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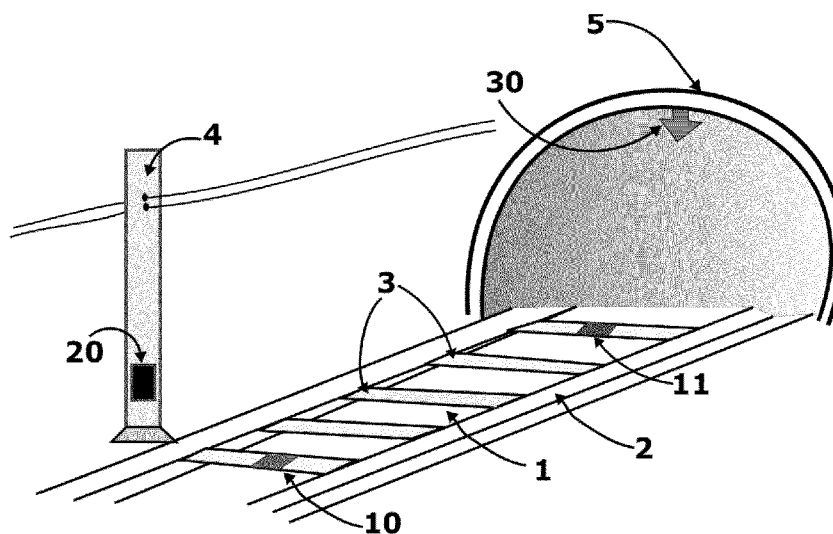
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(54) Title: SMART SENSOR DATA TRANSMISSION IN RAILWAY INFRASTRUCTURE

Fig 1



(57) Abstract: The present invention relates to a method and system for automatically transferring sensor data in railway, particularly railway infrastructure. The method can comprise any of the steps of determining relevance-criteria for sensor data; sampling sensor data by at least one sensor; automatically categorizing the sensor data according to the relevance-criteria; sending the sensor data according to their category; and receiving the sensor data at least in one server.



Smart sensor data transmission in railway infrastructure

Field

- 5 The invention relates to the transmission of sensor data in railway, particularly in railway infrastructure. The sensors are typically assembled in a wide spread network and at least to a large extent in unhostile railway infrastructure. The sensors can also comprise smart sensors that are attached to sleepers, frogs, point machines, frogs and blades on a rail. Many of them are not hardwired to the respective analytics equipment.

10

Background

- 15 Railroad, railway or rail transport has been developed for transferring goods and passengers on wheeled vehicles on rails, also known as tracks. In contrast to road transport, where vehicles run on a prepared flat surface, rail vehicles (rolling stock) are directionally guided by the tracks on which they run. Tracks commonly consist of steel rails, installed on ties or sleepers and ballast, on which the rolling stock, usually provided with metal wheels, moves. Other variations are also possible, such as slab track, where the rails are fastened to a concrete foundation resting on a subsurface. An alternative are maglev systems etc.

- 20 Rolling stock in a rail transport system generally encounters lower frictional resistance than road vehicles, so passenger and freight cars (carriages and wagons) can be coupled into longer trains. Power is provided by locomotives which either draw electric power from a railway electrification system or produce their own power, usually by diesel engines. Most tracks are accompanied by a signaling system. Railways are a safe land transport system
25 when compared to other forms of transport and is capable of high levels of passenger and cargo utilization and energy efficiency, but is often less flexible and more capital-intensive than road transport, when lower traffic levels are considered.

- The inspection of railway equipment is essential for the safe movement of trains. Many types of defect detectors are in use today. These devices utilize technologies that vary
30 from a simplistic paddle and switch to infrared and laser scanning, and even ultrasonic audio analysis. Their use has avoided many rail accidents over the past decades.

Railways must keep up with periodic inspection and maintenance in order to minimize effect of infrastructure failures that can disrupt freight revenue operations and passenger

services. Because passengers are considered the most crucial cargo and usually operate at higher speeds, steeper grades, and higher capacity/frequency, their lines are especially important. Inspection practices embrace car inspection or walking inspection. Curve maintenance especially for transit services includes gauging, fastener tightening, and rail replacement.

