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(54) **A monitoring device and a method for monitoring the operability of at least one sensing means of a rail vehicle**

Überwachungsvorrichtung und Verfahren zur Überwachung der Funktionsfähigkeit von mindestens einem Sensormittel eines Schienenfahrzeugs

Dispositif de surveillance et procédé pour surveiller la fonctionnalité d'au moins un moyen de détection d'un véhicule ferroviaire

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Description

[0001] The invention relates to a monitoring device for monitoring the operability of at least one sensing means for sensing at least one motion parameter of a rail vehicle and a method of monitoring the operability of the at least one sensing means.

[0002] Motion parameters of a rail vehicle are usually sensed using accelerometers and gyroscopes. On-board speed and distance measurements are an important part of train safety. Speed can also be measured using tachometers that measure the rotational speed of the wheels or using Doppler radar. Both methods have weaknesses. Another method is to use Inertial Navigational Systems (INS) that sense motion and rotation of the train using accelerometers and gyroscopes and calculate speed and travelled distance.

[0003] EP 0736441 A1 discloses a measurement system for determination of travel data of a rail vehicle, wherein an INS is provided in addition to a position and/or speed measurement system.

[0004] US 2006/0253233 A1 discloses a locomotive having a navigation system (such as a combined inertial/GPS location system) which moves along an initially known track and enters the "halo" surrounding a track transition to begin data collection/logging to accumulate successive position information data points as the locomotive moves into, progresses through, and exits the "halo." The collected data for movement within the "halo" is then subject to a best fit assessment relative to the data pre-stored in the track database.

[0005] The US 2004/0015276 A1 discloses a method and system for automatically activating a train warning device that uses a positioning system such as a global positioning system (GPS) receiver or an inertial navigation system (INS) to determine the train's position. The system further includes a database containing locations of grade crossings and other locations at which a train is required to give a warning signal and what regulations govern activation of the warning device at such locations.

[0006] US 2005/0065726 A1 discloses a locomotive location system and method utilizing inertial measurement inputs, including orthogonal acceleration inputs and turn rate information, in combination with wheel-mounted tachometer information and GPS/DGPS position fixes to provide processed outputs indicative of track occupancy, position, direction of travel, velocity, etc. Various navigation solutions are combined together to provide the desired information outputs using an optimal estimator designed specifically for rail applications and subjected to motion constraints reflecting the physical motion limitations of a locomotive. The system utilizes geo-reconciliation to minimize errors and solutions that identify track occupancy when traveling through a turnout.

[0007] WO 2005/048000 A2 discloses a location system for locating the position of a locomotive on a trackway comprising: an inertial sensor system for sensing linear and rotary acceleration associated with the movement

of a locomotive over a trackway, said inertial sensor system having a first plurality of rate-of-turn rotary acceleration sensors having respective first sensitive axes and a second plurality of rate-of-turn acceleration sensors having respective second sensitive axes, the first and second sensitive axes oppositely aligned; a sensor for determining, either directly or indirectly, distanced traveled over the trackway; a radio-frequency based geo-positional receiver for at least periodically determining a geo-positional value for the locomotive; an optimal estimator for accepting information on a continuous or periodic basis from the inertial sensor system, the distanced traveled sensor, and the geo-positional receiver and establishing a first computational instance for determining locomotive location as a function of information from the inertial sensor system, the distanced traveled sensor, and the geo-positional receiver.

[0008] US 2011/029180 A1 discloses a device for measuring the movement of a self-guiding vehicle, that has an enhanced measuring reliability, in particular during an adhesion loss and independently from the travel profile of the vehicle in terms of slope, turn and slant. To this end, the device for measuring the movement of a self-guiding vehicle includes on board thereof two accelerometers coupled to a movement calculator, wherein each accelerometer includes two measurement axes on which are measured projections of a vehicle acceleration resultant. The four measurement axes of the accelerometers are adjusted so that the calculator provides, from the four projection measures, at least one very accurate longitudinal acceleration value of the vehicle at each point of a route including both slopes and turns

[0009] US 2010/312461 A1 discloses a system for determining a position of a train. The system includes a plurality of diverse sensors, such as tachometers and accelerometers, structured to repetitively sense at least change in position and acceleration of the train, a global positioning system sensor, which is diverse from each of the diverse sensors, structured to repetitively sense position of the train, and a track map including a plurality of track segments which may be occupied by the train. A processor cooperates with the diverse sensors, the global positioning system sensor and the track map. The processor includes a routine structured to provide measurement uncertainty for each of the diverse sensors and the global positioning system sensor. The routine cross-checks measurements for the diverse sensors, and cross-checks the global positioning system sensor against the track map.

[0010] US 6,218,961 B1 discloses a system and method for preventing collisions between vehicles, such as railway vehicles, by exchanging data regarding track position of the vehicles. By use of an on-board track database, the system provides an indication of the distance between vehicles based not on line-of-sight but on track distance. Additionally, a system and method for accurately determining location of railway vehicles without the use of a network of trackside indicators. The disclosed

system uses a gyro, position indicator, and a satellite position determination along with a track database to maintain highly accurate estimates of measurement errors and track position.

[0011] One weakness of INS is that it can be difficult to know when an accelerometer or gyroscope is failing. If a sensor tends to indicate "zero acceleration" or "zero rotation" when it is failing, then this is not necessarily detected by the rest of the system, because at any given time it is perfectly possible that a train is experiencing zero acceleration or zero rotation. Postulate that a train has three accelerometers and three gyroscopes on board, mounted in such a way that they measure acceleration in a) the direction of travel b) up/down direction c) left/right direction and rotation about these three axes. The train is running on a straight and level track. If the speed is constant, then all accelerometers will indicate zero acceleration if the effects of gravity are disregarded. If the train is accelerating (forward) then the accelerometers will indicate an acceleration in the direction of travel, but no acceleration in the other directions (because the track is straight and level). If the accelerometer for direction of travel should fail and indicate zero acceleration, then the odometry system will fail. This can result in an incorrect control of the rail vehicle. The failure, however, will also be not detected. This is hazardous. Even if the track should start to turn or come to a gradient, the failing accelerometer is not necessarily detected.

