be understood that any method (e.g., programmatic data structure, logic equation, mathematical function, and/or the like) of mapping a key to a value is within the scope of the present disclosure.

(33) In an exemplary embodiment, after identifying the defective part **22**, the controller **14** may take an action based at least in part on the identification of the defective part **22**. In an exemplary embodiment, the controller **14** provides a notification to an occupant of the vehicle **12**, using, for example, an infotainment system or other display of the vehicle **12**. In another exemplary embodiment, the controller **14** transmits information about the identity of the defective part **22** to an external system, for example, to a diagnostic computer device operated by a service technician and in electrical communication with the controller **14**. In another exemplary embodiment, the controller **14** saves a diagnostic trouble code (DTC) in the media **20** and/or in an onboard diagnostic module of the vehicle **12**. After block **106**, the method **100** proceeds to block **108**.
(34) At block **108**, the method **100** proceeds to enter a standby state. In an exemplary embodiment, the controller **14** repeatedly exits the standby state **108** and restarts the method **100** at block **102**. In a non-limiting example, the controller **14** exits the standby state **108** and restarts the method **100** on a timer, for example, every three hundred milliseconds.
(35) Referring to FIG. **5**, a flowchart of a first exemplary embodiment **104***a* of block **104** is shown. The first exemplary embodiment **104***a* of block **104** may be used with either embodiment **10***a* or embodiment **10***b* of the system **10**, or a combination of embodiments **10***a* and **10***b*. The first exemplary embodiment **104***a* of block **104** is also referred to as a machine learning based method for determining the location of the defective part **22**. The first exemplary embodiment **104***a* of block **104** begins at block **502**. At block **502**, the controller **14** performs a plurality of measurements using the plurality of vehicle sensors **16**. In an exemplary embodiment, the plurality of measurements includes one or more of: noise measurements, vibration measurements, performance data, environmental data, and/or the like. In a non-limiting example, the plurality of measurements further includes data stored in the media **20** of the controller **14**, such as, for example, vehicle service history data. After block **502**, the first exemplary embodiment **104***a* of block **104** proceeds to block **504**.
(36) At block **504**, the controller **14** inputs the plurality of measurements acquired at block **502** into a machine learning algorithm. In an exemplary embodiment, the machine learning algorithm is configured to receive the plurality of measurements as input and produce a plurality of probabilities as output. Each of the plurality of probabilities corresponds to a probability that noises detected within the plurality of measurements emanate from a particular location within the vehicle (i.e., the location of the defective part **22**). In a non-limiting example, the machine learning algorithm includes multiple layers, including an input layer and an output layer, as well as one or more hidden layers. The input layer receives the plurality of measurements acquired at block **502** as inputs. The inputs are then passed on to the hidden layers. Each hidden layer applies a transformation (e.g., a non-linear transformation) to the data and passes the result to the next hidden layer until the final hidden layer. The output layer produces the plurality of probabilities.
(37) To train the machine learning algorithm, a dataset of inputs and the corresponding locations of defective parts is used. The algorithm is trained by adjusting internal weights between nodes in each hidden layer to minimize prediction error. During training, an optimization technique (e.g., gradient descent) is used to adjust the internal weights to reduce the prediction error. The training process is repeated with the entire dataset until the prediction error is minimized, and the resulting trained model is then used to classify new input data.
(38) After sufficient training of the machine learning algorithm, the algorithm is capable of accurately and precisely determining the plurality of probabilities based on the plurality of measurements acquired at block **502**. By adjusting the weights between the nodes in each hidden layer during training, the algorithm "learns" to recognize patterns in the data that are indicative of various locations of a defective part **22** within the vehicle **12**. After block **504**, the first exemplary embodiment **104***a* of block **104** proceeds to block **506**.
(39) At block **506**, the controller **14** determines the location of the defective part **22** within the vehicle **12** based at least in part on the plurality of probabilities determined at block **504**. In an

exemplary embodiment, the location of the defective part **22** is determined to be the location corresponding to the highest probability of the plurality of probabilities determined at block **504**. After block **506**, the first exemplary embodiment **104***a* of block **104** is concluded, and the method **100** proceeds as discussed above.