Rail corrugation is a common issue with transit systems due to the high number of light-axle, wheel passages that result in grinding of the wheel/rail interface. Since maintenance may overlap with operations, maintenance windows (nighttime hours, off-peak hours, altering train schedules or routes) must be closely followed. In addition, passenger safety during maintenance work (inter-track fencing, proper storage of materials, track work notices, hazards of equipment near states) must be regarded at all times. Moreover, maintenance access problems can emerge due to tunnels, elevated structures, and congested cityscapes. Here, specialized equipment or smaller versions of conventional maintenance gear are used.

Unlike highways or road networks where capacity is disaggregated into unlinked trips over individual route segments, railway capacity is fundamentally considered a network system. As a result, many components can cause system disruptions. Maintenance must acknowledge the vast array of a route's performance (type of train service, origination/destination, seasonal impacts), line's capacity (length, terrain, number of tracks, types of train control), trains throughput (max speeds, acceleration/deceleration rates), and service features with shared passenger-freight tracks (sidings, terminal capacities, switching routes, and design type).

Railway inspection is used for examining rail tracks for flaws that could lead to catastrophic failures. According to the United States Federal Railroad Administration Office of safety analysis track defects are the second leading cause of accidents on railways in the United States. The leading cause of railway accidents is attributed to human error. Every year, North American railroads spend millions of dollars to inspect the rails for internal and external flaws. Non-destructive testing (NDT) methods are used as a preventative measure against track failures and possible derailment.

With increased rail traffic at higher speeds and with heavier axle loads today, critical crack sizes are shrinking and rail inspection is becoming more important. In 1927, magnetic inductions had been introduced for the first rail inspection cars. This was done by passing large amounts of magnetic field through the rail and detecting flux leakage with search coils. Since then, many other inspection cars have traversed the rails in search of flaws.

There are many effects that influence rail defects and rail failure. These effects include bending and shear stresses, wheel/rail contact stresses, thermal stresses, residual stresses and dynamic effects. Defects due to contact stresses or rolling contact fatigue (RCF) can

be tongue-lipping, head-checking (gauge corner cracking) as well as squats (which start as small surface breaking cracks).

Other forms of surface and internal defects can be corrosion, inclusions, seams, shelling, transverse fissures and/or wheel burn.

- 5 One effect that can cause crack propagation is the presence of water and other liquids. When a fluid fills a small crack and a train passes over, the water becomes trapped in the void and can expand the crack tip. Also, the trapped fluid could freeze and expand or initiate the corrosion process.

10 With increased rail traffic carrying heavier loads at higher speeds, a quicker more efficient way of inspecting railways is needed. Besides that, also the control of the train-rail interaction would be advantageous; i.e., checking the load, improper loads, load-dependent fees for trains on railroads as high loads increase wear of the railroads, surveillance of the maintenance of trains or future failure thereof etc.

15 EP 2 862 778 A1 relates to a method for generating measurement results from sensor signals generated by one or more separate sensors. The signals comprise two or more data points from the same event, the sensors each being arranged at a rail configured to carry a rail vehicle. The sensors are configured to measure a physical property of the rail. The sensors each comprise a transmitter configured to transmit sensor signals to a physically distanced data management arrangement. The physically distanced data management
20 arrangement comprises a receiver configured to receive sensor signals, a processor configured to evaluate sensor signals, and a memory. The method comprises the steps of receiving sensor signals and evaluating sensor signals. The data management arrangement stores the received sensor signals in the memory and the evaluation comprises a step of combining and/or comparing at least two data points from one or more stored sensor
25 signals with each other. The document further addresses evaluation of sensor signals by comparing and or combining data points from sensor signals. Thereby a plurality of different measurement results can be allegedly calculated from sensor signals.

The measurements of such sensors can be taken to determine spots for maintenance or repair or predicted maintenance or repair.

30 Transferring of data could be time consuming so attempts have been made to transfer this data in real-time.

In CN104442931B an integrated rail traffic management system maintenance, including station subsystem, server subsystem, the client browser; station subsystem, server subsystem, the client browser to communicate over a network; the station set up at the
35 station subsystem after transmission, the device monitors for data maintenance data acquisition computer interlocking subsystem, the zone controller and maintenance data

collected by the system monitoring computer, processing the collected data to the server subsystem, the server subsystem and receiving commands; server subsystems is provided in the center system maintenance, maintenance data for automatic monitoring subsystem, the vehicle control unit receives the train, and the station subsystem receives data, data storage, processing, and real-time push client browser device. Rail integrated maintenance management system of the present invention can improve the level and efficiency of the rail system operation and maintenance.

