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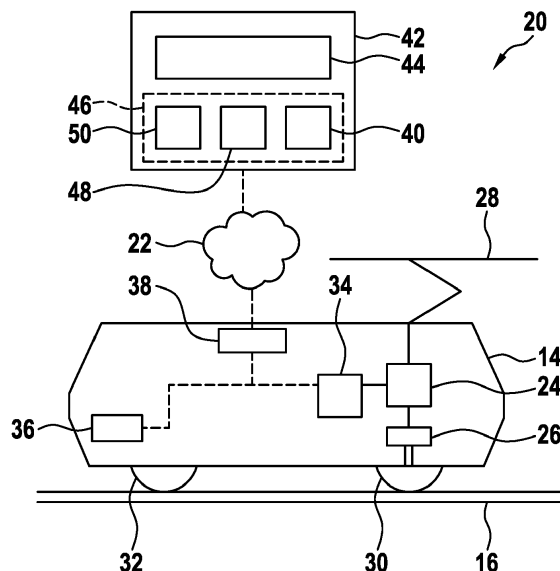
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(54) **DETECTING WEAR IN A RAILWAY SYSTEM**

(57) A method for detecting wear in a railway system (10) comprises: collecting railway vehicle data (40) acquired by railway vehicles (14), the railway vehicle data (40) at least comprising data associated with friction between a traction wheel (30) of the railway vehicle (14) and rails (16); determining a location of the railway vehicles (14) in the railway system (10); localizing the railway

vehicle data (40), such that the railway vehicle data (40) is associated with the locations, where the railway vehicle data (40) has been acquired; and determining at least one of a wear of the railways (12) at a location and a wear of a railway vehicle (14) from the localized railway vehicle data (40) of at least two railway vehicles (14).

Fig. 2



Description

FIELD OF THE INVENTION

[0001] The invention relates to a method, a computer program and a computer-readable medium for detecting wear in a railway system. Furthermore, the invention relates to a railway monitoring system and to a railway system.

BACKGROUND OF THE INVENTION

[0002] Usually, the conditions of rails of a railway system are monitored sporadically and/or only by visual inspection following a heuristic based prioritization. For example, routes with heavy traffic may be inspected more often. Due to the large extent of the rails, often only corrective maintenance may be possible, such as fixing broken rails, track switches, etc. This approach is usually expensive, because depending on the fault, huge disruptions of the scheduled railway system operation are typically unavoidable.

[0003] Most railway system operators perform experienced based inspection, where rails, which are used more often (such as locations with heavy rail traffic) or specific known failure points, are inspected more often. If defects or anomalies are detected during the visual inspection rounds, track maintenance is scheduled accordingly. This process is usually not automated, may be time-consuming and may take a significant part of the overall operating costs of the railway system together with corrective maintenance.

[0004] The railway vehicles of a railway system usually are inspected periodically to avoid defects. For example, traction wheel profiles are measured from time to time in order to assess the degradation of the traction wheels. However, also in this case, it is not always possible to do these measurements very often, as the fleet may be large and additional downtimes may be incurred for the measurements. Furthermore, geographical location and exact timing of a traction wheel defect are usually not known, thus a root-cause analysis and a following optimization are not possible.

[0005] Furthermore, the traction converters of the railway vehicles usually come with preset control parameters for slip control and traction control, which are then manually tuned on the commissioning site by a commissioning engineer to meet the requirements of the railway system operator. As a rule, no parameter modification is performed after that, unless there are significant issues during operation. Traction converters are typically optimized for maximum power delivery, no wear is considered.

DESCRIPTION OF THE INVENTION

[0006] It is an objective to improve the maintenance of a railway system. It is a further objective of the invention

to reduce the impact of wear on a railway system.

[0007] These objectives are achieved by the subject-matter of the independent claims. Further exemplary embodiments are evident from the dependent claims and the following description.

[0008] Aspects of the invention relate to a method for detecting wear in a railway system, a railway monitoring system and a railway system.

[0009] According to an embodiment of the invention, the railway system comprises a plurality of railways and a plurality of railway vehicles. The railways may comprise rails, track switches and/or signals and/or other equipment for supporting and/or monitoring the railway vehicles running on the rails. A railway vehicle may be a train, a tram and/or a metro. Each railway vehicle may comprise a traction vehicle, which may comprise drive motors for driving the railway vehicle. These motors may be supplied by an electrical converter, which may be supplied via a catenary line.

[0010] According to an embodiment of the invention, the railway system comprises a railway monitoring system, which is adapted for performing the method. The railway monitoring system may comprise devices for collecting data of the railways and/or the railway vehicles. It also may comprise a database for storing these data and/or an evaluation system for evaluating the data. The database and/or the evaluation system may be central systems. The method described in the following may be performed by the evaluation system and/or the monitoring system.

[0011] According to an embodiment of the invention, the method comprises: collecting railway vehicle data acquired by railway vehicles. The railway vehicle data at least may comprise data associated with friction between a traction wheel of the railway vehicle and rails. For example, the railway vehicle data may comprise a slip of a traction wheel, a braking force and/or braking duration, an energy dissipated by the traction wheel, torsional oscillations, etc. A traction wheel may be a wheel driven by a motor of the railway vehicle.

[0012] A railway vehicle may acquire railway vehicle data by measuring quantities with sensors on board the railway vehicle. The railway vehicle also may acquire the railway vehicle data by calculating it. For example, a controller of the railway vehicle may calculate the slip.