[0012] These problems are overcome by the present invention as defined by the monitoring device according to claim 1 and the method for monitoring the operability of at least one sensing means of a rail vehicle according to claim 13.

[0013] It is an object of the present invention to provide a monitoring device for monitoring the operability of at least one sensing means for sensing at least one motion parameter of a rail vehicle and a method of monitoring the operability of said sensing means, wherein a failure of the sensing means can be reliably and quickly detected.

It is a main idea of the invention to use at least two sensing means which are mounted or arranged with different orientations in such a way that measurements of the at least one motion parameter measured by each sensing means contain at least a portion relative to a common reference coordinate system, e.g. relative to at least one axis of the common reference coordinate system, wherein the operability is monitored depending on a comparison of the portions converted into the common reference coordinate system.

A monitoring device for monitoring the operability of at least one sensing means for sensing at least one motion parameter of a rail vehicle is proposed. The at least one motion parameter can e.g. be a distance, a velocity, an acceleration, an angle, an angular rate or an angular acceleration. The at least one sensing means can be a sensor for measuring the said motion parameter. The at least one sensing means can correspond to a first sensing

means or another sensing means which will be introduced later.

A reference coordinate system is assigned to the rail vehicle. The reference coordinate system denotes a coordinate system which is stationary with respect to the rail vehicle.

The monitoring device further comprises the first sensing means for sensing at least one motion parameter, wherein the first sensing means is designed and/or arranged such that at least one motion parameter can be sensed by the first sensing means relative to a first axis. The term "sensible" can denote that corresponding parameter can be sensed by a sensing means.

[0014] The monitoring device comprises at least one other sensing means for at least one motion parameter, wherein the other sensing means is designed and/or arranged such that at least one motion parameter can be sensed by the other sensing means relative to another axis.

[0015] In the context of this invention, the term "sensible" can mean that the at least one motion parameter is measurable by the corresponding sensing means. The first and the other sensing means can be based on the same physical measurement principle but can be designed as independent units. Relative to means that the motion parameter can be sensed or measured along the corresponding axis, e.g. an acceleration, or about the corresponding axis, e.g. an angular rate.

[0016] Further, an orientation of the first axis relative to the reference coordinate system is different from an orientation of the other axis relative to the reference coordinate system. The orientations of the first and second axes relative to the reference coordinate system can be known. In particular, the orientations can be provided by known (angular) offsets relative to the reference coordinate system. The first axis and the other axis can each provide an axis of a common coordinate system, e.g. a Cartesian coordinate system. Alternatively, the first and the other axes can each provide an axis of different, e.g. Cartesian, coordinate systems.

[0017] Further, a conversion operation for converting a motion parameter relative to the first axis into a motion parameter relative to the reference coordinate system is known. This means that e.g. the motion parameter measured along/about the first axis can be converted into a motion parameter along/about at least one axis of the reference coordinate system. In particular, the motion parameter measured along/about the first axis can be converted into motion parameters along/about multiple, in particular all, axes of the reference coordinate system. Also, a conversion operation for converting a motion parameter relative to the other axis into a motion parameter relative to the reference coordinate system is known. The conversion operation can e.g. be provided in the form of a transformation matrix, in particular in the form of a rotation matrix.

[0018] Further, the operability can be monitored depending on the motion parameter relative to the first axis,

the motion parameter relative to the other axis and the known conversion operations. This means that the operability is monitorable depending on the motion parameter relative to the first axis, the motion parameter relative to the other axis and the known conversion operations.

[0019] The proposed device can comprise at least one evaluation unit.

[0020] In particular, each of the motion parameters sensed by the at least two sensing devices can be converted into a motion parameter relative to a common coordinate system, e.g. the reference coordinate system. These motion parameters relative to the common coordinate system can also be referred to as converted motion parameters.

[0021] According to the invention, the motion parameters sensed by the at least two sensing devices are convertible into a common coordinate system, e.g. the reference coordinate system, and corresponding portions of the converted motion parameters, e.g. portions along/about a common axis of the common coordinate system, are determinable. A failure is detectable if a deviation between the corresponding portions of the converted motion parameters is not within a predetermined interval.

[0022] A failure of the at least one sensing means can also be detectable if a value of at least one converted motion parameter is not within a predetermined interval, e.g. higher than a predetermined upper threshold value and/or smaller than a predetermined lower threshold value. A correct operation of the at least one sensing means can be detectable if the value is within the predetermined interval. As it can be assumed that track characteristics, e.g. a curvature or a gradient, are usually small, small values for certain motion parameters relative to the reference coordinate system can be expected, e.g. a small left/right acceleration. If one of the sensing devices fails, however, and provides a value of zero, at least one of the converted motion parameter can be out of range, e.g. higher than the threshold value.

[0023] Alternatively or in addition, corresponding portions of the converted motion parameters, e.g. portions along/about a common axis of the common coordinate system, can be compared. A failure of the at least one sensing device is detectable if a deviation between corresponding portions of the converted motion parameters is not within a predetermined interval, e.g. higher than a predetermined upper threshold value and/or smaller than a predetermined lower threshold value. A correct operation of at least one sensing means is detectable if the deviation between corresponding portions of the converted motion parameters is within the predetermined interval.

[0024] It is possible that the first axis and/or the other axis are oriented such that a non-zero motion parameter along/about a common axis of the common coordinate system corresponds to or results in a non-zero motion parameter sensed by the first sensing means and a non-zero motion parameter sensed by the other sensing

means. Further, the first axis and/or the other axis can be oriented such that a non-zero motion parameter along/about first axis corresponds to a non-zero motion parameter along/about the other axis. The non-zero motion parameters can, however, have different values.

[0025] Further, the motion parameter of the first and/or the second sensing means can be used in order to determine a motion parameter of the rail vehicle. In this case, the motion parameters sensed by the at least two sensing devices can be converted into the reference coordinate system. Then, portions of the converted motion parameters, e.g. portions along/about the axes of the reference coordinate system, can be determined. These portions can e.g. correspond to a desired motion parameter of the rail vehicle, e.g. an acceleration. This allows a redundant determination of a motion parameter of the vehicle. To determine the motion parameter of the vehicle, only one or both converted motion parameter(s) can be used.

