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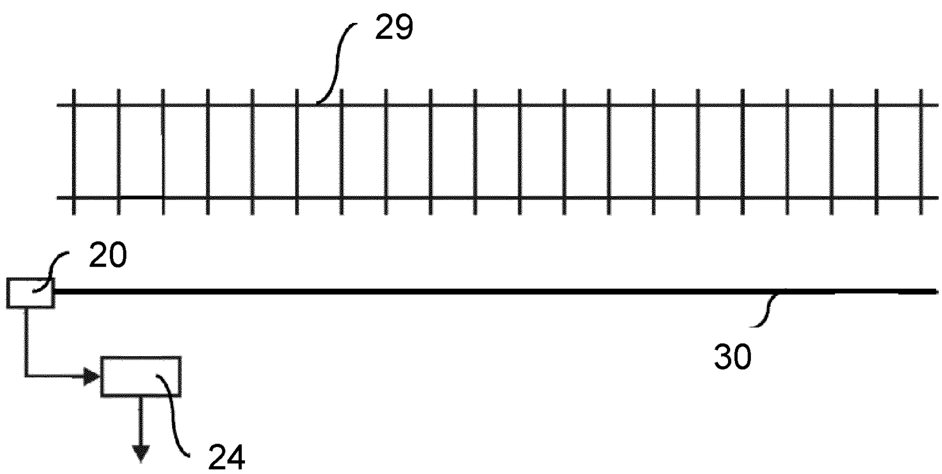
(54) METHOD FOR MONITORING A RAILWAY TRACK AND MONITORING UNIT FOR MONITORING A RAILWAY TRACK

(57) A method for monitoring a railway track (29) is provided, the method comprising: detecting a first monitoring signal (Ml) by a distributed acoustic sensor (20) at an initial position (21) while a rail vehicle passes the initial position (21), wherein the distributed acoustic sensor (20) is arranged along the track (29), detecting a second monitoring signal (M2) by the distributed acoustic sensor (20) at at least one predefined position (22) along the track (29) while a rail vehicle passes the predefined position (22), comparing the first monitoring signal (Ml) and the second monitoring signal (M2) with each other, wherein the first monitoring signal (Ml) comprises features (23) that each relate to one axle of the rail vehicle passing the initial position (21) and the second monitoring signal (M2) comprises features (23) that each relate to one axle of the rail vehicle passing the predefined position (22), and comparing the first monitoring signal (Ml) and the second monitoring signal (M2) with each other comprises counting the features (23) relating to axles of the respective passing rail vehicle for the first monitoring signal (Ml) and the second monitoring signal (M2). Furthermore, a monitoring unit (24) for monitoring a railway track (29) is provided.

FIG. 5



Description

[0001] A method for monitoring a railway track and a monitoring unit for monitoring a railway track are provided.

[0002] For monitoring a railway track it is necessary to monitor the position of moving rail vehicles. This includes monitoring the integrity of moving rail vehicles. This means, for monitoring the movement of rail vehicles on a railway track it is necessary to know if a rail vehicle is still complete or if parts of the rail vehicle were disconnected from other parts. Separated parts of rail vehicles can be dangerous for other moving rail vehicles and should be detected before another rail vehicle reaches the position of the separated part.

[0003] In order to check the integrity of a rail vehicle wheel sensors can be employed that are capable of counting the axles of passing rail vehicles. These wheel sensors are arranged at fixed positions along the rail. The distances between neighboring wheel sensors can be several 100 meters or several kilometers. This means, between two neighboring wheel sensors, it is not possible to check the integrity of a moving rail vehicle. For safety reasons only one rail vehicle is allowed between two neighboring wheel sensors, this means within one so-called block. Only if both wheel sensors adjoining the block confirmed the integrity of the rail vehicle another rail vehicle can enter the block. For large blocks this leads to an inefficient use of the rail.

[0004] It is an objective to provide a method for monitoring a railway track with an improved accuracy. It is further an objective to provide a monitoring unit for monitoring a railway track with an improved accuracy.

[0005] These objectives are achieved with the independent claims. Further embodiments are the subject of dependent claims.

[0006] According to at least one embodiment of the method for monitoring a railway track, the method comprises detecting a first monitoring signal by a distributed acoustic sensor at an initial position while a rail vehicle passes the initial position, wherein the distributed acoustic sensor is arranged along the track. The first monitoring signal is the signal detected by the distributed acoustic sensor at the initial position while the rail vehicle passes the initial position. The first monitoring signal can comprise a plurality of first monitoring signal values. The first monitoring signal values are each detected at different times during the passage of the rail vehicle at the initial position. The first monitoring signal values are detected after one another during the passage of the rail vehicle at the initial position. This means, the first monitoring signal comprises an array of first monitoring signal values that are detected by the distributed acoustic sensor at the initial position during the passage of a rail vehicle.

[0007] The distributed acoustic sensor can be arranged in the environment of the railway track. This means, the distributed acoustic sensor can be arranged close to the railway track. The length of the distributed acoustic sensor can amount to several kilometers or several hundreds of kilometers.

[0008] The method further comprises detecting a second monitoring signal by the distributed acoustic sensor at at least one predefined position along the track while a rail vehicle passes the predefined position. The second monitoring signal is the signal detected by the distributed acoustic sensor at the predefined position while the rail vehicle passes the predefined position. The second monitoring signal can comprise a plurality of second monitoring signal values. The second monitoring signal values are each detected at different times during the passage of the rail vehicle at the predefined position. The second monitoring signal values are detected after one another during the passage of the rail vehicle at the predefined position. This means, the second monitoring signal comprises an array of second monitoring signal values that are detected by the distributed acoustic sensor at the predefined position during the passage of a rail vehicle.