[0013] According to an embodiment of the invention, the railway monitoring system comprises data acquiring devices for acquiring railway vehicle data from a plurality of railway vehicles. These data acquiring devices may comprise a controller of the railway vehicle and/or sensors of the railway vehicle.

[0014] The railway vehicle data may be collected by the railway monitoring system. The railway vehicle and in particular its controller may be interconnected with the railway monitoring system and/or the evaluation system via a communication network, such as the Internet. The railway vehicle data may be sent from the railway vehicle to the evaluation system, which then may store the rail-

way vehicle data in a database.

[0015] According to an embodiment of the invention, the method comprises: determining a location of the railway vehicles in the railway system. A location of the railway vehicle may be determined by the railway vehicle itself, for example, via GPS. The location may be a geographical location. The location also may be determined from a known route of the railway vehicle, which may be at a specific location on the railways at a specific time. The location may be determined by the railway vehicle itself and/or by the evaluation system.

[0016] According to an embodiment of the invention, the method further comprises: localizing the railway vehicle data, such that the railway vehicle data is associated with the locations, where the railway vehicle data has been acquired. For example, the railway data acquired at a specific time may be associated with the location of the railway vehicle determined at that specific time. The railway vehicle data also may be associated with rails and/or components of the railway system, which themselves are associated with a location.

[0017] According to an embodiment of the invention, the method comprises: determining a wear of the railways at a location from the localized railway vehicle data of at least two railway vehicles associated with the location.

[0018] According to an embodiment of the invention, the method comprises: determining a wear of at least two railway vehicles from the localized railway vehicle data.

[0019] For example, the railway vehicle data is evaluated by a central evaluation system for determining the wear of the railways and/or the wear of the railway vehicles.

[0020] From the localized railway vehicle data one or more quantities related to wear for different railway vehicles at different locations may be determined. It may be deduced that a quantity related to wear of the rails has changed at a specific location and/or that a quantity related to wear of a specific traction wheel has changed, for example, when this is independent of a specific location.

[0021] It has to be noted that the wear may be determined and/or used with a part of the evaluation system that is adapted for machine learning and that was trained with known railway vehicle data and know wear. It is not necessary that the quantities relating to wear are determined directly.

[0022] According to an embodiment of the invention, the method further comprises: determining at least one of a wear of the railways at a location and a wear of a railway vehicle from the localized railway vehicle data of at least two railway vehicles and railway track data associated with the location. Additionally, railway track data may be used for determining the respective wear. The railway track data at least may comprise data of a state and/or a configuration of rails at specific locations. For example, the railway track data may comprise a wear of the rails at the specific location.

[0023] A state of rails may be a wear at a specific time point, the age of the rails, the last inspection of the rails, the curve radius of the rails, the slope of the rails, etc. A configuration of the rails may comprise information about track switches, curves of the rails, slopes, interconnections of the rails, etc.

[0024] A location may be encoded in the railway track data, and in general in the other types of data described below, with coordinates and/or areas in a map. For example, sections of rails and/or railways may be associated with a location or the overall spatial extent can be discretized using a grid. Each of these sections may be associated with a state and/or a configuration.

[0025] According to an embodiment of the invention, the method further comprises: collecting railway track data. For example, the railway track data may be collected by the railway monitoring system.

[0026] The railway track data may be collected by the railway monitoring system, for example by storing the data in the database. It is not necessary that the railway track data is collected online, i.e. with devices that monitor the rails. However, it is possible that the railway track data may be collected with monitoring devices, such as sensors, at the site of the respective rails.

[0027] With the method, a geographical location and timing of possible traction wheel defects may be determined based on railway vehicle data and optionally railway track data. Wheel degradation and/or wear may be determined and localized. Additionally, with the method, possible track and track switches defects and/or wear may be determined based on these data. A potential root-cause from the infrastructure, i.e. the railways, may be identified and/or maintenance may be arranged in time. With the method, a more economical maintenance by early detection and/or avoidance of track defects and/or wheel defects may be provided.

[0028] According to an embodiment of the invention, the railway monitoring system comprises a central database for storing railway track data and railway vehicle data. As already mentioned, at least a part of the railway track data and/or the railway vehicle data may be sent to a central evaluation system, for example via a communication network, which then stores the data in a central data base.

[0029] In general, the railway vehicle data may be associated with a specific railway vehicle. The railway vehicle data may comprise operational data generated by the railway vehicle itself. This data may be seen as online generated data. This online generated data may comprise data generated by a controller of a traction converter, such as currents, voltages, motor temperatures, motor speed, torque, amount of slip, time in slip mode, time of active adhesion control, torsional oscillation amplitudes and durations, etc. This data also may comprise general railway vehicle data, such as a GPS location, an altitude, a railway vehicle speed, ambient conditions, humidity, etc. This data furthermore comprise events, alarms, etc. generated by the controller and/or other com-

ponents installed in the railway vehicle.

[0030] The railway vehicle data also may comprise operational data that was collected for the railway vehicle otherwise. This data may be seen as offline generated data. The offline generated operational data may comprise traction wheel profile measurements, a railway vehicle configuration, a railway vehicle loading, a route of the railway vehicle, etc.

[0031] According to an embodiment of the invention, the railway vehicle data comprises data of a configuration of the railway vehicle and/or a route of the railway vehicle. For example, the configuration may indicate, whether a traction vehicle is pulling or pushing waggons. The localization of the railway vehicle data may be based on the route of the railway vehicle. The determination of the wear of the railways and the wear of the railway vehicles may be additionally based on the configuration of the railway vehicle.