[0026] The proposed monitoring device advantageously allows a quick and reliable detection of a failure of (the) at least one sensing device.

[0027] In another embodiment, the motion parameter is an acceleration or an angular rate. The acceleration can be measured along an axis of the corresponding coordinate system. The angular rate can be measured about an axis of the corresponding coordinate system.

[0028] As an acceleration or an angular rate are easily determinable by known sensors, a simple implementation of the proposed monitoring device is advantageously provided.

[0029] In another embodiment, a longitudinal axis of the reference coordinate system is oriented parallel to a roll axis of the rail vehicle, wherein a lateral axis of the reference coordinate system is oriented parallel to pitch axis of the rail vehicle, wherein a vertical axis of the reference coordinate system is oriented parallel to a yaw axis of the vehicle.

[0030] Thus, a standard reference coordinate system for determining motion parameters of the rail vehicle, in particular a distance travelled, is used.

[0031] In another embodiment, either the first axis or the other axis corresponds to an axis of the reference coordinate system. If the reference coordinate system is chosen as the common coordinate system, this advantageously reduces a computational effort since one of the motion parameters is already measured relative to the common coordinate system.

[0032] In a preferred embodiment, however, neither the first axis nor the other axis corresponds to an axis of reference coordinate system. This means that neither the first sensing device nor the other sensing device senses a motion parameter along/about the traditional directions, in particular along/about the axes of the reference coordinate system.

[0033] In another embodiment, an acceleration along the first axis can be sensed, in particular by the first sensing means. Further, an acceleration along the other axis

can be sensed, in particular by the other sensing means.

[0034] Further, the first axis and the other axis are oriented relative to another such that a non-zero acceleration along the first axis corresponds to or results in a non-zero acceleration along the other axis.

[0035] This means that if the rail vehicle accelerates in a direction which comprises at least a portion along the first axis, a non-zero acceleration can be sensed by the first as well as by the other sensing means. This advantageously enhances the reliability of the monitoring.

[0036] In another embodiment, the first axis and the other axis are oriented such that a non-zero acceleration along an axis of the reference coordinate system results in or corresponds to a non-zero acceleration along the first axis. In this case, the non-zero acceleration along the axis of the reference coordinate system will also result in or correspond to a non-zero acceleration along the other axis.

[0037] In another embodiment an angular rate of a rotation about the first axis can be sensed, e.g. by the first sensing means or yet another sensing means (e.g. a third sensing means). Further, an angular rate of a rotation about the other axis can be sensed, e.g. by the other sensing means (e.g. the second sensing means) or yet another sensing means (e.g. a fourth sensing means).

[0038] The first axis and the other axis are oriented relative to another such that a non-zero angular rate of the rotation about the first axis results in or corresponds to a non-zero angular rate of the rotation about the other axis. This means that if the rail vehicle rotates about an axis wherein the rotation comprises at least a portion about the first axis, a non-zero angular rate can be sensed by the first and/or by the third as well as by the second and/or by the fourth sensing means. This advantageously enhances the reliability of the monitoring.

[0039] In another embodiment, the first axis and the other axis are oriented such that a non-zero angular rate of the rotation about an axis of the reference coordinate system results in or corresponds to a non-zero angular rate of the rotation about the first axis. In this case, the non-zero angular rate of the rotation about the axis of the reference coordinate system will also result in or correspond to a non-zero angular rate of the rotation about the other axis.

[0040] The axis of the reference coordinate system can e.g. be the longitudinal axis, the lateral axis or the vertical axis of the rail vehicle.

[0041] In another preferred embodiment, the first and the other sensing means are provided by at least one sensor of at least one inertial measurement unit (IMU). In particular, the first and the other sensing means can be sensors, e.g. accelerometers and/or gyroscopes and/or magnetometers, of a single IMU or sensors of different IMUs.

[0042] The inertial measurement unit can denote a device, in particular an electronic device, that measures a velocity and/or an orientation and/or a gravitational force and/or an acceleration. An inertial measurement unit can

comprise one or more accelerometer(s) and/or gyroscope(s) and/or magnetometer(s).

[0043] In particular, an IMU allows measuring an acceleration along three axes, which can be axes of a coordinate system, e.g. a Cartesian coordinate system. Further, the IMU allows measuring an angular rate about three axes of the said coordinate system. The proposed first and other axis can each be provided by an axis of the coordinate system of the IMU.

[0044] This advantageously allows using a well-established reliable device for sensing one or more motion parameters.

[0045] In another embodiment, the motion parameters sensed by the at least two sensing devices are convertible into a common coordinate system, e.g. the reference coordinate system.

[0046] A failure is detectable if, in addition, a value of at least one converted motion parameter is not within a predetermined interval. The at least one converted motion parameter can e.g. be a motion parameter relative to a yaw or pitch axis of the rail vehicle.

[0047] In another embodiment, an acceleration along three independent axes of a coordinate system and an angular rate of a rotation about the three axes of a coordinate system can be sensed, wherein the coordinate system is different from the reference coordinate system. This can mean that at least one axis of the coordinate system is not equal or collinear to any axis of the reference coordinate system. This advantageously provides reliable monitoring of the sensing means since a large set of motion parameters can be determined.

[0048] Further described is a rail vehicle comprising a monitoring device according to one of the previously described embodiments. At least one of the sensing means of the proposed monitoring device can be a part of a motion parameter measurement system of the rail vehicle, e.g. a speed or a position measurement system.

[0049] Further proposed is a method for monitoring the operability of at least one sensing means for sensing at least one motion parameter of a rail vehicle, wherein a reference coordinate system is assigned to the rail vehicle, wherein at least one motion parameter relative to a first axis is sensed, wherein at least one motion parameter relative to another axis is sensed, wherein an orientation of the first axis relative to the reference coordinate system is different from an orientation of the other axis relative to the reference coordinate system, wherein a conversion operation for converting a motion parameter relative to the first axis into at least one motion parameter relative to the reference coordinate system and a conversion operation for converting a motion parameter relative to the other axis into at least one motion parameter relative to the reference coordinate system are known, wherein the operability is monitored depending on the motion parameter relative to the first axis, the motion parameter relative to the other axis and the known conversion operations.