(40) Referring to FIG. **6**, a flowchart of a second exemplary embodiment **104***b* of block **104** is shown. The second exemplary embodiment **104***b* of block **104** is used with embodiment **10***a* of the system **10**. The second exemplary embodiment **104***b* of block **104** is also referred to as a first analytical method for determining the location of the defective part **22**. The second exemplary embodiment **104***b* of block **104** begins at blocks **602**, **604**, and **606**. At blocks **602**, **604**, and **606**, the controller **14** performs the plurality of measurements.

(41) At block **602**, the controller **14** performs a first plurality of vibration measurements using the first vibration sensor **24***a*. In an exemplary embodiment, the first plurality of vibration measurements includes continuously recording vibration data at a predetermined frequency (e.g., one hundred hertz) for a predetermined time period (e.g., five seconds). After block **602**, the second exemplary embodiment **104***b* of block **104** proceeds to block **608**, as will be discussed in greater detail below.

(42) At block **604**, the controller **14** performs a second plurality of vibration measurements using the second vibration sensor **24***b*. In an exemplary embodiment, the second plurality of vibration measurements includes continuously recording vibration data at a predetermined frequency (e.g., one hundred hertz) for a predetermined time period (e.g., five seconds). After block **604**, the second exemplary embodiment **104***b* of block **104** proceeds to block **608**, as will be discussed in greater detail below.

(43) At block **606**, the controller **14** performs a third plurality of vibration measurements using the third vibration sensor **24***c*. In an exemplary embodiment, the third plurality of vibration measurements includes continuously recording vibration data at a predetermined frequency (e.g., one hundred hertz) for a predetermined time period (e.g., five seconds). After block **606**, the second exemplary embodiment **104***b* of block **104** proceeds to block **608**.

(44) At block **608**, the controller **14** identifies a vibration event based at least in part on the first plurality of vibration measurements, the second plurality of vibration measurements, and the third plurality of vibration measurements performed at blocks **602**, **604**, and **606**. Referring to FIG. **2** with continued reference to FIG. **6**, in an exemplary embodiment, the vibration event includes at least a first vibration pair **32***a*, a second vibration pair **32***b*, and a third vibration pair **32***c* (i.e., at least three vibration pairs **32***a*, **32***b*, **32***c*). The first vibration pair **32***a* is detected in the first plurality of vibration measurements (i.e., the first vibration pair **32***a* is detected by the first vibration sensor **24***a*). The second vibration pair **32***b* is detected in the second plurality of vibration measurements (i.e., the second vibration pair **32***b* is detected by the second vibration sensor **24***b*). The third vibration pair **32***c* is detected in the third plurality of vibration measurements (i.e., the third vibration pair **32***c* is detected by the third vibration sensor **24***c*). Each of the first vibration pair **32***a*, the second vibration pair **32***b*, and the third vibration pair **32***c* includes a longitudinal vibration **34***a* and a transversal vibration **34***b*. It should be understood that while the first vibration pair **32***a*, the second vibration pair **32***b*, and the third vibration pair **32***c* are depicted as individual waves, the first vibration pair **32***a*, the second vibration pair **32***b*, and the third vibration pair **32***c* may also be part of a wavefront radiating radially outward from the defective part **22**. Identification of the vibration event will be discussed in greater detail below. After block **608**, the second exemplary embodiment **104***b* of block **104** proceeds to block **610**.

(45) At block **610**, if the vibration event was not identified at block **608**, the second exemplary embodiment **104***b* of block **104** proceeds to enter the standby state at block **108**. If the vibration event was identified at block **608**, the second exemplary embodiment **104***b* of block **104** proceeds to blocks **612**, **614**, and **616**.

(46) At block **612**, the controller **14** determines a first distance between the first vibration sensor

24*a* and the defective part **22**. Referring to FIG. **2** with continued reference to FIG. **6**, in an exemplary embodiment, to determine the first distance, the controller **14** determines a first difference **36***a* between a reception time of the longitudinal vibration **34***a* of the first vibration pair **32***a* and a reception time of the transversal vibration **34***b* of the first vibration pair **32***a* based at least in part on the first plurality of vibration measurements performed at block **602**. As discussed above, the longitudinal vibration **34***a* and the transversal vibration **34***b* propagate at different speeds through the structure of the vehicle **12**. Therefore, the first difference **36***a* is positively correlated with the first distance (e.g., the first difference **36***a* may be proportional to the first distance). After block **612**, the second exemplary embodiment **104***b* of block **104** proceeds to block **618**, as will be discussed in greater detail below.