[0032] The railway track data may be associated with specific components of the railways, such as rails and/or track switches. The railway track data may be seen as associated with the infrastructure of the railway system. The railway track data may comprise track conditions and/or states, such as a last measured track wear. It also may comprise expected track conditions, which may be experience based.

[0033] The central database also may store environmental data, such as weather data and/or weather forecast data, which, for example, may be obtained by a weather service.

[0034] According to an embodiment of the invention, the method further comprises: determining an anomalous behaviour of the railway vehicle at a location, wherein an anomalous behaviour is a change of a quantity determined from the railway vehicle data at the location, which change is bigger than a threshold. In general, anomalous behaviour may be determined by thresholding with a constant threshold, by adaptive thresholding, by correlation analysis, by model comparison and/or by machine learning methods.

[0035] The evaluation system may calculate one or more quantities (which may be numerical values), which are associated with a railway vehicle and a location. These quantities may be determined from the railway vehicle data and the railway track data by correlation, with a machine learning and/or other methods. A change in one or more of these quantities that is bigger than a threshold may be called anomalous behaviour. Anomalous behaviour may be encoded as a numerical value, which is associated with a railway vehicle and a location.

[0036] In the end, the evaluation system may determine a plurality of anomalous behaviour. Railway vehicle generating a specific amount of anomalous behaviour and/or locations, where a specific amount of anomalous behaviour takes place, may be selected. Railway vehicles and/or rails with defects and/or with high wear may be identified.

[0037] According to an embodiment of the invention,

the method further comprises: deciding that rails at the location are worn, when a plurality of railway vehicles have an anomalous behaviour at the same location. In the case, when anomalous behaviour at a location is higher as expected, i.e. higher than a threshold, it may be decided that the part of the railways at the location may be worn and/or has a defect.

[0038] It has to be noted that specific locations may be excluded or may be associated with a higher threshold as other locations, when the railway track data indicates that the rails may generate higher anomalous behaviour as at other locations, such as a specific configuration of the railways, such as track switch, curvy rails, etc.

[0039] According to an embodiment of the invention, the method further comprises: deciding that the railway vehicle has a worn traction wheel, when one railway vehicle has an anomalous behaviour at several locations, where no other railway vehicles have anomalous behaviour. In the case, when anomalous behaviour of a railway vehicle is higher as expected, i.e. higher than a threshold, it may be decided that the railway vehicle and in particular its traction wheel may be worn and/or has a defect.

[0040] According to an embodiment of the invention, the method further comprises: timestamping railway vehicle data, when it is acquired; and determining a location, where railway vehicle data has been acquired from a timestamp of the railway vehicle data and a route of the railway vehicle, which has acquired the railway vehicle data. The timestamping may be done by the railway vehicle and/or the evaluation system receiving the railway vehicle data. From a route of the railway vehicle, which may be determined from a schedule, the location of the railway vehicle at a specific time may be determined. This location then may be associated with the railway vehicle data acquired at the specific time, for example by the evaluation system.

[0041] According to an embodiment of the invention, a location of the railway vehicle is determined by the railway vehicle and the railway vehicle data is localized by the railway vehicle. It also may be possible that the railway vehicle itself localizes the railway vehicle data, which it sends to the evaluation system. For example, this may be done by GPS measurements acquired in the railway vehicle.

[0042] According to an embodiment of the invention, the railway vehicle data of a railway vehicle is determined with a controller of a traction converter of the railway vehicle adapted for supplying an electrical motor, which drives a traction wheel of the railway vehicle. In particular, the controller of the traction converter may generate many quantities that may be evaluated in view of wear.

[0043] For example, the railway vehicle data may comprise a slip of a traction wheel of the railway vehicle. Slip may be the difference between a speed of the railway vehicle (which, for example, may be measured by radar) and a speed of the traction wheel (which, for example, may be determined from a rotational speed of the wheel, a frequency of the motor driving the wheel, etc.). As high-

er the slip as higher the friction between the traction wheel and the rails.

[0044] As a further example, the railway vehicle data may comprise a time in a slip mode, in which the controller controls the slip. Already the time/duration, when slip is present, may be an indicator for a low friction between traction wheel and rails.

[0045] As a further example, the railway vehicle data may comprise torsional oscillations of the traction wheel. Torsional oscillations may be higher order components of the speed of the traction wheel. These also have an impact and/or may be an indicator for a worn traction wheel.

[0046] As a further example, the railway vehicle data may comprise a time braking affecting the traction wheel. Braking may be performed electrically, pneumatically and/or with sand. This may be a further quantity indication of energy dissipated by the traction wheel and therefore of a wear of the traction wheel.

[0047] According to an embodiment of the invention, the method further comprises: collecting railway weather data, the railway weather data comprising data associated with weather conditions at locations of the railways and/or at specific time points. For example, an unusual weather situation, such as rain and snow, may result in more anomalous behaviour as in usual weather situations. The determination of the wear of the railways and the wear of the railway vehicles may be additionally based on the railway weather data. The railway weather data may be included into the determination of wear of the rails and/or the railway vehicles. The railway weather data also may be used for determining anomalous behaviour and/or for excluding locations with anomalous behaviour (for example locations with unusual weather).

[0048] According to an embodiment of the invention, the method further comprises: generating a list of locations for railway maintenance based on the determined wear of the rails. The method may help a railway operator in assessing the state of the track infrastructure and in performing condition based or predictive maintenance. Locations with anomalous behaviour higher than a threshold may be included in a list, which indicate where maintenance may take place.