[0050] The proposed method can be performed by a

monitoring device according to one of the previously described embodiments. In turn, the previously proposed monitoring device can be designed such that the proposed method is performable.

[0051] In another embodiment, the motion parameters sensed by the at least two sensing devices are converted into a common coordinate system, wherein a failure is detected if a value of at least one converted motion parameter is not within a predetermined interval, e.g. is higher than a predetermined upper threshold value or smaller than a predetermined lower threshold value. In contrast, a correct operability can be detected if the value is within the predetermined interval, e.g. is smaller than or equal to the upper threshold value and higher than or equal to the lower threshold value.

[0052] Alternatively or in addition, corresponding portions of the converted motion parameters are determined, wherein a failure is detected if a deviation between the corresponding portions of the converted motion parameters is not within the predetermined interval, e.g. is higher than a predetermined threshold value or smaller than a predetermined lower threshold value. The deviation can e.g. be a difference or an absolute value of a difference between the converted motion parameters. In contrast, a correct operability can be detected if the deviation is within the predetermined interval, e.g. is smaller than or equal to the upper threshold value and higher than or equal to the lower threshold value.

[0053] This advantageously provides a reliable monitoring of the operability.

[0054] In another embodiment the common coordinate system is provided by the reference coordinate system.

[0055] The invention will be described with reference to the attached figure.

[0056] Fig. 1 shows a schematic perspective view of a rail vehicle 1. The rail vehicle 1 comprises a first inertial measurement unit (IMU) 2. Further, the rail vehicle 1 comprises an evaluation unit 4 which is connected to the IMU 2.

[0057] A reference coordinate system C_{ref} is assigned to the rail vehicle 1. The reference coordinate system C_{ref} is a Cartesian coordinate system and comprises a first axis x_V , a second axis y_V , and a third axis z_V . The first axis x_V corresponds to a roll axis, the second axis y_V to a pitch axis and the third axis z_V to a yaw axis of the rail vehicle 1.

[0058] A first coordinate system $C1$ is assigned to the first IMU 2. The first coordinate system $C1$ is a Cartesian coordinate system and comprises a first axis $x1$, a second axis $y1$, and a third axis $z1$. Each of the axes $x1$, $y1$, $z1$ of the first coordinate system $C1$ comprises a portion along each of the axes x_V , y_V , z_V of the reference coordinate system C_{ref} . This can mean that a direction along one of the axes $x1$, $y1$, $z1$ comprises a non-zero direction portion along each of the axes x_V , y_V , z_V .

[0059] An orientation of the first axis $x1$ relative to the reference coordinate system C_{ref} is different from the orientation of the second axis $y1$ and the third axis $z1$

relative to the reference coordinate system C_{ref} . Also, the orientation of the second axis $y1$ relative to the reference coordinate system C_{ref} is different from the orientation of the third axis $z1$ relative to the reference coordinate system C_{ref} .

[0060] The first IMU 2 senses an acceleration along each of the axes $x1$, $y1$, $z1$ of the first coordinate system $C1$, e.g. by different, in particular three, acceleration sensors (not shown). The IMU 2 can e.g. comprise three accelerometers which each measure the acceleration along one of the axes $x1$, $y1$, $z1$. Also, the first IMU 2 senses an angular rate of a rotation about each of the axes $x1$, $y1$, $z1$ of the first coordinate system $C1$, e.g. by different, in particular three, angular rate sensors. The IMU 2 can e.g. comprise three gyrometers which each measure the angular rate about one of the axes $x1$, $y1$, $z1$.

[0061] An acceleration along the first axis x_V of the reference coordinate system C_{ref} which can be directed into a direction of travel of the rail vehicle 1 can be determined by measuring the accelerations along each axes $x1$, $y1$, $z1$ of the first coordinate system $C1$ and perform a calculation involving a rotation matrix that is a function of known offset angles, wherein the orientation of the first coordinate system $C1$ relative to the reference coordinate system C_{ref} is provided or encoded by the offset angles.

[0062] If the train is accelerating on a straight and level track, all measured accelerations have non-zero values, in particular due to the acceleration in the direction of travel and due to gravity. The up/down acceleration (acceleration along the third axis z_V of the rail vehicle 1) and right/left acceleration (acceleration along the second axis y_V of the rail vehicle 1) which are determined using the rotation matrix will have a value of g and zero, respectively.

[0063] If any of the aforementioned sensors, e.g. one of the acceleration sensors and/or one of the angular rate sensors, should fail, then the calculated values cannot only be incorrect, but more importantly out of range. This means that the failure can be detected if the at least one of the calculated values of an acceleration along the first axis, the second axis and/or the third axis x_V , y_V , z_V is not within a predetermined interval. Also, a failure can be detected if the at least one of the calculated values of an angular rate about the first axis, the second axis and/or the third axis x_V , y_V , z_V is not within a predetermined interval.

[0064] Since the gradients and curvature of the track are usually small for railways, it is highly likely that a sensor failure will be detected immediately, or at least very soon. The motion of a train is always such that sliding in the direction of travel is always possible but not in any other direction, unlike a car. A detected sensor failure means that an alarm can be given and restrictive action can be taken.