(47) At block **614**, the controller **14** determines a second distance between the second vibration sensor **24***b* and the defective part **22**. Referring to FIG. **2** with continued reference to FIG. **6**, in an exemplary embodiment, to determine the second distance, the controller **14** determines a second difference **36***b* between a reception time of the longitudinal vibration **34***a* of the second vibration pair **32***b* and a reception time of the transversal vibration **34***b* of the second vibration pair **32***b* based at least in part on the second plurality of vibration measurements performed at block **604**. As discussed above, the longitudinal vibration **34***a* and the transversal vibration **34***b* propagate at different speeds through the structure of the vehicle **12**. Therefore, the second difference **36***b* is positively correlated with the second distance (e.g., the second difference **36***b* may be proportional to the second distance). After block **614**, the second exemplary embodiment **104***b* of block **104** proceeds to block **618**, as will be discussed in greater detail below.

(48) At block **616**, the controller **14** determines a third distance between the third vibration sensor **24***c* and the defective part **22**. Referring to FIG. **2** with continued reference to FIG. **6**, in an exemplary embodiment, to determine the third distance, the controller **14** determines a third difference **36***c* between a reception time of the longitudinal vibration **34***a* of the third vibration pair **32***c* and a reception time of the transversal vibration **34***b* of the third vibration pair **32***c* based at least in part on the third plurality of vibration measurements performed at block **606**. As discussed above, the longitudinal vibration **34***a* and the transversal vibration **34***b* propagate at different speeds through the structure of the vehicle **12**. Therefore, the third difference **36***c* is positively correlated with the third distance (e.g., the third difference **36***c* may be proportional to the third distance). After block **616**, the second exemplary embodiment **104***b* proceeds to block **618**.

(49) At block **618**, the controller **14** determines the location of the defective part **22**. In an exemplary embodiment, to determine the location of the defective part **22**, the controller **14** uses trilateration based on the first distance determined at block **612**, the second distance determined at block **614**, and the third distance determined at block **616**. In the scope of the present disclosure, trilateration is a mathematical technique used to determine the position of an object based on distance measurements between the object and three known reference points. In a non-limiting example, the process of trilateration involves determining the intersection point of three spheres. A first sphere is centered at the location of the first vibration sensor **24***a* and has a radius equal to the first distance. A second sphere is centered at the location of the second vibration sensor **24***b* and has a radius equal to the second distance. A third sphere is centered at the location of the third vibration sensor **24***c* and has a radius equal to the third distance. After block **618**, the second exemplary embodiment **104***b* of block **104** is concluded, and the method **100** proceeds as discussed above.

(50) Referring to FIG. **7**, a flowchart of a first exemplary embodiment **608***a* of block **608** for identifying the vibration event is provided. The first exemplary embodiment **608***a* of block **608** begins at block **702**. At block **702**, the controller **14** performs a spectral analysis of the first plurality of vibration measurements performed at block **602**, the second plurality of vibration measurements performed at block **604**, and the third plurality of vibration measurements performed at block **606**. In an exemplary embodiment, the spectral analysis includes identifying a plurality of frequencies present in the first, second, and third pluralities of vibration measurements. In a non-

limiting example, the spectral analysis further includes identifying an intensity of each of the plurality of frequencies present in the first, second, and third pluralities of vibration measurements. In a non-limiting example, the spectral analysis is performed using a Fourier transform (e.g., using a fast Fourier transform algorithm). After block **702**, the first exemplary embodiment **608***a* of block **608** proceeds to block **704**.

(51) At block **704**, the controller **14** compares the plurality of frequencies identified at block **702** to a range of normal operation frequencies. In the scope of the present disclosure, the range of normal operation frequencies includes vibration frequencies which are produced during normal operation of the vehicle **12** (e.g., normal vibration produced by an internal combustion engine of the vehicle **12**). In an exemplary embodiment, the range of normal vibration frequencies is stored in the media **20** of the controller **14**. Therefore, if one or more of the plurality of frequencies identified at block **702** is outside of the range of normal operation frequencies, the vibration event is determined to be identified at block **610**, as discussed above. After block **704**, the first exemplary embodiment **608***a* of block **608** is concluded, and the second exemplary embodiment **104***b* of block **104** proceeds as described above.