[0049] The method may suggest, for example based on machine learning methods, where to inspect the rails and/or may predict critical conditions of rails in the future.

[0050] According to an embodiment of the invention, the method further comprises: generating a list of railway vehicles for maintenance based on the determined wear of the railway vehicles. With the method, the wear of traction wheels may be identified and maintenance may be arranged accordingly. This may enable pro-active maintenance, which may be scheduled and may not disrupt the railway system.

[0051] According to an embodiment of the invention, the method further comprises: updating a control parameter of a controller of a railway vehicle based on the wear determined from the railway vehicle data and the railway

track data. The controller may control a traction converter of the railway vehicle, which traction converter is adapted for supplying an electrical motor, which drives a traction wheel of the railway vehicle.

[0052] The method may suggest and/or may determine how to adapt control parameters of a traction converter in order to optimize the wheel-track interaction using the railway vehicle data and the railway track data. An adaptation of one or more control parameters may directly minimize the wear of traction wheels and/or rails at the same time. This may directly translate into savings for railway vehicle maintenance and infrastructure maintenance costs.

[0053] According to an embodiment of the invention, the control parameter is at least one of: a bound for a slip of the traction wheel; a bound for torsional oscillations of the traction wheel; and/or a control parameter for controlling adhesion between the traction wheel and rails. These control parameters may be determined from an actual wear of a traction wheel, which has been determined from the railway vehicle data and railway track data.

[0054] According to an embodiment of the invention, the method may comprise generating reports and/or alarms for manual work force management and scheduling maintenance of at least one of rail inspection or rail maintenance, wheel profile measurements, maintenance and re-profiling and/or retuning of traction converter control parameters.

[0055] According to an embodiment of the invention, the method may comprise automatically issuing tickets for work force management and scheduling maintenance of at least one of rail inspection or rail maintenance, wheel profile measurements, maintenance and re-profiling and/or retuning of traction converter control parameters.

[0056] Further aspects of the invention relate to a computer program, which, when executed on at least one processor, is adapted for performing the method as described in the above and in the following, and to a computer-readable medium, in which such a computer program is stored.

[0057] The computer program may be executed in the evaluation system and optionally in the railway vehicles, for example in the controllers of the converters of the railway vehicles.

[0058] A computer-readable medium may be a floppy disk, a hard disk, an USB (Universal Serial Bus) storage device, a RAM (Random Access Memory), a ROM (Read Only Memory), an EPROM (Erasable Programmable Read Only Memory) or a FLASH memory. A computer-readable medium may also be a data communication network, e.g. the Internet, which allows downloading a program code. In general, the computer-readable medium may be a non-transitory or transitory medium.

[0059] It has to be understood that features of the method as described in the above and in the following may be features of the computer program, the computer-readable medium, the railway system and the railway moni-

toring system as described in the above and in the following, and vice versa.

[0060] These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0061] The subject-matter of the invention will be explained in more detail in the following text with reference to exemplary embodiments which are illustrated in the attached drawings.

Fig. 1 schematically shows a railway system according to an embodiment of the invention.

Fig. 2 schematically shows a railway monitoring system according to an embodiment of the invention.

Fig. 3 shows a flow diagram for a method for detecting wear in a railway system according to an embodiment of the invention.

[0062] The reference symbols used in the drawings, and their meanings, are listed in summary form in the list of reference symbols. In principle, identical parts are provided with the same reference symbols in the figures.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0063] Fig. 1 shows a railway system 10, which comprises a plurality of railways 12 and a plurality of railway vehicles 14. The railways 12 may be composed of rails 16, track switches 18 and further components. Every railway vehicle 14 may comprise a traction vehicle and one or more waggons.

[0064] Fig. 1 furthermore shows a railway monitoring system 20, which is connected via a communication network 22, such as the Internet, with each railway vehicle 14.

[0065] Fig. 2 shows one railway vehicle 14 and the railway monitoring system 20 in more detail. The railway vehicle 14 comprises an electrical traction converter 24, which is adapted for supplying an electrical motor 26 with current, which may be converted from a current of a catenary line 28. The electrical motor 26 drives a traction wheel 30 of the railway vehicle 14. It may be that the railway vehicle 14 has additional wheels 32 and/or multiple traction motors. The traction converter 24 is controlled by a controller 34, which upon commands from a vehicle control and monitoring system 36 determines a frequency and a power of an actual current to be supplied to the electrical motor 26.

[0066] The vehicle control and monitoring system 36 and the controller 34 are interconnected with a communication device 38, which sends railway vehicle data 40, which is collected from the system 36, the controller 34

and optional further components, via the communication network 22 to a central part 42 of the railway monitoring system 20.

[0067] The railway monitoring system 20 comprises a central evaluation system 44 and a central database 46, which stores the railway vehicle data 40 and further data like railway track data 48 and weather data 50.

[0068] The central evaluation system 44 may be implemented as a cloud service in a cloud computing facility and/or the central database 46 may be provided in the cloud computing facility.

[0069] The railway vehicle data 40 may be associated with a specific railway vehicle 14. The railway vehicle data 40 may comprise operational data generated by the railway vehicle 14 itself, such as a slip value, converter current and/or voltages, a vehicle speed, etc. This data may be seen as online generated data.

[0070] The online generated data may comprise data generated by the controller 34, such as currents, voltages, motor temperatures, motor speed, torque, amount of slip, time in slip mode, time of active adhesion control, etc.