Claims

1. A monitoring device for monitoring the operability of at least one sensing means for sensing at least one motion parameter of a rail vehicle (1), wherein a reference coordinate system (Cref) is assigned to the rail vehicle (1), wherein the monitoring device comprises a first sensing means for sensing at least one motion parameter, wherein the first sensing means is designed and/or arranged such that the least one motion parameter is sensible by the first sensing means relative to a first axis, wherein the monitoring device comprises at least one other sensing means for at least one motion parameter, wherein the other sensing means is designed and/or arranged such that the at least one motion parameter is sensible by the other sensing means relative to another axis, wherein an orientation of the first axis relative to the reference coordinate system (Cref) is different from an orientation of the other axis relative to the reference coordinate system (Cref), wherein the motion parameter relative to the first axis is converted into at least one motion parameter relative to the reference coordinate system (Cref) and the motion parameter relative to the other axis is converted into at least one motion parameter relative to the reference coordinate system (Cref) by known conversion operations, wherein the operability is monitorable depending on the motion parameter relative to the first axis, the motion parameter relative to the other axis and the known conversion operations,
characterized in that
corresponding portions of the converted motion parameters are determinable, wherein a failure is detectable if a deviation between the corresponding portions of the converted motion parameters is not within a predetermined interval.
2. The monitoring device according to claim 1, **characterized in that** the motion parameter is an acceleration or an angular rate.
3. The monitoring device according to one of the claims 1 or 2, **characterized in that** a longitudinal axis of the reference coordinate system (Cref) is oriented parallel to a roll axis of the rail vehicle (1), wherein a lateral axis of the reference coordinate system (Cref) is oriented parallel to pitch axis of the rail vehicle (1), wherein a vertical axis of the reference coordinate system (Cref) is oriented parallel to a yaw axis of the vehicle (1).
4. The monitoring device according to one of the claims 1 to 3, **characterized in that** the first axis or the other axis corresponds to an axis of the reference coordinate system (Cref).
5. The monitoring device according to one of the claims 1 to 3, **characterized in that** neither the first axis nor the other axis corresponds to an axis of the reference coordinate system (Cref).
6. The monitoring device according to one of the claims 1 to 5, **characterized in that** an acceleration along a first axis is sensible, wherein an acceleration along the other axis is sensible, wherein the first axis and the other axis are oriented relative to another such that a non-zero acceleration along the first axis results in a non-zero acceleration along the other axis.
7. The monitoring device according to claim 6, **characterized in that** the first axis and the other axis are oriented such that a non-zero acceleration along an axis of the reference coordinate system (Cref) results in a non-zero acceleration along the first axis.
8. The monitoring device according to one of the claims 1 to 7, **characterized in that** an angular rate of a rotation about the first axis is sensible, wherein an angular rate of a rotation about the other axis is sensible, wherein the first axis and the other axis are oriented relative to another such that a non-zero angular rate of the rotation about the first axis results in a non-zero angular rate of the rotation about the other axis.
9. The monitoring device according to claim 8, **characterized in that** the first axis and the other axis are oriented such that a non-zero angular rate of the rotation about an axis of the reference coordinate system (Cref) results in a non-zero angular rate of the rotation about the first axis.
10. The monitoring device according to one of the claims 1 to 9, **characterized in that** the first and the other sensing device are provided by at least one sensor or at least one inertial measurement unit (2).
11. The monitoring device according to one of the claims 1 to 10, **characterized in that** the motion parameters sensed by the at least two sensing devices are convertible into a common coordinate system, wherein a failure is detectable if additionally a value of at least one converted motion parameter is not within a predetermined interval.
12. The monitoring device according to one of the claims 1 to 11, **characterized in that** an acceleration along three independent axes of a coordinate system and an angular rate of a rotation about the three axes of a coordinate system is sensible, wherein the coordinate system is different from the reference coordinate system (Cref).
13. A method for monitoring the operability of at least

one sensing means for sensing at least one motion parameter of a rail vehicle (1), wherein a reference coordinate system (Cref) is assigned to the rail vehicle (1), wherein at least one motion parameter relative to a first axis is sensed, wherein at least one motion parameter relative to another axis is sensed, wherein an orientation of the first axis relative to the reference coordinate system (Cref) is different from an orientation of the other axis relative to the reference coordinate system, wherein the motion parameter relative to the first axis is converted into at least one motion parameter relative to the reference coordinate system (Cref) and the motion parameter relative to the other axis is converted into at least one motion parameter relative to the reference coordinate system (Cref) by known conversion operations, wherein the operability is monitored depending on the motion parameter relative to the first axis, the motion parameter relative to the other axis and the known conversion operations, **characterized in that** corresponding portions of the converted motion parameters are determinable, wherein a failure is detectable if a deviation between the corresponding portions of the converted motion parameters is not within a predetermined interval.

14. The method according to claim 13, **characterized in that** the sensed motion parameters are converted into a common coordinate system, wherein a failure is detected if a value of at least one converted motion parameter is not within a predetermined interval and/or wherein corresponding portions of the converted motion parameters are determined, wherein a failure is detected if a deviation between the corresponding portions of the converted motion parameters is not within a predetermined interval.
15. The method according to claim 14, **characterized in that** the common coordinate system is provided by the reference coordinate system (Cref).

Patentansprüche

1. Überwachungsvorrichtung zur Überwachung der Funktionsfähigkeit von mindestens einem Sensormittel zum Erfassen von mindestens einem Bewegungsparameter eines Schienenfahrzeugs (1), wobei dem Schienenfahrzeug (1) ein Referenzkoordinatensystem (Cref) zugeordnet ist, wobei die Überwachungsvorrichtung ein erstes Sensormittel zum Erfassen von mindestens einem Bewegungsparameter umfasst, wobei das erste Sensormittel so ausgebildet und/oder angeordnet ist, dass der mindestens eine Bewegungsparameter durch das erste Sensormittel bezogen auf eine erste Achse erfassbar ist, wobei die Überwachungsvorrichtung mindestens

eins ein anderes Sensormittel für mindestens einen Bewegungsparameter umfasst, wobei das andere Sensormittel so ausgebildet und/oder angeordnet ist, dass der mindestens eine Bewegungsparameter durch das andere Sensormittel bezogen auf eine weitere Achse erfassbar ist, wobei eine Ausrichtung der ersten Achse bezogen auf das Bezugskoordinatensystem (Cref) sich von einer Ausrichtung der anderen Achse bezogen auf das Referenzkoordinatensystem (Cref) unterscheidet, wobei der Bewegungsparameter bezogen auf die erste Achse in mindestens einen Bewegungsparameter bezogen auf das Referenzkoordinatensystem (Cref) umgewandelt wird und der Bewegungsparameter bezogen auf die andere Achse in mindestens einen Bewegungsparameter bezogen auf das Referenzkoordinatensystem (Cref) umgewandelt wird durch bekannte Umwandlungsoperationen, wobei die Funktionsfähigkeit in Abhängigkeit von dem Bewegungsparameter bezogen auf die erste Achse, dem Bewegungsparameter bezogen auf die andere Achse und den bekannten Umwandlungsoperationen überwachbar ist, **dadurch gekennzeichnet, dass**

einander entsprechende Anteile der umgewandelten Bewegungsparameter bestimmbar sind, wobei ein Fehler detektierbar ist, wenn eine Abweichung zwischen den einander entsprechenden Anteilen der umgewandelten Bewegungsparameter nicht innerhalb eines vorbestimmten Intervalls liegt.

2. Überwachungsvorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** der Bewegungsparameter eine Beschleunigung oder eine Winkelgeschwindigkeit ist.
3. Überwachungsvorrichtung nach einem der Ansprüche 1 oder 2, **dadurch gekennzeichnet, dass** eine Längsachse des Referenzkoordinatensystems (Cref) parallel zu einer Rollachse des Schienenfahrzeugs (1) ausgerichtet ist, wobei eine Querachse des Referenzkoordinatensystems (Cref) parallel zur Nickachse des Schienenfahrzeugs (1) ausgerichtet ist, wobei eine vertikale Achse des Referenzkoordinatensystems (Cref) parallel zu einer Gierachse des Fahrzeugs (1) ausgerichtet ist.
4. Überwachungsvorrichtung nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, dass** die erste Achse oder die andere Achse einer Achse des Referenzkoordinatensystems (Cref) entspricht.
5. Überwachungsvorrichtung nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet, dass** weder die erste Achse noch die andere Achse einer Achse des Referenzkoordinatensystems (Cref) entspricht.
6. Überwachungsvorrichtung nach einem der Ansprüche

- che 1 bis 5, **dadurch gekennzeichnet, dass** eine Beschleunigung entlang einer ersten Achse erfassbar ist, wobei eine Beschleunigung entlang der anderen Achse erfassbar ist, wobei die erste Achse und die andere Achse so zueinander ausgerichtet sind, dass eine Beschleunigung von nicht null entlang der ersten Achse zu einer Beschleunigung von nicht null entlang der anderen Achse führt.
7. Überwachungsvorrichtung nach Anspruch 6, **dadurch gekennzeichnet, dass** die erste Achse und die andere Achse so ausgerichtet sind, dass eine Beschleunigung von nicht null entlang einer Achse des Referenzkoordinatensystems (Cref) zu einer Beschleunigung von nicht null entlang der ersten Achse führt.
8. Überwachungsvorrichtung nach einem der Ansprüche 1 bis 7, **dadurch gekennzeichnet, dass** eine Winkelgeschwindigkeit einer Drehung um die erste Achse erfassbar ist, wobei eine Winkelgeschwindigkeit einer Drehung um die andere Achse erfassbar ist, wobei die erste Achse und die andere Achse so zueinander ausgerichtet sind, dass eine Winkelgeschwindigkeit der Drehung um die erste Achse von nicht null zu einer Winkelgeschwindigkeit der Drehung um die andere Achse von nicht null führt.
9. Überwachungsvorrichtung nach Anspruch 8, **dadurch gekennzeichnet, dass** die erste Achse und die andere Achse so ausgerichtet sind, dass eine Winkelgeschwindigkeit der Drehung um eine Achse des Referenzkoordinatensystems (Cref) von nicht null zu einer Winkelgeschwindigkeit der Drehung um die erste Achse von nicht null führt.
10. Überwachungsvorrichtung nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet, dass** die erste und die andere Sensoreinrichtung durch mindestens einen Sensor von mindestens einer Trägheitsmesseinheit (2) bereitgestellt werden.
11. Überwachungsvorrichtung nach einem der Ansprüche 1 bis 10, **dadurch gekennzeichnet, dass** die von den mindestens zwei Sensoreinrichtungen erfassten Bewegungsparameter in ein gemeinsames Koordinatensystem umwandelbar sind, wobei ein Fehler detektierbar ist, wenn zusätzlich ein Wert von mindestens einem umgewandelten Bewegungsparameter nicht innerhalb eines vorbestimmten Intervalls liegt.
12. Überwachungsvorrichtung nach einem der Ansprüche 1 bis 11, **dadurch gekennzeichnet, dass** eine Beschleunigung entlang drei unabhängiger Achsen eines Koordinatensystems und eine Winkelgeschwindigkeit einer Drehung um die drei Achsen eines Koordinatensystems erfassbar ist, wobei das Koordinatensystem sich von dem Referenzkoordinatensystem (Cref) unterscheidet.
13. Verfahren zur Überwachung der Funktionsfähigkeit von mindestens einem Sensormittel zum Erfassen von mindestens einem Bewegungsparameter eines Schienenfahrzeugs (1), wobei dem Schienenfahrzeug (1) ein Referenzkoordinatensystem (Cref) zugeordnet ist, wobei mindestens ein Bewegungsparameter bezogen auf eine erste Achse erfasst wird, wobei mindestens ein Bewegungsparameter bezogen auf eine andere Achse erfasst wird, wobei eine Ausrichtung der ersten Achse bezogen auf das Referenzkoordinatensystem (Cref) sich von der Ausrichtung der anderen Achse bezogen auf das Referenzkoordinatensystem unterscheidet, wobei der Bewegungsparameter bezogen auf die erste Achse in mindestens einen Bewegungsparameter bezogen auf das Referenzkoordinatensystem (Cref) umgewandelt wird und der Bewegungsparameter bezogen auf die andere Achse in mindestens einen Bewegungsparameter bezogen auf das Referenzkoordinatensystem (Cref) umgewandelt wird durch bekannte Umwandlungsoperationen, wobei die Funktionsfähigkeit in Abhängigkeit von dem Bewegungsparameter bezogen auf die erste Achse, dem Bewegungsparameter bezogen auf die andere Achse und den bekannten Umwandlungsoperationen überwacht wird, **dadurch gekennzeichnet, dass** einander entsprechende Anteile der umgewandelten Bewegungsparameter bestimmbar sind, wobei ein Fehler detektierbar ist, wenn eine Abweichung zwischen den einander entsprechenden Anteilen der umgewandelten Bewegungsparameter nicht innerhalb eines vorbestimmten Intervalls liegt.
14. Verfahren nach Anspruch 13, **dadurch gekennzeichnet, dass** die erfassten Bewegungsparameter in ein gemeinsames Koordinatensystem umgewandelt werden, wobei ein Fehler detektiert wird, wenn ein Wert von mindestens einem umgewandelten Bewegungsparameter nicht innerhalb eines vorbestimmten Intervalls liegt und/oder wobei einander entsprechende Anteile der umgewandelten Bewegungsparameter bestimmt werden, wobei ein Fehler detektierbar ist, wenn eine Abweichung zwischen den einander entsprechenden Anteilen der umgewandelten Bewegungsparameter nicht innerhalb eines vorbestimmten Intervalls liegt.
15. Verfahren nach Anspruch 14, **dadurch gekennzeichnet, dass** das gemeinsame Koordinatensystem durch das Referenzkoordinatensystem (Cref) bereitgestellt wird.