[0009] The method further comprises comparing the first monitoring signal and the second monitoring signal with each other. The comparison of the first monitoring signal with the second monitoring signal can be carried out electronically. For example, a comparison unit of a monitoring unit is configured to compare the first monitoring signal and the second monitoring signal with each other.

[0010] The first monitoring signal comprises features that each relate to one axle of the rail vehicle passing the initial position and the second monitoring signal comprises features that each relate to one axle of the rail vehicle passing the predefined position. The features can for example be peaks in the first monitoring signal or the second monitoring signal. This means, features of the first monitoring signal can be points or regions of an increased amplitude in comparison to the points or regions between the features. Features of the second monitoring signal can be points or regions of an increased amplitude in comparison to the points or regions between the features. The first monitoring signal comprises one feature for each axle of the rail vehicle passing the initial position. The second monitoring signal comprises one feature for each axle of the rail passing the predefined position. Each feature of the first monitoring signal is detected during the passage of one of the axles of the passing rail vehicle at the initial position. Each feature of the second monitoring signal is detected during the passage of one of the axles of the passing rail vehicle at the predefined position. Therefore, the number of features of the first monitoring signal is the same as the number of axles of the rail vehicle passing the initial position. The number of features of the second monitoring signal is the same as the number of axles of the rail vehicle passing the predefined position.

[0011] Comparing the first monitoring signal and the second monitoring signal with each other comprises counting the features relating to axles of the respective passing rail vehicle for the first monitoring signal and the second monitoring signal. This means, for the first monitoring signal the number of features is determined and for the second monitoring signal the number of features is determined. The number of features of the first monitoring signal is compared to the number of features of the second monitoring signal.

[0012] From the first monitoring signal the number of axles of the passing rail vehicle can be determined. The number of axles of the passing rail vehicle at the initial position is the same as the number of features of the first monitoring signal. From the second monitoring signal the number of axles of the passing rail vehicle can be determined for the predefined position. The axles of the passing rail vehicle at the predefined position is the same as the number of features of the second monitoring signal. Therefore, from the first monitoring signal and the second monitoring signal it can be determined if the passing rail vehicle has same number of axles at the predefined position as at the initial position. For this purpose, the number of features of the first monitoring signal is compared to the number of features of the second monitoring signal.

[0013] Consequently, the method described herein enables monitoring the integrity of passing rail vehicles. If the integrity of a rail vehicle is known for the initial position a comparison of the number of features of the first and the second monitoring signal provides the information if the rail vehicle has the same number of axles at the predefined position as at the initial position. This means, the integrity of the rail vehicle can be monitored.

[0014] The predefined position can be any position along the railway track where the second monitoring signal comprises distinctive features that each relate to an axle of a passing rail vehicle. This is for example the case for positions along the railway track where the amplitude of the monitoring signal is increased in comparison to other regions of the railway track. Thus, predefined positions can be at defects of the rail, at turnouts, at connections of different rails or at other irregularities of the rail. A typical rail has a plurality of positions that can be employed as predefined positions. Therefore, in comparison to employing wheel sensors the integrity of a passing rail vehicle can be monitored for a significantly larger number of positions. This means, the accuracy of monitoring the railway track is improved. Furthermore, the railway track can be employed more efficiently as rail vehicles can be arranged on the track with shorter distances between each other, this means their density can be increased. At the same time, safety standards can be guaranteed since the integrity of rail vehicles is monitored for a plurality of positions. Another advantage is that distributed acoustic sensors are already arranged parallel to many existing railway tracks. Thus, no new equipment is required. This means, the cost for improved accuracy, efficiency and security is low.

[0015] According to at least one embodiment of the method, comparing the first monitoring signal and the second monitoring signal with each other further comprises calculating a correlation between the first monitoring signal and the second monitoring signal. This means, in addition to counting the features relating to axles of the respective passing rail vehicle for the first monitoring signal and the second monitoring signal, a correlation between the first monitoring signal and the second monitoring signal is calculated. This means, the shape of the first monitoring signal is compared to the shape of the second monitoring signal. For the correlation the amplitude of the first monitoring signal is correlated with the amplitude of the second monitoring signal. The amplitude of the monitoring signals is influenced by a plurality of factors, as for example the weight of different parts of the rail vehicle, the interaction of different wheels of the rail vehicle with the rail and also the length of the rail vehicle, this means the number of axles of the rail vehicle.

[0016] This means, the shape of the features in the first monitoring signal and in the second monitoring signal depends on these factors. Thus, each monitoring signal has a particular shape for each rail vehicle. For example, for a heavy wagon the amplitude of the respective monitoring signal is larger than for a lighter wagon. Furthermore, the shape of the wheels determines the interaction with the rail and thus the amplitude of the respective monitoring signal. By calculating a correlation between the first monitoring signal and the second monitoring signal it is determined if the rail vehicle passing the predefined position leads to the same characteristic shape of the second monitoring signal as the first monitoring signal. From this correlation it can be determined if all parts of the rail vehicle that passed the initial position are still detected at the predefined position. In this way, the integrity of the rail vehicle can be monitored at the predefined position.

[0017] In order to confirm the integrity of the rail vehicle at the predefined position it is determined from the correlation if the characteristic shape of the second monitoring signal is the same as that of the first monitoring signal. If one or more characteristic features of the first monitoring signal that relate to one or more axles of the rail vehicle are missing in the second monitoring signal, the integrity of the rail vehicle is not confirmed. Furthermore, the integrity of the rail vehicle is not confirmed if the order of the characteristic features of the second monitoring signal is different from the order of the corresponding characteristic features of the first monitoring signal.

[0018] Advantageously, calculating the correlation between the first monitoring signal and the second monitoring signal is a further possibility to monitor the integrity of the rail vehicle at the predefined position. Thus, two measures can be employed to determine the integrity of a rail vehicle at the predefined position, namely counting the axles and calculating the correlation between the first and the second monitoring signal. In this way, the security of monitoring the railway track is increased.