[0071] The data online generated in the railway vehicle 40 also may comprise general railway vehicle data, such as a GPS location, an altitude, a railway vehicle speed, ambient conditions, humidity, etc. This data furthermore comprise events, alarms, etc. generated by the system 36 and/or other components installed in the railway vehicle 14.

[0072] The railway vehicle data 40 also may comprise operational data that was collected for the railway vehicle 14 otherwise. This data may be seen as offline generated data. The offline generated operational data may comprise traction wheel profile measurements, a railway vehicle configuration, a railway vehicle loading, a route of the railway vehicle, etc.

[0073] On the other hand, the railway track data 48 may be associated with specific components of the railways 12, such as rails 16 and/or track switches 18. The railway track data 48 may comprise track conditions and/or states, such as a last measured track wear. It also may comprise expected track conditions.

[0074] Fig. 3 shows a method for detecting wear in a railway system 10, which may be performed by the monitoring system shown in Fig. 2.

[0075] In step S10, data is collected that is not provided by the railway vehicles 14 via the communication network 22. This data may include offline data associated with the railway vehicles 14 and/or with the railways 12. Examples of these data are provided above.

[0076] For example, railway track data 48 may be collected. Railway track data 48 may at least comprise data of a state and/or a configuration of rails 16 at specific locations.

[0077] As a further example, weather data 50 may be collected. The weather data 50 may comprise data associated with weather conditions at locations of the railways 12 and/or at specific time points.

[0078] Also, railway vehicle data 40 may be collected

that is not acquired online in the railway vehicles 14.

[0079] In step S10, all the data may be collected by the evaluation system 44, which also may store the data in the database 46.

[0080] In step S12, which may be performed regularly and/or more often than step S10, the railway vehicle data 40 acquired by the railway vehicles 14 is collected.

[0081] The railway vehicle data 40 of a railway vehicle 14 may be determined with the controller 34, the system 36 and/or with other components of the railway vehicle, such as a GPS sensor. The railway vehicle data 40 then may be sent with the communication device 38 to the central part 42 of the monitoring system 20. Again, the evaluation system 44 also may store this data 40 in the database 46.

[0082] In step S14, a location of the railway vehicles 14 in the railway system 10 is determined and the railway vehicle data 40 acquired at the location is associated with this location.

[0083] For example, the location of the railway vehicle 14 may be determined by the railway vehicle 14 itself and the railway vehicle data 40 also may be localized by the railway vehicle 14 before it is sent to the evaluation system 44.

[0084] Another possibility is that the railway vehicle data 40 is timestamped by the railway vehicle 14, when it is acquired. Then the railway vehicle data 40 may be sent to the evaluation system 44. The timestamps of different railway vehicles 14 may then be synchronized by the evaluation system 44. The evaluation system 44 may determine a location, where railway vehicle data 40 has been acquired, from the timestamp of the railway vehicle data 40 and a route of the respective railway vehicle 14. This may be performed with a schedule of the railway system 10.

[0085] In step S16, which may be seen as the main processing step, anomalous behaviour of the railways 12 and/or the railway vehicles 14 is determined from the collected data. This step may be performed using heuristics, correlations and/or a machine learning based algorithm, which identifies and classifies anomalies for specific track locations.

[0086] Step S16 and also the following steps may be performed by the evaluation system 44.

[0087] An anomalous behaviour may be a change of a quantity determined from the railway vehicle data 40 at the location, which change is bigger than a threshold.

[0088] For example, the quantity may be the slip of the traction wheel 30 of the railway vehicle 14. When the slip becomes bigger than a threshold and/or the slip rises more than a threshold at a specific location, anomalous behaviour at the specific location may be determined.

[0089] An anomalous behaviour may be associated with a specific railway vehicle 14, when the anomalous behaviour based on the same quantity occurs for the same railway vehicle 14 at different locations and/or at locations, where other railway vehicles 14 do not have anomalous behaviour.

[0090] An anomalous behaviour also may be associated with a component of the railway system 10, such as a rail 16, when anomalous behaviour occurs at the same location.

[0091] The determination of the anomalous behaviour also may be based on the railway weather data 50. For example, anomalous behaviour, where it is expected that the rails 16 were wet due to rain, may be excluded.

[0092] In step S18, a wear of the railways 12 at a location and/or a wear of railway vehicles 14, which have passed this location, is determined from the railway vehicle data 40 associated with the location and the railway track data 48 associated with the location. Again, the determination of the wear of the railways 12 and the wear of the railway vehicles 14 may be additionally based on the railway weather data 50.

[0093] As an example, the determination of wear may be based on the anomalous behaviour determined in step S16. For example, when a plurality of railway vehicles 14 have an anomalous behaviour at the same location, it may be decided that rails 16 at the location are worn. Furthermore, when one railway vehicle 14 has an anomalous behaviour at several locations, where other railway vehicles 14 have less anomalous behaviour, it may be decided that the railway vehicle 14 has a worn traction wheel 36.

[0094] It also may be that a wear of the railway vehicles 14 and in particular a wear of their traction wheels 30 may be determined directly from the collected data, for example with correlations of quantities stored in the data and/or with a machine learning based algorithm.

[0095] Analogously, a wear of the railways 12 may be determined directly from the collected data, for example with correlations of quantities stored in the data and/or with a machine learning based algorithm.

[0096] Following steps S20 to S26 are optional. Only one or some of these steps may be performed.

[0097] In step S20, railway faults are localized and/or suggestions for maintenance may be given to an inspection team. This may be very helpful, because the inspection team then knows where to look for faults.