(52) Referring to FIG. **8**, a flowchart of a second exemplary embodiment **608***b* of block **608** for identifying the vibration event is provided. The second exemplary embodiment **608***b* of block **608** begins at block **802**. At block **802**, the controller **14** inputs the first plurality of vibration measurements performed at block **602**, the second plurality of vibration measurements performed at block **604**, and the third plurality of vibration measurements performed at block **606** into a machine learning algorithm. In an exemplary embodiment, the machine learning algorithm is configured to use unsupervised learning to separate the vibration measurements of the first, second, and third pluralities of vibration measurements into a normal measurement subset and an abnormal measurement subset. In a non-limiting example, unsupervised learning is used to analyze the first, second, and third pluralities of vibration measurements and identify patterns and/or trends. The normal measurement subset includes vibrations caused by normal operation of the vehicle **12**. The abnormal measurement subset includes vibrations caused by the defective parts (e.g., the defective part **22**). Therefore, if one or more of the vibration measurements of the first, second, and third pluralities of vibration measurements is categorized in the abnormal measurement subset, the vibration event is determined to be identified at block **610**, as discussed above. After block **804**, the second exemplary embodiment **608***b* of block **608** is concluded, and the second exemplary embodiment **104***b* of block **104** proceeds as described above.

(53) Referring to FIG. **9**, a flowchart of a third exemplary embodiment **104***c* of block **104** is shown. The third exemplary embodiment **104***c* is used with embodiment **10***b* of the system **10**. The third exemplary embodiment **104***c* of block **104** is also referred to as a second analytical method for determining the location of the defective part **22**. The third exemplary embodiment **104***c* begins at blocks **902**, **904**, and **906**. At blocks **902**, **904**, and **906**, the controller **14** performs the plurality of measurements. At block **902**, the controller **14** performs a first plurality of noise measurements using the first microphone **26***a*. After block **902**, the third exemplary embodiment **104***c* of block **104** proceeds to block **914**, as will be discussed in greater detail below.

(54) At block **904**, the controller **14** performs a second plurality of noise measurements using the second microphone **26***b*. After block **904**, the third exemplary embodiment **104***c* of block **104** proceeds to block **914**, as will be discussed in greater detail below. At block **906**, the controller **14** performs a third plurality of noise measurements using the third microphone **26***c*. After block **906**, the third exemplary embodiment **104***c* of block **104** proceeds to block **914**, as will be discussed in greater detail below.

(55) At block **914**, the controller **14** identifies a noise event based at least in part on the first plurality of noise measurements determined at block **902**, the second plurality of noise measurements determined at block **904**, and the third plurality of noise measurements determined at block **906**. In an exemplary embodiment, to identify the noise event, the controller **14** first

performs a spectral analysis of the first, second, and third pluralities of noise measurements. In an exemplary embodiment, the spectral analysis includes identifying a plurality of noise frequencies present in the first, second, and third, pluralities of noise measurements. Then, the controller **14** compares the plurality of noise frequencies to a range of normal operation noise frequencies. If one or more of the plurality of noise frequencies is outside of the range of normal operation frequencies, the noise event is determined to be identified. After block **914**, the third exemplary embodiment **104***c* of block **104** proceeds to block **916**.

(56) At block **916**, if the noise event was not identified at block **914**, the third exemplary embodiment **104***c* of block **104** proceeds to enter the standby state at block **108**. If the noise event was identified at block **914** (e.g., if one or more of the plurality of noise frequencies is outside of the range of normal operation frequencies), the third exemplary embodiment **104***c* of block **104** proceeds to blocks **918**, **920**, and **922**.