[0019] According to at least one embodiment of the method, at the initial position the integrity of the rail vehicle passing the initial position is given. This means, for the initial position it is known or confirmed that the rail vehicle is complete. That the rail vehicle is complete means that no wagon of the rail vehicle is missing or disconnected. The initial position is therefore a position that can be employed as a reference. The first monitoring signal comprises the features that relate to the complete rail vehicle. Advantageously, by comparing the first monitoring signal detected at the initial position to the second monitoring signal the integrity of the rail vehicle can be monitored.

[0020] According to at least one embodiment of the method, the integrity of the rail vehicle passing the initial position is confirmed by personnel of the respective rail vehicle or by an external device. For example, the initial position is a position where personnel of the rail vehicle can check if the rail vehicle is complete. The initial position can be within a station or close to a station. The information that the rail vehicle is complete at the initial position can be provided to a monitoring unit carrying out the method for monitoring the railway track. The external device can be a wheel sensor arranged at the rail. The wheel sensor is configured to count the axles of a passing rail vehicle at a very high safety standard. This means, the signal provided by the wheel sensor is very reliable and provides the information how many axles the rail vehicle has. For confirming the integrity of the rail vehicle at the initial position advantageously only reliable sources of information as personnel of the rail vehicle or the external device are employed.

[0021] According to at least one embodiment of the method, the integrity of the rail vehicle passing the initial position is confirmed for the case that the first monitoring signal comprises the same number of features that each relate to one axle of the rail vehicle passing the initial position as a previous monitoring signal for which the integrity of the rail vehicle passing the position, where the previous monitoring signal is detected, is confirmed by personnel of the respective rail vehicle or by an external device. This means, the integrity of the rail vehicle passing the initial position is confirmed by comparing the previous monitoring signal and the first monitoring signal with each other where the features relating to axles of the respective passing rail vehicle are counted for the previous monitoring signal and for the first monitoring signal. If the first monitoring signal comprises the same number of features that each relate to one axle of the passing rail vehicle as the previous monitoring signal the rail vehicle has the same length at the initial position as at the position where the previous monitoring signal is detected. For the position where the previous monitoring signal is detected the integrity of the rail vehicle is confirmed or known. The position where the previous monitoring signal is detected can be within a station or close to a station. At the station personnel of the rail vehicle has the possibility to check the integrity of the rail vehicle. The external device can be a wheel sensor arranged at the rail. Consequently, a reliable source of information is employed to confirm the integrity of the rail vehicle at the initial position. Thus, the security for monitoring the integrity of the rail vehicle at the predefined position is improved.

[0022] According to at least one embodiment of the method, the distributed acoustic sensor comprises an optical fibre arranged along the track and the monitoring signals are backscattered signals of an input signal which is provided to the optical fibre. The optical fibre can be arranged within the ground close to the railway track. It is further possible that the optical fibre is arranged above the ground close to the railway track. The optical fibre extends approximately parallel to the railway track. The input signal can be an optical signal, for example a laser pulse. The input signal is provided to the optical fibre at an input of the optical fibre. A small part of the laser light is reflected back to the input since the laser light is scattered at scatter sites, as for example impurities in the optical fibre which can be natural or artificial. Changes in the backscattered signal are related to physical changes in the optical fibre which can be caused by noise, structure-borne noise, vibrations or soundwaves along the optical fibre. Therefore, a backscattered signal can be detected when a rail vehicle is moving on the track. By evaluating the backscattered signal, the location of the noise or the rail vehicle along the optical fibre can be determined. Each monitoring signal value is the amplitude of the backscattered signal for a distinct position along the railway track at a distinct time. By detecting the backscattered signals rail vehicles moving on the railway track can be monitored.

[0023] According to at least one embodiment of the method, the position of a rail vehicle moving on the track is provided. In addition to monitoring the integrity of moving rail vehicles it is possible to provide the position of moving rail vehicles on the railway track. The distributed acoustic sensor is capable of detecting backscattered signals from the optical fibre arranged along the track. The noise emitted by a moving rail vehicle leads to a characteristic shape of the backscattered signal. By analyzing from which position along the track the characteristic shape of the backscattered signal relating to a moving rail vehicle originates from, it is possible to determine at which position along the railway track the rail vehicle is moving. As the backscattered signals can be detected continuously, the movement of a rail vehicle on the railway track can be monitored continuously as well. This leads to an increased security and accuracy in monitoring the railway track.

[0024] According to at least one embodiment of the method, a confirmation signal is provided if the first monitoring signal and the second monitoring signal relate to the same number of axles of the respective passing rail vehicle. The confirmation signal can be provided by a monitoring unit that is configured to carry out the comparison of the first monitoring signal and the second monitoring signal. The confirmation signal is provided under the condition that the comparison of the first monitoring signal and the second monitoring signal yields that the rail vehicle is complete at the predefined position. This means, the confirmation signal is a confirmation of the integrity of the rail vehicle at the predefined position. If no confirmation signal is provided after the passage of the rail vehicle at the predefined position safety precautions can be carried out, for example no further rail vehicle could be allowed in the section of the track between the initial position and the predefined position. Thus, providing the confirmation signal under the condition that the first monitoring signal and the second monitoring signal relate to the same number of axles of the respective passing rail vehicle increases the security.