[0098] For example, a railway fault may be determined as a location with a rather high wear and/or with a large amount of abnormal behavior. The evaluation system 44 may generate a list of locations for railway maintenance based on the determined wear of the rails 16 and/or the determined abnormal behaviour.

[0099] In step S22, railway conditions and/or railway faults are predicted. For example at locations, where the number of abnormal behaviours and/or the wear is rising fast, may be locations, where a fault may occur in near future. The results of steps S16 and/or S18 may be used to predict what kind of conditions may be encountered in the future for critical locations. Again, this information may be used to schedule maintenance actions, which are not very urgent, to dispatch a maintenance team if the condition is critical, or many other actions involving service teams, component suppliers, etc.

[0100] In step S24, traction wheel wear is used for suggesting traction vehicle maintenance. As already mentioned, knowing where railways 12 are in a good condition, railway vehicles 14 with traction wheel degradation problems may be identified. This can be used to anticipate or reschedule maintenance of a specific railway vehicle 14. A list of railway vehicles 14 for maintenance may be generated and/or updated, based on the determined wear and/or determined abnormal behaviour.

[0101] In general, an interaction of the evaluation system 44 with expert personnel may happen through automatic reports, which may be used as a basis for decision making in the above described cases. It also may be possible that warnings and alarms may be generated, which, for example, are provided to a central operating center.

[0102] It also may be that suggestions generated by the evaluation system 44 are used to automatically issue a ticket and/or deploying a maintenance team to a suspected location, where a fault has been detected. It also is possible to directly signalize to a railway vehicle operator that a wheel condition is bad and that depending on the criticality of the condition, immediate maintenance or other actions are necessary.

[0103] In step S26, a control parameter of the controller 34 is updated based on the wear and/or the abnormal behaviour determined in steps S16 and/or S18.

[0104] For example, the abnormal behaviour may be based on a traction wheel slip-slide, on an active adhesion control and/or on torsional oscillations of the axle of the traction wheel 30. The abnormal behaviours may then be clustered and it may be determined, if a parameter adaptation is necessary by comparing control performances among different railway vehicles 14. This may be done again using heuristic methods and/or machine learning methods.

[0105] The control parameter to be updated may be at least one of a bound for a slip of the traction wheel 30, a bound for torsional oscillations of the traction wheel 30 and/or a control parameter for controlling adhesion between the traction wheel 30 and rails 16.

[0106] Based on the determined wear and/or abnormal behavior associated with a railway vehicle 14, the evaluation system 44 may output a suggestion for an updated control parameter. Such a suggestion may comprise indications as to perform "less aggressive" and "more aggressive" tuning.

[0107] In one example, an automatic report may be generated, which is reviewed by an expert, who is able to decide on scheduling a control parameter update in the next maintenance interval.

[0108] In another example, the evaluation system 44 may update the control parameter automatically, for example online. This update may be performed via the communication network 22, in particular, when the communication network offers a bi-directional communication.

[0109] While the invention has been illustrated and described in detail in the drawings and foregoing descrip-

tion, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art and practising the claimed invention, from a study of the drawings, the disclosure, and the appended claims. In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single processor or controller or other unit may fulfil the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage. Any reference signs in the claims should not be construed as limiting the scope.

LIST OF REFERENCE SYMBOLS

[0110]

10	railway system
12	railway
14	railway vehicle
16	rail
18	track switch
20	railway monitoring system
22	communication network
24	traction converter
26	electrical motor
28	catenary line
30	traction wheel
32	additional wheels
34	controller
36	vehicle control and monitoring system
38	communication device
40	railway vehicle data
42	central part of the railway monitoring system / cloud computing facility
44	evaluation system
46	database
48	railway track data
50	weather data

Claims

1. A method for detecting wear in a railway system (10), wherein the railway system (10) comprises a plurality of railways (12) and a plurality of railway vehicles (14);
the method comprising:

collecting railway vehicle data (40) acquired by railway vehicles (14), the railway vehicle data (40) at least comprising data associated with friction between a traction wheel (30) of the railway vehicle (14) and rails (16);