(57) At block **918**, the controller **14** identifies a first possible location range of the defective part **22** relative to the first microphone **26***a* and the second microphone **26***b*. In an exemplary embodiment, the first possible location range is determined based at least in part on a first phase difference between the first plurality of noise measurements performed at block **902** and the second plurality of noise measurements performed at block **904**. The first phase difference quantifies a difference in time of arrival of received noises, as discussed above. Furthermore, as discussed above, the first possible location range may include a range of possible locations if the defective part **22** is located on the cone of confusion **30** of the first microphone **26***a* and/or the second microphone **26***b*. Therefore, the first possible location range may be represented by a three-dimensional cone shape. In some cases, if the defective part **22** is located outside of the cone of confusion **30**, the first possible location range may contain only one possible location. After block **918**, the third exemplary embodiment **104***c* of block **104** proceeds to block **924**, as will be discussed in greater detail below.

(58) At block **920**, the controller **14** identifies a second possible location range of the defective part **22** relative to the first microphone **26***a* and the third microphone **26***c*. In an exemplary embodiment, the second possible location range is determined based at least in part on a second phase difference between the first plurality of noise measurements performed at block **902** and the third plurality of noise measurements performed at block **906**. The second phase difference quantifies a difference in time of arrival of received noises, as discussed above. Furthermore, as discussed above, the second possible location range may include a range of possible locations if the defective part **22** is located on the cone of confusion **30** of the first microphone **26***a* and/or the third microphone **26***c*. Therefore, the second possible location range may be represented by a three-dimensional cone shape. In some cases, if the defective part **22** is located outside of the cone of confusion **30**, the second possible location range may contain only one possible location. After block **920**, the third exemplary embodiment **104***c* of block **104** proceeds to block **924**, as will be discussed in greater detail below.

(59) At block **922**, the controller **14** identifies a third possible location range of the defective part **22** relative to the second microphone **26***b* and the third microphone **26***c*. In an exemplary embodiment, the third possible location range is determined based at least in part on a third phase difference between the second plurality of noise measurements performed at block **904** and the third plurality of noise measurements performed at block **906**. The third phase difference quantifies a difference in time of arrival of received noises, as discussed above. Furthermore, as discussed above, the third possible location range may include a range of possible locations if the defective part **22** is located on the cone of confusion **30** of the second microphone **26***b* and/or the third microphone **26***c*. Therefore, the third possible location range may be represented by a three-dimensional cone shape. In some cases, if the defective part **22** is located outside of the cone of confusion **30**, the third possible location range may contain only one possible location. After block **922**, the third exemplary embodiment **104***c* of block **104** proceeds to block **924**.

(60) At block **924**, the controller **14** determines the location of the defective part **22** based at least in part on the first possible location range determined at block **918**, the second possible location range determined at block **920**, and third possible location range determined at block **922**. In an exemplary embodiment, to determine the location of the defective part **22**, the controller **14** determines an intersection of a first three-dimensional cone which represents the first possible location range determined at block **918**, a second three-dimensional cone which represents the second possible location range determined at block **920**, and a third three-dimensional cone which represents the third possible location range determined at block **922**. The location of the defective part **22** is determined to be at the intersection of the first three-dimensional cone, the second three-dimensional cone, and the third three-dimensional cone. After block **924**, the third exemplary embodiment **104***c* of block **104** proceeds to block **926**.
(61) At block **926**, the controller **14** scans the location determined at block **924** using one or more of the first microphone **26***a*, the second microphone **26***b*, and the third microphone **26***c* configured as a beamforming microphone array. In another embodiment, the controller **14** scans one of the first three-dimensional cone, the second three-dimensional cone, and the third three-dimensional cone. Therefore, a more localized and isolated noise measurement may be performed, allowing confirmation of the location of the defective part **22** and further analysis of the defective part **22**, including information such as, for example, a nature and/or severity of the defect. After block **926**, the third exemplary embodiment **104***c* of block **104** is concluded, and the method **100** proceeds as discussed above.
(62) It should be understood that the first exemplary embodiment **104***a* of block **104**, the second exemplary embodiment **104***b* of block **104**, and the third exemplary embodiment **104***c* of block **104** may be used in conjunction, for example, in series, in parallel, and/or in other combination, without departing from the scope of the present disclosure. In a non-limiting example, a possible location of the defective part **22** is determined using the second exemplary embodiment **104***b* of block **104** and/or the third exemplary embodiment **104***c* of block **104** (i.e., using an analytical method). The possible location is then used as an input to the first exemplary embodiment **104***a* of block **104** (i.e., as one of the plurality of measurements discussed in reference to block **502**). Subsequently, the first exemplary embodiment **104***a* of block **104** is used to determine the location of the defective part **22** based at least in part on the possible location determined using the second exemplary embodiment **104***b* of block **104** and/or the third exemplary embodiment **104***c* of block **104** (i.e., using an analytical method) and the plurality of measurements performed at block **502**.
(63) The system **10** and method **100** of the present disclosure offer several advantages. By continuously and/or repeatedly executing the method **100**, defective parts may be identified in the vehicle **12** in a timely manner, allowing for prompt service and repair. Additionally, the plurality of vehicle sensors **16** may be used to identify and diagnose parts nearing failure based on subtle vibrational and/or noise signals. The system **10** and method **100** improve vehicle reliability, reduce service cost/time, and increase occupant convenience.
(64) The description of the present disclosure is merely exemplary in nature and variations that do not depart from the gist of the present disclosure are intended to be within the scope of the present disclosure. Such variations are not to be regarded as a departure from the spirit and scope of the present disclosure.