[0025] According to at least one embodiment of the method, a confirmation signal is provided if the first monitoring signal and the second monitoring signal have at least a predefined level of correlation. The predefined level of correlation is chosen in such a way that for the predefined level of correlation for each feature of the first monitoring signal that relates to an axle of the passing rail vehicle the second monitoring signal comprises a corresponding feature. Thus, the predefined level of correlation is a threshold above which the first monitoring signal and the second monitoring signal comprise features that relate to the passage of the same rail vehicle with all its parts. The first monitoring signal and the second monitoring signal having at least the predefined level of correlation relates to the rail vehicle being complete at the predefined position. Providing the confirmation signal under the condition that the first monitoring signal and the second monitoring signal have at least the predefined level of correlation increases the security in monitoring the railway track.

[0026] According to at least one embodiment of the method, the at least one predefined position is determined by carrying out a correlation analysis for monitoring signals detected at a plurality of positions along the track during the passage of a rail vehicle with the first monitoring signal, wherein a position along the track is a predefined position if the monitoring signal at the respective position has at least a predefined correlation coefficient with the first monitoring signal. Predefined positions can be positions along the rail that have irregularities. At these positions the monitoring signals can have an increased amplitude in comparison to the monitoring signals in the environment of the predefined positions. The predefined positions are employed in the methods described herein as it is possible to discriminate distinct features in the monitoring signals that are detected at predefined positions. At positions that lie between the predefined positions and that do not have any irregularities, features in the monitoring signal relating to the axles of a passing rail vehicle can be discriminated less clearly than for the predefined positions or not at all. This means the predefined positions are selected in such a way that the features relating to axles of a passing rail vehicle can be discriminated in the monitoring signals detected at the predefined positions. In order to determine if a position can be employed as a predefined position a correlation of the monitoring signal detected at the particular position with the first monitoring signal is determined. The predefined correlation coefficient is a threshold above which the first monitoring signal and the second monitoring signal comprise distinct features that relate to the passage of the same rail vehicle with all its parts.

[0027] If a position can be employed as a predefined position depends on the contact between the wheel and the rail at the particular position, on the environment of the rail and the distributed acoustic sensor and on the distance between the rail and the distributed acoustic sensor. These three factors are different for different positions along the rail and they are independent from each other. The contact between the wheel and the rail is influenced by the shape of the rail. Rails usually have a plurality of irregularities that are distributed over the length of the rail. At the irregularities vibrations can occur during the passage of a wheel of a rail vehicle. These vibrations are restricted to a small environment around the irregularity and their amplitude decreases quickly so that they are relatively short. Therefore, the vibrations caused by the passage of a wheel at the position of an irregularity of the rail can be recognized as a separate feature in a monitoring signal detected at this position. Thus, for each axle passing the position of the irregularity a distinct feature is present in the monitoring signal detected at this position. This enables to count the axles of a passing rail vehicle. The position of these irregularities usually does not change except for the case that rails are exchanged or repaired. Therefore, the positions of irregularities can be employed as predefined positions in monitoring the integrity of passing rail vehicles. Advantageously, under usual conditions each rail comprises a plurality of positions that can be employed as predefined positions so that the integrity of a passing rail vehicle can be monitored at more positions than it is possible with wheel sensors that are arranged with larger distances between each other. Therefore, the accuracy of monitoring the railway track is improved.

[0028] According to at least one embodiment of the method, at the predefined position the rail has a defect or an irregularity. At these positions a monitoring signal detected during the passage of a rail vehicle advantageously comprises a distinctive feature for each axle of the passing rail vehicle. Thus, it is possible to count the axles of a passing rail vehicle in order to monitor the integrity of the rail vehicle.

[0029] According to at least one embodiment of the method, the second monitoring signal has an amplitude that is above a predefined threshold and monitoring signals detected during the passage of a rail vehicle at positions different from the at least one predefined position have an amplitude that is below the predefined threshold. This means, the predefined position is selected in such a way that the amplitude of the second monitoring signal is larger than the amplitude of monitoring signals detected at positions different from the predefined position. The amplitude of the second monitoring signal can be higher than the amplitude of the monitoring signals detected during the passage of a rail vehicle at positions different from the at least one predefined position since the rail has an irregularity at the predefined position which leads to an increased amplitude of the second monitoring signal. The at least one predefined position is selected in this way in order to enable that distinct features relating to axles of the passing rail vehicle can be distinguished in the second monitoring signal. For the positions along the rail that are different from the at least one predefined position it is usually not possible to differentiate distinct features in the monitoring signals, for example because the amplitude is too low or the signal-to-noise ratio is too high. Thus, by employing the at least one predefined position for monitoring the railway track the integrity of a passing rail vehicle can be monitored at the at least one predefined position.

[0030] According to at least one embodiment of the method, the method is carried out for a plurality of predefined positions. The plurality of predefined positions can be arranged along the railway track. For each of the plurality of predefined positions features in the second monitoring signal relating to axles of a passing rail vehicle can be distinguished. In this way, advantageously the integrity of a passing rail vehicle can be monitored for a plurality of positions along the railway track.

[0031] Furthermore, a monitoring unit for monitoring a railway track is provided. The monitoring unit can preferably be employed in the methods described herein. This means all features disclosed for the method for monitoring a railway track are also disclosed for the monitoring unit for monitoring a railway track and vice-versa.

[0032] In at least one embodiment of the monitoring unit for monitoring a railway track, the monitoring unit comprises an input that is connected to a distributed acoustic sensor being arranged along the track. The monitoring unit can be configured to receive data or signals from the distributed acoustic sensor at its input.

[0033] The monitoring unit further comprises a detection unit that is configured to receive monitoring signals that are detected by the distributed acoustic sensor. The detection unit can be connected to the input of the monitoring unit.

[0034] The monitoring unit further comprises a comparison unit that is configured to compare a first monitoring signal detected by the distributed acoustic sensor at an initial position while a rail vehicle passes the initial position and a second monitoring signal detected by the distributed acoustic sensor at at least one predefined position along the track while a rail vehicle passes the predefined position with each other. The comparison unit can be connected to the detection unit. The comparison unit can be configured to receive the first monitoring signal and the second monitoring signal from the detection unit.