- determining a location of the railway vehicles (14) in the railway system (10);
 localizing the railway vehicle data (40), such that the railway vehicle data (40) is associated with the locations, where the railway vehicle data (40) has been acquired;
 determining at least one of a wear of the railways (12) at a location and a wear of a railway vehicle (14) from the localized railway vehicle data (40) of at least two railway vehicles (14).
2. The method of claim 1, further comprising:
 determining at least one of a wear of the railways (12) at a location and a wear of a railway vehicle (14) from the localized railway vehicle data (40) of at least two railway vehicles (14) and railway track data (48) associated with the location; wherein the railway track data (48) at least comprises data of a state and/or a configuration of rails (16) at specific locations.
3. The method of claim 1 or 2, further comprising:
 determining an anomalous behaviour of the railway vehicle (14) at a location, wherein an anomalous behaviour is a change of a quantity determined from the railway vehicle data (40) at the location, which change is bigger than a threshold;
 when a plurality of railway vehicles (14) have an anomalous behaviour at the same location, deciding that rails (16) at the location are worn;
 when one railway vehicle (14) has an anomalous behaviour at several locations, where other railway vehicles have less anomalous behaviour, deciding that the railway vehicle (14) has a worn traction wheel (36).
4. The method of one of the previous claims, further comprising:
 timestamping railway vehicle data (40), when it is acquired;
 determining a location, where railway vehicle data (40) has been acquired from a timestamp of the railway vehicle data (40) and a route of the railway vehicle (14), which has acquired the railway vehicle data (40).
5. The method of one of the previous claims, wherein a location of the railway vehicle (14) is determined by the railway vehicle (14) and the railway vehicle data (40) is localized by the railway vehicle (14).
6. The method of one of the previous claims, wherein the railway vehicle data (40) of a railway vehicle (14) is determined with a controller (34) of a traction converter (24) of the railway vehicle (14) adapted for supplying an electrical motor (26), which drives a traction wheel (30) of the railway vehicle (14); and/or wherein the railway vehicle data (40) comprises at least one of:
 a slip of a traction wheel (30) of the railway vehicle (14);
 a time in a slip mode, in which the controller (34) controls the slip;
 torsional oscillations of the traction wheel (30);
 a tractive and braking effort of the traction wheel (30) and the railway vehicle (14).
7. The method of one of the previous claims, further comprising:
 wherein the determination of the wear of the railways (12) and/or the wear of the railway vehicles (14) is additionally based on railway weather data (50);
 wherein the railway weather data (50) comprising data associated with weather conditions at locations of the railways (12) and/or at specific time points.
8. The method of one of the previous claims, wherein the railway vehicle data (40) and/or railway track data (48) and is stored in a central database (46); wherein the railway vehicle data (40) and/or railway track data (48) are evaluated by a central evaluation system (44) for determining the wear of the railways (12) and the wear of the railway vehicles (14).
9. The method of one of the previous claims, further comprising:
 generating a list of locations for railway maintenance based on the determined wear of the rails (16).
10. The method of one of the previous claims, further comprising:
 updating a control parameter of a controller (34) of a railway vehicle (14) based on the wear determined from the railway vehicle data (40) and/or railway track data (48); wherein the controller (34) controls a traction converter (24) of the railway vehicle (14) adapted for supplying an electrical motor (26), which drives a traction wheel (30) of the railway vehicle (14).
11. The method of claim 10,

wherein the control parameter is at least one of:

a bound for a slip of the traction wheel (30);
a bound for torsional oscillations of the traction
wheel (30); 5
a control parameter for controlling adhesion be-
tween the traction wheel (30) and rails (16).

12. A computer program, which, when executed on at
least one processor, is adapted for performing the 10
method of one of the previous claims.

13. A computer-readable medium, in which a computer
program according to claim 13 is stored. 15

14. A railway monitoring system (20), comprising:

data acquiring devices (34, 36, 38) for acquiring
railway vehicle data (40) from a plurality of rail- 20
way vehicles (14);
a central database (46) for storing railway vehi-
cle data (40) and/or railway track data (48);
an evaluation system (44) for performing the
method according to one of claims 1 to 11. 25

15. A railway system (10), comprising:

a plurality of railways (12);
a plurality of railway vehicles (14);
a railway monitoring system (20) according to 30
claim 14.