Claims

1. A system for noise localization for a vehicle, the system comprising: a plurality of vehicle sensors, wherein the plurality of vehicle sensors includes at least one of: a microphone, at least three vibration sensors, a vehicle road speed sensor, and a vehicle motor speed sensor, wherein each of the at least three vibration sensors is affixed to a different location in the vehicle; and a controller in electrical communication with the plurality of vehicle sensors, wherein the controller

is programmed to: perform a plurality of measurements of a noise produced by a defective part of the vehicle using the plurality of vehicle sensors, wherein to perform the plurality of measurements, the controller is further programmed to: perform a first plurality of vibration measurements with a first vibration sensor of the plurality of vehicle sensors; perform a second plurality of vibration measurements with a second vibration sensor of the plurality of vehicle sensors; and perform a third plurality of vibration measurements with a third vibration sensor of the plurality of vehicle sensors; determine a location of the defective part within the vehicle based at least in part on the plurality of measurements using at least one of: a machine learning based method and an analytical method, wherein to determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to: identify a vibration event based at least in part on the first, second, and third pluralities of vibration measurements, wherein the vibration event emanates from the location of the defective part within the vehicle, wherein the vibration event includes at least three vibration pairs, wherein a first vibration pair is detected in the first plurality of vibration measurements, a second vibration pair is detected in the second plurality of vibration measurements, and a third vibration pair is detected in the third plurality of vibration measurements, and wherein each of the first, second, and third vibration pairs includes a longitudinal vibration and transversal vibration, and wherein to identify the vibration event, the controller is further programmed to: perform a spectral analysis to identify a plurality of frequencies present in the first, second, and third pluralities of vibration measurements; compare the plurality of frequencies to a range of normal operation frequencies; and identify the vibration event in response to determining that at least one of the plurality of frequencies is outside of the range of normal operation frequencies; determine a first distance between the first vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the first vibration pair and a reception time of the transversal vibration of the first vibration pair; determine a second distance between the second vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the second vibration pair and a reception time of the transversal vibration of the second vibration pair; determine a third distance between the third vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the third vibration pair and a reception time of the transversal vibration of the third vibration pair; and determine the location of the defective part using trilateration based at least in part on the first distance, the second distance, and the third distance; and identify the defective part of the vehicle based at least in part on the location of the defective part within the vehicle.
2. The system of claim 1, wherein to determine the location of the defective part within the vehicle using the machine learning based method, the controller is further programmed to: input the plurality of measurements into a machine learning algorithm, wherein the machine learning algorithm is configured to receive the plurality of measurements as input and produce a plurality of probabilities as output, and wherein each of the plurality of probabilities corresponds to a probability that noises within the plurality of measurements emanate from a particular location within the vehicle; and determine the location of the defective part within the vehicle based at least in part on the plurality of probabilities.
3. The system of claim 1, wherein to identify the vibration event, the controller is further programmed to: input the first, second, and third pluralities of vibration measurements to a machine learning algorithm, wherein the machine learning algorithm is configured to use unsupervised learning to separate the first, second, and third pluralities of vibration measurements into a normal measurement subset and an abnormal measurement subset; and identify the vibration event based at least in part on the abnormal measurement subset.
4. The system of claim 1, wherein the plurality of vehicle sensors includes at least three microphones, wherein each of the at least three microphones is affixed to a different location in the vehicle, and wherein to perform the plurality of measurements, the controller is further

programmed to: perform a first plurality of noise measurements with a first microphone of the at least three microphones; perform a second plurality of noise measurements with a second microphone of the at least three microphones; and perform a third plurality of noise measurements with a third microphone of the at least three microphones.