Revendications

1. Dispositif de surveillance permettant de surveiller le fonctionnement d'au moins un moyen de détection permettant de détecter au moins un paramètre de déplacement d'un véhicule ferroviaire (1), un système de coordonnées de référence (Cref) étant affecté au véhicule ferroviaire (1), le dispositif de surveillance comprenant un premier moyen de détection permettant de détecter au moins un paramètre de déplacement, le premier moyen de détection étant conçu et/ou disposé de sorte que l'au moins un paramètre de déplacement soit détectable par le premier moyen de détection par rapport à un premier axe, le dispositif de surveillance comprenant au moins un autre moyen de détection permettant de détecter au moins un paramètre de déplacement, l'autre moyen de détection étant conçu et/ou disposé de sorte que l'au moins un paramètre de déplacement soit détectable par l'autre moyen de détection par rapport à un autre axe, une orientation du premier axe par rapport au système de coordonnées de référence (Cref) étant différente d'une orientation de l'autre axe par rapport au système de coordonnées de référence (Cref), le paramètre de déplacement par rapport au premier axe étant converti en au moins un paramètre de déplacement par rapport au système de coordonnées de référence (Cref) et le paramètre de déplacement par rapport à l'autre axe étant converti en au moins un paramètre de déplacement par rapport au système de coordonnées de référence (Cref) par des opérations de conversion connues, le fonctionnement pouvant être surveillé selon le paramètre de déplacement par rapport au premier axe, le paramètre de déplacement par rapport à l'autre axe et les opérations de conversion connues, le dispositif **caractérisé en ce que** des parties correspondantes des paramètres de déplacement convertis sont déterminables, une panne étant détectable si un écart entre les parties correspondantes des paramètres de déplacement convertis n'est pas dans un intervalle prédéterminé.
2. Dispositif de surveillance selon la revendication 1, **caractérisé en ce que** le paramètre de déplacement est une accélération ou une vitesse angulaire.
3. Dispositif de surveillance selon l'une des revendications 1 ou 2, **caractérisé en ce qu'un** axe longitudinal du système de coordonnées de référence (Cref) est orienté parallèlement à un axe de roulis du véhicule ferroviaire (1), un axe latéral du système de coordonnées de référence (Cref) étant orienté parallèlement à un axe de tangage du véhicule ferroviaire (1), un axe vertical du système de coordonnées de référence (Cref) étant orienté parallèlement à un axe de lacet du véhicule.
4. Dispositif de surveillance selon l'une des revendications 1 ou 3, **caractérisé en ce que** le premier axe ou l'autre axe correspondent à un axe du système de coordonnées de référence (Cref).
5. Dispositif de surveillance selon l'une des revendications 1 ou 3, **caractérisé en ce que** ni le premier axe ni l'autre axe ne correspondent à un axe du système de coordonnées de référence (Cref).
6. Dispositif de surveillance selon l'une des revendications 1 à 5, **caractérisé en ce qu'une** accélération selon d'un premier axe est détectable, une accélération le long de l'autre axe étant détectable, le premier axe et l'autre axe étant orientés l'un par rapport à l'autre de sorte qu'une accélération non nulle le long du premier axe résulte en une accélération non nulle le long de l'autre axe.
7. Dispositif de surveillance selon la revendication 6, **caractérisé en ce que** le premier axe et l'autre axe sont orientés de sorte qu'une accélération non nulle le long d'un axe du système de coordonnées de référence (Cref) résulte en une accélération non nulle le long du premier axe.
8. Dispositif de surveillance selon l'une des revendications 1 à 7, **caractérisé en ce qu'une** vitesse angulaire d'une rotation par rapport au premier axe est détectable, une vitesse angulaire d'une rotation par rapport à l'autre axe étant détectable, le premier axe et l'autre axe étant orientés l'un par rapport à l'autre de sorte qu'une vitesse angulaire non nulle de la rotation par rapport au premier axe résulte en une vitesse angulaire non nulle de la rotation par rapport à l'autre axe.
9. Dispositif de surveillance selon la revendication 8, **caractérisé en ce que** le premier axe et l'autre axe sont orientés de sorte qu'une vitesse angulaire non nulle de la rotation par rapport à un axe du système de coordonnées de référence (Cref) résulte en une vitesse angulaire non nulle de la rotation par rapport au premier axe.
10. Dispositif de surveillance selon l'une des revendications 1 à 9, **caractérisé en ce que** le premier et l'autre dispositif de détection sont fournis par au moins un capteur d'au moins une unité de mesure d'inertie (2).
11. Dispositif de surveillance selon l'une des revendications 1 à 10, **caractérisé en ce que** les paramètres de déplacement détectés par les au moins deux dispositifs de détection peuvent être convertis en un système de coordonnées commun, une panne étant détectable si en outre une valeur d'au moins un paramètre de déplacement converti n'est pas dans un

intervalle prédéterminé.