[0035] The first monitoring signal comprises features that each relate to one axle of the rail vehicle passing the initial position and the second monitoring signal comprises features that each relate to one axle of the rail vehicle passing the predefined position.

[0036] Comparing the first monitoring signal and the second monitoring signal with each other comprises counting the features relating to axles of the respective passing rail vehicle for the first monitoring signal and the second monitoring signal.

[0037] The monitoring unit can advantageously be employed to monitor the integrity of a rail vehicle passing the predefined position. Since a typical railway track has a plurality of positions that can be employed as predefined positions the integrity of a passing rail vehicle can be monitored for a significantly larger number of positions than for the case when wheel sensors are employed. This means, the monitoring unit enables to monitor the railway track with an improved accuracy.

[0038] In at least one embodiment of the monitoring unit the monitoring unit further comprises an output at which a confirmation signal is provided for the case that the first monitoring signal and the second monitoring signal relate to the same number of axles. Whether the first monitoring signal and the second monitoring signal relate to the same number of axles is determined by the comparison unit. For this purpose the comparison unit is configured to determine if the first monitoring signal comprises the same number of features that relate to an axle of a passing rail vehicle, respectively, as the second monitoring signal. Providing the confirmation signal has the advantage that the railway track is monitored with an improved security.

[0039] In at least one embodiment of the monitoring unit, the monitoring unit is capable of providing the position of a rail vehicle moving on the track. The position of a rail vehicle moving on the railway track can be determined from the signals provided by the distributed acoustic sensor. By providing the position of a rail vehicle moving on the railway track, the railway track is monitored with an improved accuracy.

[0040] In at least one embodiment of the monitoring unit, the monitoring unit comprises the distributed acoustic sensor or at least a part of the distributed acoustic sensor.

[0041] The following description of figures may further illustrate and explain exemplary embodiments. Components that are functionally identical or have an identical effect are denoted by identical references. Identical or effectively identical components might be described only with respect to the figures where they occur first. Their description is not necessarily repeated in successive figures.

[0042] With figure 1 an exemplary embodiment of the method for monitoring a railway track is described.

[0043] Figure 2 shows monitoring signals for monitoring a railway track.

[0044] Figures 3 and 4 show exemplary embodiments of the monitoring unit for monitoring a railway track.

[0045] Figure 5 shows an exemplary embodiment of the monitoring unit with a distributed acoustic sensor.

[0046] With figure 1 the steps of an exemplary embodiment of the method for monitoring a railway track 29 are described. In a first step S1 of the method a first monitoring signal M1 is detected by a distributed acoustic sensor 20 at an initial position 21 while a rail vehicle passes the initial position 21. The distributed acoustic sensor 20 is arranged along the track 29. The first monitoring signal M1 comprises features 23 that each relate to one axle of the rail vehicle passing the initial position 21. In a second step S2 of the method a second monitoring signal M2 is detected by the distributed acoustic sensor 20 at at least one predefined position 22 along the track 29 while a rail vehicle passes the predefined position 22. The second monitoring signal M2 comprises features 23 that each relate to one axle of the rail vehicle passing the predefined position 22. In a third step S3 of the method the first monitoring signal M1 and the second monitoring signal M2 are compared with each other. Comparing the first monitoring signal M1 and the second monitoring signal M2 with each other comprises counting the features 23 relating to axles of the respective passing rail vehicle for the first monitoring signal M1 and the second monitoring signal M2. At the initial position 21 the integrity of the rail vehicle passing the initial position 21 is given. For example, the integrity of the rail vehicle passing the initial position 21 is confirmed by personnel of the respective rail vehicle or by an external device. Alternatively, the integrity of the rail vehicle passing the initial position 21 can be confirmed for the case that the first monitoring signal M1 comprises the same number of features 23 that each relate to one axle of the rail vehicle passing the initial position 21 as a previous monitoring signal for which the integrity of the rail vehicle passing the position, where the previous monitoring signal is detected, is confirmed by personnel of the respective rail vehicle or by an external device.

[0047] In an optional fourth step S4 a correlation is calculated between the first monitoring signal M1 and the second monitoring signal M2. The correlation can for example be a cross correlation. The calculation of the correlation between the first monitoring signal M1 and the second monitoring signal M2 is a further possibility to monitor the integrity of the rail vehicle at the predefined position 22.

[0048] In an optional fifth step S5 a confirmation signal is provided if the first monitoring signal M1 and the second monitoring signal M2 relate to the same number of axles of the respective passing rail vehicle. It is further possible that a confirmation signal is provided if the first monitoring signal M1 and the second monitoring signal M2 have at least a predefined level of correlation.

[0049] The at least one predefined position 22 is determined by carrying out a correlation analysis for monitoring signals detected at a plurality of positions along the track 29 during the passage of a rail vehicle with the first monitoring signal M1, wherein a position along the track 29 is a predefined position 22 if the monitoring signal at the respective position has at least a predefined correlation coefficient with the first monitoring signal M1. For example, at the predefined position 22 the rail has a defect or an irregularity. Thus, the second monitoring signal M2 can have an amplitude that is above a predefined threshold and monitoring signals detected during the passage of a rail vehicle at positions different from the at least one predefined position 22 have an amplitude that is below the predefined threshold.

[0050] The method can be carried out for a plurality of predefined positions 22.

[0051] In addition, the method enables to provide the position of a rail vehicle moving on the track 29.