5. The system of claim 4, wherein to determine the location of the defective part within the vehicle using the analytical method, the controller is further programmed to: identify a noise event based at least in part on the first, second, and third pluralities of noise measurements, wherein the noise event emanates from the location of the defective part within the vehicle; determine a first possible location range of the defective part relative to the first microphone of the at least three microphones and the second microphone of the at least three microphones based at least in part on a first phase difference between the first plurality of noise measurements and the second plurality of noise measurements; determine a second possible location range of the defective part relative to the first microphone of the at least three microphones and the third microphone of the at least three microphones based at least in part on a second phase difference between the first plurality of noise measurements and the third plurality of noise measurements; determine a third possible location range of the defective part relative to the second microphone of the at least three microphones and the third microphone of the at least three microphones based at least in part on a third phase difference between the second plurality of noise measurements and the third plurality of noise measurements; and determine the location of the defective part based at least in part on the first possible location range, the second possible location range, and the third possible location range.

6. The system of claim 5, further comprising a beamforming microphone array, wherein the controller is further programmed to: scan the location of the defective part for noise produced by the defective part using the beamforming microphone array.

7. The system of claim 1, wherein the controller is further programmed to: determine a possible location of the defective part within the vehicle based at least in part on the plurality of measurements using the analytical method; and determine the location of the defective part within the vehicle based at least in part on the plurality of measurements and the possible location using the machine learning based method.

8. A method for noise localization, the method comprising: performing a plurality of measurements of a noise produced by a defective part using a plurality of vehicle sensors, wherein performing the plurality of measurements further comprises: performing a first plurality of vibration measurements with a first vibration sensor of the plurality of vehicle sensors; performing a second plurality of vibration measurements with a second vibration sensor of the plurality of vehicle sensors; and performing a third plurality of vibration measurements with a third vibration sensor of the plurality of vehicle sensors; determining a location of the defective part based at least in part on the plurality of measurements using at least one of: a machine learning based method and an analytical method, wherein determining the location of the defective part using the analytical method further comprises: identifying a vibration event based at least in part on the first, second, and third pluralities of vibration measurements, wherein the vibration event emanates from the location of the defective part, wherein the vibration event includes at least three vibration pairs, wherein a first vibration pair is detected in the first plurality of vibration measurements, a second vibration pair is detected in the second plurality of vibration measurements, and a third vibration pair is detected in the third plurality of vibration measurements, and wherein each of the first, second, and third vibration pairs includes a longitudinal vibration and transversal vibration, and wherein identifying the vibration event further comprises: performing a spectral analysis to identify a plurality of frequencies present in the first, second, and third pluralities of vibration measurements; comparing the plurality of frequencies to a range of normal operation frequencies; and identifying the vibration event in response to determining that at least one of the plurality of frequencies is outside of the range of normal operation frequencies; determining a first distance between the first vibration sensor and the defective part based at least in part on a difference between a reception