12. Dispositif de surveillance selon l'une des revendications 1 à 11, **caractérisé en ce qu'**une accélération le long de trois axes indépendants d'un système de coordonnées et une vitesse angulaire d'une rotation par rapport aux trois axes d'un système de coordonnées sont détectables, le système de coordonnées étant différent du système de coordonnées de référence (Cref). 5
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13. Procédé de surveillance du fonctionnement d'au moins un moyen de détection permettant de détecter au moins un paramètre de déplacement d'un véhicule ferroviaire (1), un système de coordonnées de référence (Cref) étant affecté au véhicule ferroviaire (1), au moins un paramètre de déplacement par rapport à un premier axe étant détecté, au moins un paramètre de déplacement par rapport à un autre axe étant détecté, une orientation du premier axe par rapport au système de coordonnées de référence (Cref) étant différente d'une orientation de l'autre axe par rapport au système de coordonnées de référence, le paramètre de déplacement par rapport au premier axe étant converti en au moins un paramètre de déplacement par rapport au système de coordonnées de référence (Cref) et le paramètre de déplacement par rapport à l'autre axe étant converti en au moins un paramètre de déplacement par rapport au système de coordonnées de référence (Cref) par des opérations de conversion connues, le fonctionnement étant surveillé selon le paramètre de déplacement par rapport au premier axe, le paramètre de déplacement par rapport à l'autre axe et les opérations de conversion connues, 15
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le procédé étant **caractérisé en ce que** des parties correspondantes des paramètres de déplacement convertis sont déterminables, une panne étant détectable si un écart entre les parties correspondantes des paramètres de déplacement convertis n'est pas dans un intervalle prédéterminé. 40

14. Procédé selon la revendication 13, **caractérisé en ce que** les paramètres de déplacement détectés sont convertis en un système de coordonnées commun, une panne étant détectée si une valeur d'au moins un paramètre de déplacement converti n'est pas dans un intervalle prédéterminé, et/ou des parties correspondantes des paramètres de déplacement convertis étant déterminées, une panne étant détectée si un écart entre les parties correspondantes des paramètres de déplacement convertis n'est pas dans un intervalle prédéterminé. 45
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15. Procédé selon la revendication 14, **caractérisé en ce que** le système de coordonnées commun est fourni par le système de coordonnées de référence (Cref). 55

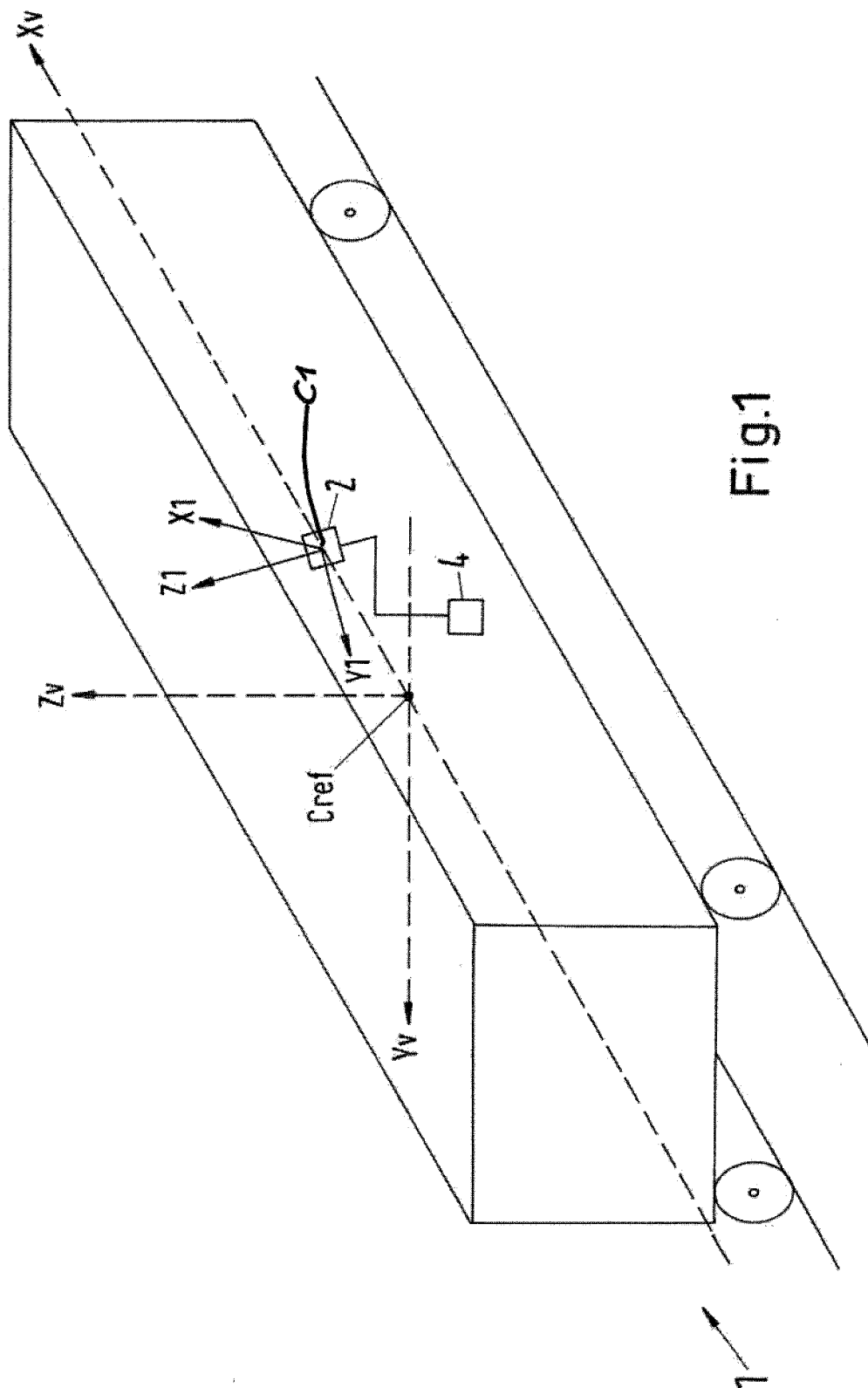


Fig.1

REFERENCES CITED IN THE DESCRIPTION

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