Furthermore, in US6668216B2 A system and method for automated, wireless short-range data collection and communications for interconnected mobile systems, such as trains includes a master control unit and a plurality of data transmission units communicating in a daisy-chain fashion along the collection of interconnected mobile systems. The master control unit can verify collected data and serve as an interface with an external communications system for providing real-time data to a central control site, for example via wayside readers, satellite communications, cell phone linkage, 2-way radio, etc. Data could include sensor information, railcar identification, status, trouble spots, location, and warnings.

In CN103442055A the invention discloses a train real-time monitoring system based on a B/S architecture. The train real-time monitoring system comprises a three-layer mode architecture based on the B/S architecture, and the three-layer mode architecture comprises an uppermost man-machine interaction layer, a middle data processing layer and a lowermost data interface layer. The train real-time monitoring system has the advantages of adaptability and extendibility of the B/S architecture, convenient maintenance and low total cost; the train real-time monitoring system also has real-time communication capacity of an application system under a C/S architecture, operates on the internet, overcomes space and regional limits and can have access to the system through a browser anywhere, a train can be monitored in time whenever and wherever possible, a communication method is simple, network resources are saved, network distribution is convenient to achieve, and the train real-time monitoring system is convenient to use and has good application prospects.

Also, in US20090079560A1 the invention mentions remote monitoring and diagnosis of railroad devices using data structures defined for each of the railroad devices. The railroad devices are configured to populate the data structures with status data. The railroad devices transmit the status data for analysis using a network protocol. The analysis of the data results in reduced maintenance. All the before mentioned documents are herein incorporated by reference.

For transmitting information and control signal etc. there are many ways of transmittal, particularly wired or wireless, as is known. The most common and current ways are to communicate via GSM, EDGE, UMTS, LTE and in the future with 5G.

5 Summary

It is an object of the present invention to provide an improved or alternative system and method for railway sensor data transmission.

This object is attained with the embodiments in accordance with the present specification and/or subject matter in accordance with the embodiments and/or claims.

- 10 The present invention relates to a method for automatically transferring sensor data from in railway, particularly in or from railway infrastructure. The method can comprise any of the steps of determining relevance-criteria for sensor data; sampling sensor data by at least one sensor; automatically categorizing the sensor data according to the relevance-criteria; sending the sensor data according to their category; and receiving the sensor data
15 at least in one server.

- The relevance-criteria can differentiate the sensor data in many different aspects, as will be listed further below. The criteria can thus be of different kinds and can address any more formal or content-relevant criteria or both. This can help to transfer the data more efficiently regarding costs for the data transfer, computing and storing thereof, etc., and
20 further to transfer the data more reliably in order to keep any network as open as possible and therefore be able to transmit relevant data only. Other relevance-criteria can be addressed as well, when appropriate. Further examples are discussed below.

- The present invention also relates to a system for automatically transferring sensor data from or in railway infrastructure, particularly railway infrastructure and particularly for
25 carrying out the method as specified above and below. The system can comprise a determining component for determining relevance-criteria for sensor data as specified before and below. This component can be realized in hard and/or software. The software part of it, like any other software parts can be static or dynamic. In the latter case the software can adapt itself by applying any analytic approach as is discussed further below.

- 30 Moreover, the system can comprise at least one sensor for sampling sensor data. The kind of sensors and the respective kinds of data are further discussed below. Moreover, a categorization component can be arranged for automatically categorizing/classifying the sensor data according to the relevance-criteria. The categorization is intended to be done in automated fashion and can make use of any appropriate and known interpretation

models and can make use of classifying the format and/or the content. Inter alia semantic classifiers can be used for that as well.

Moreover, the system can comprise a sending component for sending the sensor data according to their category. This is particularly done by a push function although a pull function can be applied alternatively or as well.

The system also comprises a server for receiving the sensor data. The server can be placed remotely and can also be arranged in a remote system also called cloud.

The method according to the present invention can also comprise a number of relevance criteria. This can be one or more of a volume of the sensor data, a content of the sensor data, risk related information, such as risk of failure of a component, of parts or the whole system, risk for rolling stock, for other traffic participants, risk of incomplete transmittal etc. The relevance can further comprise at least one of a quality of a communication channel for the sending of the sensor data, traffic on the communication channel for the sending of the sensor data, costs for the sending of the sensor data, energy available for sending the sensor data, energy consumption of the sending of the sensor data, communication bandwidth and derived energy cost per data volume, result of an analytic approach of measured data, a specific expected data feature or combination of data features, a specific expected data threshold passage, detected anomaly in the data, a detected trend in the data, a difference of the result in comparison to historical results, a difference of the result in comparison to last transmitted results, a trend analysis of result, trace quality metrics for selection, experience with communication quality from previous days and/or frequency of sending data.