[0052] In figure 2 monitoring signals for monitoring a railway track 29 are shown. On the x-axis the distance along the railway track 29 is plotted in arbitrary units. The y-axis the time is plotted in arbitrary units along the arrow, this means from top to bottom. The third axis is not shown in this two-dimensional representation, however, the lines shown in the diagram are monitoring signals detected by the distributed acoustic sensor 20 arranged along the railway track 29. The five lines represent the signal that is detected by the distributed acoustic sensor 20 along a distance of the railway track 29 over a certain period of time. The five lines only schematically represent the shape of the signal. Under normal conditions nearly no distinct features can be discriminated in the monitoring signals. It can only be discriminated that the amplitude of the monitoring signals is increased at the positions where a rail vehicle moves for the time where the rail vehicle moves at these positions. This means, for the white areas in the diagram the amplitude of the monitoring signals is not increased. Between the five lines the amplitude of the monitoring signals is increased as well. Thus, the movement of a rail vehicle is represented by an area of increased amplitude of the monitoring signals in this diagram.

[0053] The diagram in figure 2 further shows an initial position 21 and three predefined positions 22. For these four positions the monitoring signals have pronounced features 23. The initial position 21 is the position that the rail vehicle passes at first out of these four positions. At the initial position 21 the rail can have an irregularity or any other feature that leads to localized vibrations in the moment when a wheel of a rail vehicle passes the initial position 21. At the initial position 21 the first monitoring signal M1 is detected. The first monitoring signal M1 comprises five features 23 that can be distinguished from each other. Each of the five features 23 relates to one axle of the rail vehicle passing the initial position 21. Thus, by counting the features 23 in the first monitoring signal M1 the number of axles of the rail vehicle passing the initial position 21 can be determined. At the initial position 21 the integrity of the rail vehicle is given.

[0054] After passing the initial position 21 the moving rail vehicle passes the three predefined positions 22. Also at the predefined positions 22 the rail can have an irregularity or any other feature that leads to localized vibrations in the moment when a wheel of a rail vehicle passes the respective predefined position 22. At the predefined positions 22 second monitoring signals M2 are detected. Each second monitoring signal M2 comprises five features 23 that can be distinguished from each other. Each of the five features 23 relates to one axle of the rail vehicle passing the respective predefined position 22. Thus, by counting the features 23 in the second monitoring signal M2 the number of axles of the rail vehicle passing the respective predefined position 22 can be determined. Alternatively, the space between two passing axles can be regarded as a feature 23. In this way, the number of axles of the rail vehicle passing the respective predefined position 22 can be determined as well.

[0055] In the example of figure 2 the rail vehicle has the same number of axles at the initial position 21 and the three predefined positions 22. Therefore, for the three predefined positions 22 the integrity of the rail vehicle is confirmed.

[0056] Figure 3 shows an exemplary embodiment of the monitoring unit 24 for monitoring a railway track 29. The monitoring unit 24 comprises an input 25 that is connected to a distributed acoustic sensor 20 being arranged along the track 29. The monitoring unit 24 further comprises a detection unit 26 that is configured to receive monitoring signals that are detected by the distributed acoustic sensor 20. The detection unit 26 is connected to the input 25. The monitoring unit 24 further comprises a comparison unit 27 that is configured to compare the first monitoring signal M1 and the second monitoring signal M2 with each other. The comparison unit 27 is connected to the detection unit 26. The monitoring unit 24 further comprises an output 28 at which a confirmation signal is provided for the case that the first monitoring signal M1 and the second monitoring signal M2 relate to the same number of axles. The comparison unit 27 is connected to the output 28.

[0057] Figure 4 shows another exemplary embodiment of the monitoring unit 24. The only difference to the setup shown in figure 3 is that the monitoring unit 24 comprises the distributed acoustic sensor 20 or at least a part of the distributed acoustic sensor 20.

[0058] Figure 5 shows an exemplary embodiment of the monitoring unit 24 with the distributed acoustic sensor 20. The monitoring unit 24 is connected to the distributed acoustic sensor 20. The distributed acoustic sensor 20 comprises an optical fibre 30 that is arranged along the track 29. Therefore, the monitoring signals are backscattered signals of an input signal which is provided to the optical fibre 30.

Reference numerals

[0059]

20:	distributed acoustic sensor
21:	initial position
22:	predefined position
23:	feature
24:	monitoring unit
25:	input
26:	detection unit
27:	comparison unit
28:	output
29:	railway track
30:	optical fibre
M1:	first monitoring signal
M2:	second monitoring signal
S1-S5:	steps

Claims

1. Method for monitoring a railway track (29), the method comprising:

   - detecting a first monitoring signal (M1) by a distributed acoustic sensor (20) at an initial position (21) while a rail vehicle passes the initial position (21), wherein the distributed acoustic sensor (20) is arranged along the track (29),
   - detecting a second monitoring signal (M2) by the distributed acoustic sensor (20) at at least one predefined position (22) along the track (29) while a rail vehicle passes the predefined position (22),
   - comparing the first monitoring signal (M1) and the second monitoring signal (M2) with each other, wherein
   - the first monitoring signal (M1) comprises features (23) that each relate to one axle of the rail vehicle passing the initial position (21) and the second monitoring signal (M2) comprises features (23) that each relate to one axle of the rail vehicle passing the predefined position (22), and
   - comparing the first monitoring signal (M1) and the second monitoring signal (M2) with each other comprises counting the features (23) relating to axles of the respective passing rail vehicle for the first monitoring signal (M1) and the second monitoring signal (M2).

2. Method for monitoring a railway track (29) according to the preceding claim, wherein comparing the first monitoring signal (M1) and the second monitoring signal (M2) with each other further comprises calculating a correlation between the first monitoring signal (M1) and the second monitoring signal (M2) .

3. Method for monitoring a railway track (29) according to one of the preceding claims, wherein at the initial position (21) the integrity of the rail vehicle passing the initial position (21) is given.