time of the longitudinal vibration of the first vibration pair and a reception time of the transversal vibration of the first vibration pair; determining a second distance between the second vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the second vibration pair and a reception time of the transversal vibration of the second vibration pair; determining a third distance between the third vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the third vibration pair and a reception time of the transversal vibration of the third vibration pair; and determining the location of the defective part using trilateration based at least in part on the first distance, the second distance, and the third distance; and identifying the defective part based at least in part on the location of the defective part.
9. The method of claim 8, wherein determining the location of the defective part using the machine learning based method further comprises: inputting the plurality of measurements into a machine learning algorithm, wherein the machine learning algorithm is configured to receive the plurality of measurements as input and produce a plurality of probabilities as output, and wherein each of the plurality of probabilities corresponds to a probability that noises within the plurality of measurements emanate from a particular location; and determining the location of the defective part based at least in part on the plurality of probabilities.
10. The method of claim 8, wherein performing the plurality of measurements further comprises: performing a first plurality of noise measurements with a first microphone of at least three microphones; performing a second plurality of noise measurements with a second microphone of the at least three microphones; and performing a third plurality of noise measurements with a third microphone of the at least three microphones.
11. The method of claim 10, wherein determining the location of the defective part using the analytical method further comprises: identifying a noise event based at least in part on the first, second, and third pluralities of noise measurements, wherein the noise event emanates from the location of the defective part; determining a first possible location range of the defective part relative to the first microphone of the at least three microphones and the second microphone of the at least three microphones based at least in part on a first phase difference between the first plurality of noise measurements and the second plurality of noise measurements; determining a second possible location range of the defective part relative to the first microphone of the at least three microphones and the third microphone of the at least three microphones based at least in part on a second phase difference between the first plurality of noise measurements and the third plurality of noise measurements; determining a third possible location range of the defective part relative to the second microphone of the at least three microphones and the third microphone of the at least three microphones based at least in part on a third phase difference between the second plurality of noise measurements and the third plurality of noise measurements; and determining the location of the defective part based at least in part on the first possible location range, the second possible location range, and the third possible location range.
12. A system for noise localization for a vehicle, the system comprising: a plurality of vehicle sensors, wherein the plurality of vehicle sensors includes at least three vibration sensors, wherein each of the at least three vibration sensors is affixed to a different location in the vehicle; and a controller in electrical communication with the plurality of vehicle sensors, wherein the controller is programmed to: perform a plurality of measurements of a noise produced by a defective part of the vehicle using each of the at least three vibration sensors, wherein to perform the plurality of measurements, the controller is further programmed to: perform a first plurality of vibration measurements with a first vibration sensor of the plurality of vehicle sensors; perform a second plurality of vibration measurements with a second vibration sensor of the plurality of vehicle sensors; and perform a third plurality of vibration measurements with a third vibration sensor of the plurality of vehicle sensors; determine a location of the defective part within the vehicle based at least in part on the plurality of measurements, wherein to determine the location of the defective

part within the vehicle, the controller is further programmed to: identify a vibration event based at least in part on the first, second, and third pluralities of vibration measurements, wherein the vibration event emanates from the location of the defective part within the vehicle, wherein the vibration event includes at least three vibration pairs, wherein a first vibration pair is detected in the first plurality of vibration measurements, a second vibration pair is detected in the second plurality of vibration measurements, and a third vibration pair is detected in the third plurality of vibration measurements, and wherein each of the first, second, and third vibration pairs includes a longitudinal vibration and transversal vibration, and wherein to identify the vibration event, the controller is further programmed to: perform a spectral analysis to identify a plurality of frequencies present in the first, second, and third pluralities of vibration measurements; compare the plurality of frequencies to a range of normal operation frequencies; and identify the vibration event in response to determining that at least one of the plurality of frequencies is outside of the range of normal operation frequencies; determine a first distance between the first vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the first vibration pair and a reception time of the transversal vibration of the first vibration pair; determine a second distance between the second vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the second vibration pair and a reception time of the transversal vibration of the second vibration pair; determine a third distance between the third vibration sensor and the defective part based at least in part on a difference between a reception time of the longitudinal vibration of the third vibration pair and a reception time of the transversal vibration of the third vibration pair; and determine the location of the defective part using trilateration based at least in part on the first distance, the second distance, and the third distance; and identify the defective part of the vehicle based at least in part on the location of the defective part within the vehicle.
13. The system of claim 12, wherein to identify the vibration event, the controller is further programmed to: input the first, second, and third pluralities of vibration measurements to a machine learning algorithm, wherein the machine learning algorithm is configured to use unsupervised learning to separate the first, second, and third pluralities of vibration measurements into a normal measurement subset and an abnormal measurement subset; and identify the vibration event based at least in part on the abnormal measurement subset.
14. The system of claim 13, further comprising a beamforming microphone array, wherein the controller is further programmed to: scan the location of the defective part for noise produced by the defective part using the beamforming microphone array.