The determining component in accordance with the present system can comprise and/or apply these relevance criteria.

The inventive method can also comprise an automated rating that will be used for determining the order of receiving the sensor data in the server. The rating can be done by any known method, such as a score card analysis or numbering. etc.

The system can comprise at least one of the sensor and the remote component any of these can comprise a rating component that provides a rating that will be used for determining the order of receiving the sensor data in the server.

The system can also comprise a plurality of sensors of different kind that are provided for sampling sensor data, particularly also of different kind.

The system can further comprise a remote component that is configured to collect sensor data from one of particularly a plurality of sensors. These sensors are particularly close to the remote component that is then a central transmitting station for these sensors. This can be particularly advantageous in areas with a larger number of sensors that are still remote from a receiving station. An example can be a section with a more dense railway infrastructure.

The method can further comprise the step of an automated categorizing comprises a rating that will be used for determining the maximum numbers of attempts for the sending of data transmission in case the communication channel prevents the sending of the data.

The system can thus comprise at least one of the sensor and the remote component comprising a rating component that provides a rating that will be used for determining the maximum numbers of attempts for the sending of data transmission in case the communication channel prevents the sending of the data.

The system or step of rating can further comprise the step of accommodating command input signals from a range of server or cloud-based algorithmic decision modules, comprising inspection signals for maintenance decision making, inspection signals for component fault diagnostics and/or a client requests, etc.

The input signals according to the method or system can modify at least one of a range of sampling frequency of the sensor data, target rolling stock type, target rolling stock speeds, target acceleration features, target sampling campaign trace count, specific data features characteristics, trend thresholds, anomaly thresholds and distributions, change the computation of the optimum strategy, activate or deactivate specific sensors, change sensor payload; and sensor data sending frequency. The latter is the frequency of the submitting of data to the back-end or server rather than the frequency of sampling the sensor data.

The method can further comprise of at least one of the steps of predicting, estimating and determining the condition(s) for sending the sensor data as well as the respective component(s). At least one of the sensor and the remote component can comprise the condition component.

The method can moreover comprise the step of automatically optimizing the sending of the sensor data. The system can further comprise a respective optimizing component for automatically optimizing the sending of the sensor data.

The method according to the preceding embodiment wherein the automatically optimizing is done after the categorizing of the sensor data. The at least one of the sensor and the remote component can comprise the optimizing component that can be further connected

with the categorizing component. The optimizing component can even further be configured to automatically optimize the sending after the categorizing of the sensor data by the categorizing component.

The sending of sensor data, particularly performed by the sensor component, can be done in real-time.

The optimizing of sending the data can be controlled by at least one of the server, the sensor component and the remote component.

In the system according to the invention at least two of the categorizing component, the optimizing component, the rating component, the condition component and the sending component can be comprised by at least one of the servers, the sensor and the remote component.

The optimizing and respective optimizing component can be configured to comprise at least one of reducing the volume of the sensor data, compressing the sensor data, encrypting the sensor data, timing the sending of the sensor data and/or routing the sending of the sensor data over one out of a plurality of available sending routes.

A further step of or component for pre-storing the sensor data at a further sensor component that is being housed together with or adjacent to the sensor and/or a remote component that is remote to the sensor and preferably closer to the sensor than to the server can be realized.

The sensor component can comprise a module to communicate via at least one of a hardwired and wireless communication network that can be further configured to send the data by the module towards the server.

The remote component can at least in part be hardwired with the server and/or connected by a long range wireless component.

At least one of the sensors can be configured to send the respective sensor data to the remote component wirelessly. The sensors can further be connected to the remote component by a short range wireless component.

Moreover, the method can comprise the step of pre-storing the sensor data, automatically determining a time-slot for the sending the data and sending the sensor data at the time-slot that has been determined to the server. The sending component(s) can thus be configured to automatically send the sensor data at the time-slot that has been determined by the condition component.

The pre-storing of the sensor data is performed by the sensor component and/or the remote component, respectively.