4. Method for monitoring a railway track (29) according to the preceding claim, wherein the integrity of the

rail vehicle passing the initial position (21) is confirmed by personnel of the respective rail vehicle or by an external device.

5. Method for monitoring a railway track (29) according to one of claims 3 or 4, wherein the integrity of the rail vehicle passing the initial position (21) is confirmed for the case that the first monitoring signal (M1) comprises the same number of features (23) that each relate to one axle of the rail vehicle passing the initial position (21) as a previous monitoring signal for which the integrity of the rail vehicle passing the position, where the previous monitoring signal is detected, is confirmed by personnel of the respective rail vehicle or by an external device.

6. Method for monitoring a railway track (29) according to one of the preceding claims, wherein the distributed acoustic sensor (20) comprises an optical fibre (30) arranged along the track (29) and the monitoring signals are backscattered signals of an input signal which is provided to the optical fibre (30).

7. Method for monitoring a railway track (29) according to one of the preceding claims, wherein the position of a rail vehicle moving on the track (29) is provided.

8. Method for monitoring a railway track (29) according to one of the preceding claims, wherein a confirmation signal is provided if the first monitoring signal (M1) and the second monitoring signal (M2) relate to the same number of axles of the respective passing rail vehicle.

9. Method for monitoring a railway track (29) according to one of the preceding claims, wherein a confirmation signal is provided if the first monitoring signal (M1) and the second monitoring signal (M2) have at least a predefined level of correlation.

10. Method for monitoring a railway track (29) according to one of the preceding claims, wherein the at least one predefined position (22) is determined by carrying out a correlation analysis for monitoring signals detected at a plurality of positions along the track (29) during the passage of a rail vehicle with the first monitoring signal (M1), wherein a position along the track (29) is a predefined position (22) if the monitoring signal at the respective position has at least a predefined correlation coefficient with the first monitoring signal (M1).

11. Method for monitoring a railway track (29) according to one of the preceding claims, wherein at the predefined position (22) the rail has a defect or an irregularity.

12. Method for monitoring a railway track (29) according to one of the preceding claims, wherein the second monitoring signal (M2) has an amplitude that is above a predefined threshold and monitoring signals detected during the passage of a rail vehicle at positions different from the at least one predefined position (22) have an amplitude that is below the predefined threshold.

13. Method for monitoring a railway track (29) according to one of the preceding claims, wherein the method is carried out for a plurality of predefined positions (22).

14. Monitoring unit (24) for monitoring a railway track (29), the monitoring unit (24) comprising:

- an input (25) that is connected to a distributed acoustic sensor (20) being arranged along the track (29),
- a detection unit (26) that is configured to receive monitoring signals that are detected by the distributed acoustic sensor (20),
- a comparison unit (27) that is configured to compare a first monitoring signal (M1) detected by the distributed acoustic sensor (20) at an initial position (21) while a rail vehicle passes the initial position (21) and a second monitoring signal (M2) detected by the distributed acoustic sensor (20) at at least one predefined position (22) along the track (29) while a rail vehicle passes the predefined position (22) with each other, wherein
- the first monitoring signal (M1) comprises features (23) that each relate to one axle of the rail vehicle passing the initial position (21) and the second monitoring signal (M2) comprises features (23) that each relate to one axle of the rail vehicle passing the predefined position (22), and
- comparing the first monitoring signal (M1) and the second monitoring signal (M2) with each other comprises counting the features (23) relating to axles of the respective passing rail vehicle for the first monitoring signal (M1) and the second monitoring signal (M2).

15. Monitoring unit (24) according to the preceding claim, wherein the monitoring unit (24) further comprises an output (28) at which a confirmation signal is provided for the case that the first monitoring signal (M1) and the second monitoring signal (M2) relate to the same number of axles.