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Fig. 1

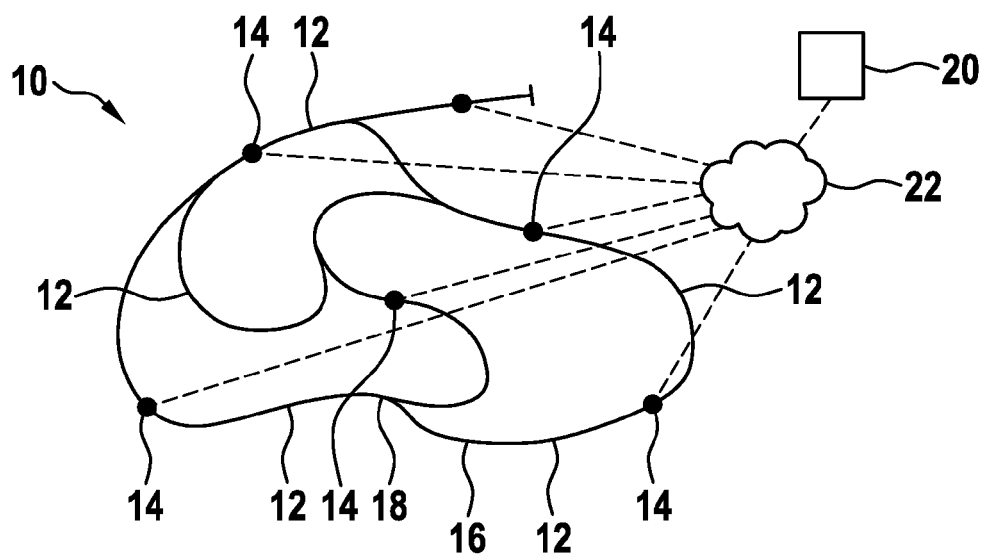


Fig. 2

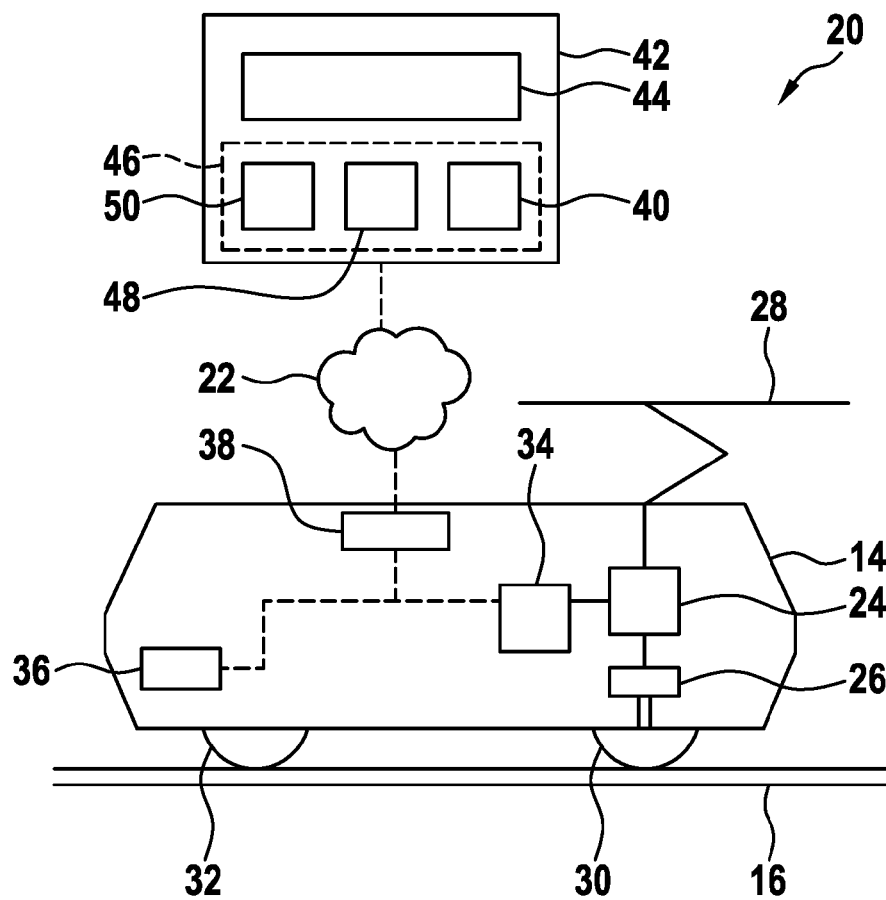
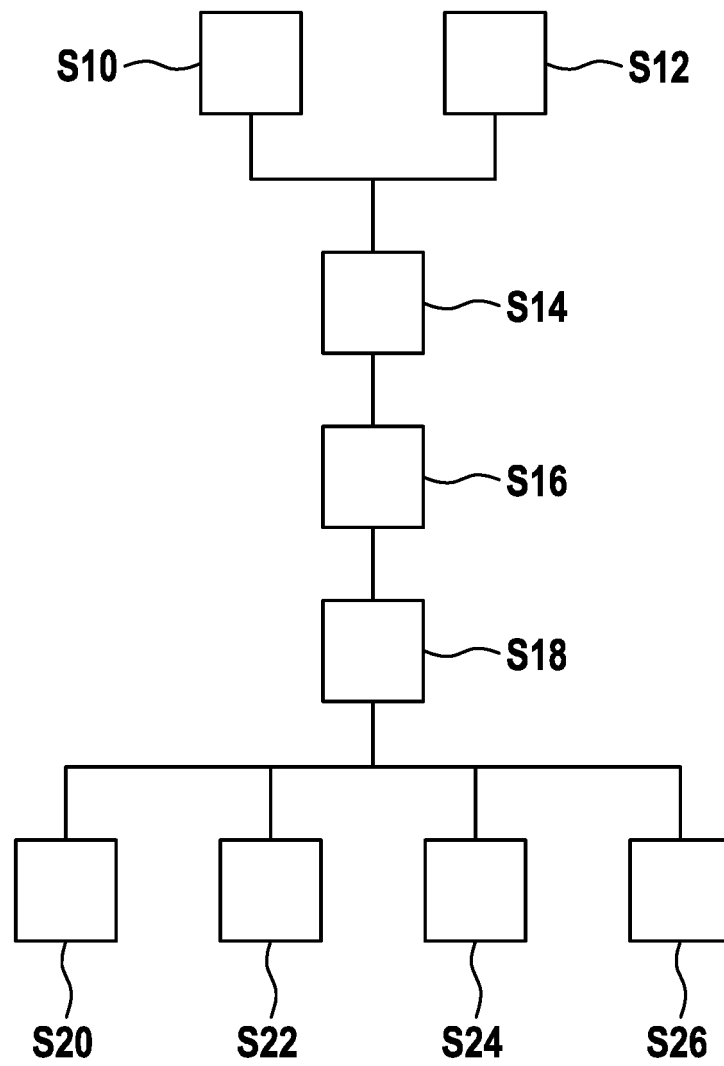


Fig. 3





EUROPEAN SEARCH REPORT

Application Number
EP 18 19 4603

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2018/222504 A1 (BIRCH THOMAS A [US] ET AL) 9 August 2018 (2018-08-09)	1-15	INV. B61L15/00 B61L23/04 B61L27/00
Y	* abstract *	6,11	
	* paragraphs [0016] - [0036] *		
	* paragraphs [0047] - [0053] *		
	* paragraphs [0059] - [0063] *		
	* paragraphs [0067] - [0068] *		
	* paragraphs [0073] - [0079] *		
Y	US 2016/159381 A1 (FAHMY SAMEH [CA]) 9 June 2016 (2016-06-09)	6,11	
	* abstract; figures 2, 3 *		
	* paragraphs [0028] - [0043] *		
	* paragraphs [0063], [0064] *		
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 18 March 2019	Examiner Robinson, Victoria
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

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The members are as contained in the European Patent Office EDP file on
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18-03-2019

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US 2016159381 A1	09-06-2016	NONE	

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EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82