The method can even further comprise the step of pre-filtering the sensor data, automatically determining a time-slot for the sending the data and sending the pre-filtered sensor data at the time-slot that has been determined to the server. The system can thus have at least one of the sensor and the remote component to comprise a pre-filtering component that is configured to pre-filter the sensor data and the pre-filtering is done according to the relevance-criteria according to embodiment mentioned before and below.

The pre-filtering can be either the filtering of the complete sensor data sampled by the sensor so that the sensor data won't get stored at all or by reducing volume of the sensor data by filtering out less relevant parts of the sensor data and/or compressing the sensor data.

The pre-filtering of the sensor data can be performed by the sensor component and/or the remote component, respectively.

The method can have the further step of increasing the sampling rate of the sensors after the filtering of the sensor data. The server can further be configured to compute the sensor data or filtered sensor data by at least one analytical approach.

The sensor data can comprise information of at least one of length, mass, time, current, electric tension, temperature, humidity, luminous intensity and any parameters derived therefrom such as acceleration, vibration, speed, time, distance, illumination, images, gyroscopic information, acoustics, ultra-sound, (air) pressure, magnetism, electro-magnetism, position, optical sensor information, precipitation,

The present invention is also directed to the use of the method according to any of the preceding method embodiments and/or the system according to any of the preceding system embodiments for transferring sensor data in railway, particularly in railway infrastructure.

The invention can provide a sensor data sending strategy that can be optimized for different parameters by the edge device itself, the back-end or computer controlling the device. Certain events can be triggered in the field, predefined cycles or time frames.

The advantages of the present invention can comprise optimizing data delivery from sensors or smart sensors. More specifically this can comprise an extend battery lifetime, a general improvement of data transfer regarding time, costs, efficiency etc. In rather extreme cases of low network coverage the data transfer can be provided more reliable as well.

Temporarily, data resolution can be increased, e.g. with a higher sampling rate, improved data quality or improved rate of data quality versus costs. Moreover, different sensors may

be activated the data of which might not be sent normally. Therefore, the sensor payload can be positively changed.

Also under conditions that won't allow an immediate sending of data, e.g. due to the bad transmission quality, relevant data can be stripped from the data set and a real-time
5 sending can be realized. A more accurate monitoring would thus be possible.

One preferred advantage of the data sending strategy can be a rating of the measured data to enable the device to decide which data has to be transferred to the cloud system and in which order. The order can be crucial, because the communication might get interrupted by external factors like weather and the system might not be able to send all
10 the data that it wants to send. For this the sending strategy also includes a retry logic, adapted to the specific situation and criticality of the data to send. For example, for a crucial file the system might try it 5 times at different times, for a file less crucial it might try it only 1 time and then drop it. The retry logic should also be driven by the rating of the files. The rating algorithm and parameters need be configured either locally or
15 remotely.

A further advantage can be a data sending algorithm in form of a stage machine or much more advanced forms, maybe even a neural network that is able to decide based on events occurring in the field what is the optimum data to send.

The afore and below mentioned control signals can allow customized updates to a
20 probabilistic reasoning layer that can consequently improve the quality of predictions for use in predictive maintenance. Hence adaptive data sending can not only make optimal use of the available energy in the sensor, it also improves the overall system performance by targeting the most appropriate and beneficial signal data.

The invention can optimize the data sending strategy based on one, or a combination of
25 parameters (see above). These parameters can be configured over the air from multiple sources (see above).

Depending on the needed complexity the data sending can be a simple rating of the files or an advanced ML algorithm optimized for a specific task.

The algorithm or data sending strategy can be also able to accommodate command input
30 signals from other sources. These input signals can modify a range of system parameters (see also above and below).

The data sending strategy can be further optimized to run on an embedded system.

The term railway infrastructure is defined further below and is apparent from the entire description and claims. It basically comprises any position a sensor can be placed that will

allow providing sensor information that may be directly or indirectly relevant to the railway. The invention can further provide the steps of processing the first signal by at least a first analytical approach to obtain first analytical data. Similarly or differently it can also comprise capturing at least a second signal from a second sensor and processing the second signal by a second analytical approach to obtain second analytical data. The signal can be captured wirelessly and/or hard-wired.

The system according to the present invention is particularly configured to perform the method discussed above and below. In particular, the system comprises at least one, preferably a plurality of further sensors for capturing further signals.