FIG. 1

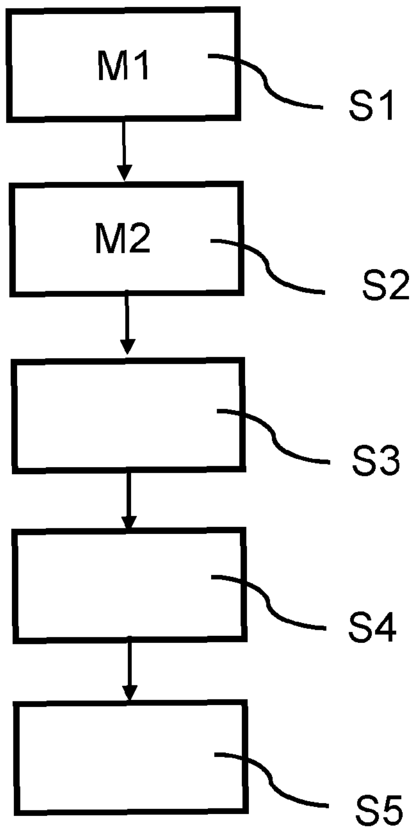


FIG. 2

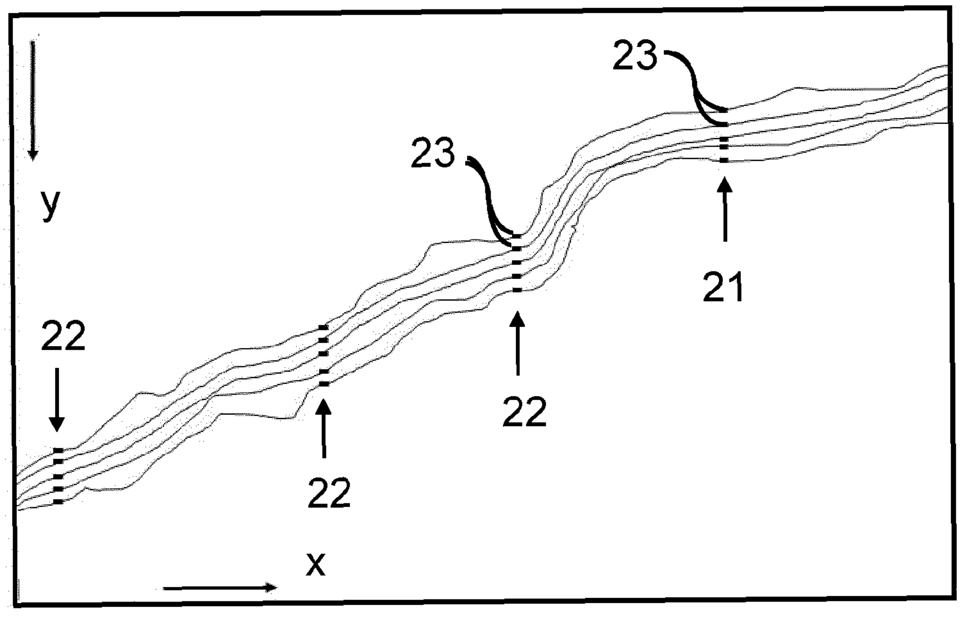


FIG. 3

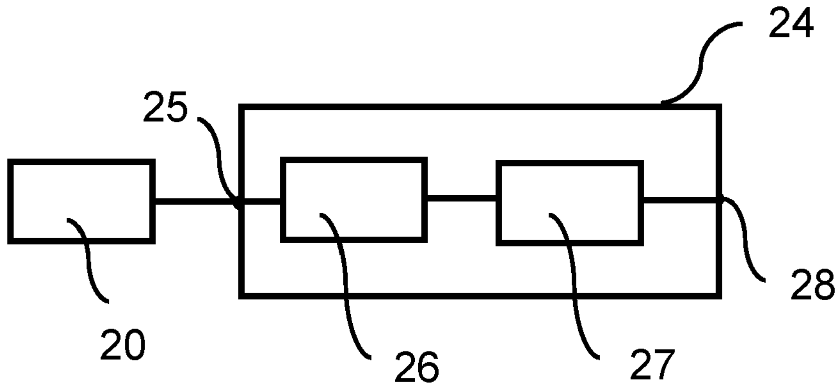


FIG. 4

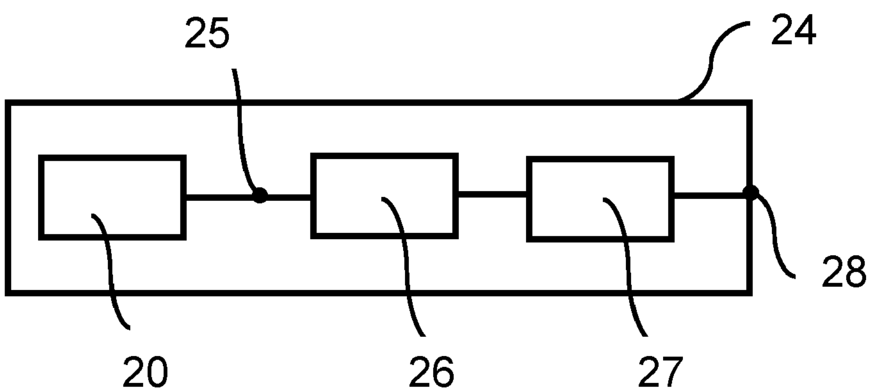
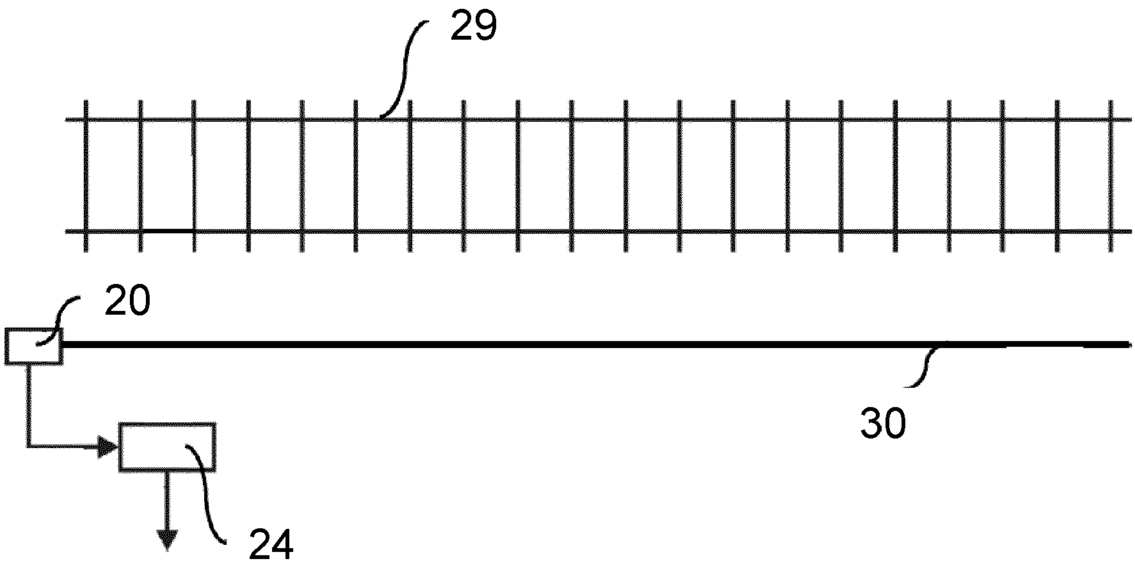


FIG. 5



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EUROPEAN SEARCH REPORT

Application Number
EP 20 20 0042

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1

Place of search	Date of completion of the search	Examiner
Munich	17 March 2021	Martínez Martínez, J

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