Another example can be a sensor system mounted on a railway sleeper that measures, records, processes and sends acceleration data of various sensitivity, range, resolution, etc. to a remote system. Compared to the state of the art, the aforementioned adaption

The term "railway infrastructure" is intended to comprise railway tracks, trackage, permanent ways, electrification systems, sleepers or crossties, tracks, rails, rail-based suspension railways, switches, frogs, point machines, crossings, interlockings, turnouts, masts, signaling equipment, electronic housings, buildings, tunnels, railway stations and/or informational and computational network.

The term "rolling stock" is intended to comprise any vehicle(s) moving on a railway, wheeled vehicles, powered and unpowered vehicles, such as for example, locomotives, railroad cars, coaches, wagons, construction site vehicles, draisines and/or trolleys.

The term "railway system" is intended to comprise railway infrastructure and rolling stock.

The term "sensor" is intended to comprise at least one device, module, model and/or subsystem whose purpose is to detect parameters and/or changes in its environment and provides a respective signal to other devices. Parameters can be length, mass, time, current, electric tension, temperature, humidity, luminous intensity and any parameters derived therefrom such as acceleration, vibration, speed, time, distance, illumination, images, gyroscopic information, acoustics, ultra-sound, air pressure, magnetism, electro-magnetism, position, optical sensor information etc.

The term "sensor" is intended to comprise at least one device, module, model and/or subsystem whose purpose is to detect parameters and/or changes in its environment and provides a respective signal to other devices. Parameters can be length, mass, time, current, electric tension, temperature, humidity, luminous intensity and any parameters derived therefrom such as acceleration, vibration, speed, time, distance, illumination, images, gyroscopic information, acoustics, ultra-sound, (air) pressure, magnetism, electro-magnetism, position, optical sensor information, precipitation etc.

The sensors can be associated with or arranged to at least one of the railway infrastructure, like a sleeper, a frog, a point machine, rail frog, a rail blade and/or an interlocking for particularly measuring current at the interlocking. This list is not exhaustive.

5 The term "analytical approach" is intended to comprise any analytical tool that is used to analyze signals or data. Non-limiting examples are digital analytical methods, such as filter processing, pattern recognition, data mining, statistical analytics, probabilistic analytics, statistical models, principle component analysis, ICA, dynamic time warping, maximum likelihood estimates, modeling, estimating, machine learning, supervised learning, unsupervised learning, reinforcement learning, neural network, convolutional network,
10 deep convolutional network, deep learning, ultra-deep learning, genetic algorithms, Markov models, hidden Markov models, Bayesian scores etc. These analytical methods can be applied alone or any combination thereof, sequentially and/or in parallel. Different analytical approaches can thus be different in the kind of one or more analytical method(s) and/or just the order of a plurality of analytical methods when even using the same
15 methods but just in a different order.

The term "optimization" (or optimizing) is intended to comprise the (semi-) automated selection of a best available element (with regard to some criterion) from some set of available alternatives. It can be the best value(s) of some objective function given a defined domain (or input), including a variety of different types of objective functions and different
20 types of domains.

The term "estimation" (or estimating) is intended to mean the (semi-) automated finding of an estimate, or approximation, which is a value that is usable for some purpose even if input data may be large to finding an exact value, incomplete, uncertain, or unstable.

25 The term "prediction" (or predicting) is intended to mean predictive analytics that encompasses a variety of statistical techniques from predictive modelling, machine learning, and data mining that analyze current and historical facts to make predictions about future or otherwise unknown events.

The term "server" can be a computer program and/or a device and/or a plurality of each
30 or both that provides functionality for other programs or devices. Servers can provide various functionalities, often called "services", such as sharing data or resources among multiple clients or performing computation and/or storage functions. A single server can serve multiple clients, and a single client can use multiple servers. A client process may run on the same device or may connect over a network to a server on a different device,
35 such as a remote server or the cloud. The server can have rather primitive functions, such as just transmitting rather short information to another level of infrastructure, or can have a more sophisticated structure, such as a storing, processing and transmitting unit.

The term "communication network" may comprise any hardwired or wireless network, e.g. as mentioned in the IEEE 802 standard.

The term "GSM" can comprise any kind of mobile communication system, such as 2G, CSD, HSCSD, GPRS, EDGE, 3G, LTE, 4G, 5G, BOS-GSM, streaming, generic access, cell broadcast, etc.

The present technology is also defined by the following numbered embodiments.

Embodiments

Below, sample detection method embodiments will be discussed. The letter M followed by a number abbreviates these embodiments. Whenever reference is herein made to method embodiments, these embodiments are meant.

Method
M1. A method for automatically transferring sensor data from or in railway, particularly railway infrastructure, comprising the steps of a. determining relevance-criteria for sensor data; b. sampling sensor data by at least one sensor; c. automatically categorizing the sensor data according to the relevance-criteria; d. sending the sensor data according to their category; and e. receiving the sensor data at least in one server.
M2. The method according to the preceding embodiment wherein the relevance criteria is at least one of a. a volume of the sensor data; b. a content of the sensor data; c. risk related information; d. a quality of a communication channel for the sending of the sensor data; e. traffic on the communication channel for the sending of the sensor data; f. costs for the sending of the sensor data; g. energy available for sending the sensor data; and h. energy consumption of the sending of the sensor data; i. communication bandwidth and derived energy cost per data volume; j. result of an analytic approach of measured data; k. specific expected data feature or combination of data features;

- l. specific expected data threshold passage;
 - m. detected anomaly in the data;
 - n. detected trend in the data;
 - o. difference of the result in comparison to historical results;
 - 5 p. difference of the result in comparison to last transmitted results;
 - q. trend analyses of result;
 - r. trace quality metrics for selection;
 - s. experience with communication quality from previous days; and
 - t. frequency of sending data.
- 10 M3. The method according to any of the preceding embodiments wherein the step of automated categorizing comprises a rating that will be used for determining the order of receiving the sensor data in the server.
- M4. The method according to any of the preceding embodiments wherein the step of automated categorizing comprises a rating that will be used for determining the
- 15 maximum numbers of attempts for the sending of data transmission in case the communication channel prevents the sending of the data.
- M5. The method according to any of the preceding two embodiments the step of rating further comprising accommodating command input signals from a range of server or cloud-based algorithmic decision modules, comprising:
- 20 a. inspection signals for maintenance decision making;
- b. inspection signals for component fault diagnostics;
- c. client requests;
- M6. The method according to the preceding embodiment wherein the input signals can modify a range of comprising:
- 25 a. sampling frequency of the sensor data;
- b. target rolling stock type;
- c. target rolling stock speeds;
- d. target acceleration features;
- e. target sampling campaign trace count;
- 30 f. specific data features characteristics;
- g. trend thresholds;
- h. anomaly thresholds and distributions;
- i. change the computation of the optimum strategy;
- j. activate or deactivate specific sensors;
- 35 k. change sensor payload; and
- l. sensor data sending frequency.

- M7. The method according to any of the preceding embodiments wherein the method further comprises the step of at least one of predicting, estimating and determining the condition(s) for sending the sensor data.
- 5 M8. The method according to any of the preceding embodiments further comprising the step of automatically optimizing the sending of the sensor data.
- M9. The method according to the preceding embodiment wherein the automatically optimizing is done after the categorizing of the sensor data.
- M10. The method according to any of the preceding embodiments wherein the sending of sensor data is done in real-time.
- 10 M11. The method according to any of the two preceding claims wherein the optimizing of sending the data is controlled by at least one of the servers, the sensor component and the remote component.
- M12. The method according to any of the preceding embodiment wherein the optimizing can comprise at least one of
- 15 a. reducing the volume of the sensor data;
 b. compressing the sensor data;
 c. encrypting the sensor data;
 d. timing the sending of the sensor data;
 e. routing the sending of the sensor data over one out of a plurality of available
- 20 sending routes.
- M13. The method according to the preceding embodiments with the further step of pre-storing the sensor data at a further sensor component being housed together with or adjacent to the sensor and/or a remote component that is remote to the sensor and preferably closer to the sensor than to the server.
- 25 M14. The method according to the preceding embodiment wherein the sensor component comprises a module to communicate via at least one of a hardwired and wireless communication network and is configured to send the data by the module towards the server.
- M15. The method according to the three preceding embodiments wherein the remote
- 30 component is configured to pre-store data of a plurality of sensors.
- M16. The method according to the three preceding embodiments wherein the remote component is at least in part hardwired with the server and/or connected by a long range wireless component, such as GSM.

- M17. The method according to the preceding embodiment wherein the at least one of the sensors is configured to send the respective sensor data to the remote component wirelessly.
- 5 M18. The method according to the preceding embodiment wherein the sensors are connected to the remote component by a short range wireless component.
- M19. The method according to any of the preceding embodiments with the further step of pre-storing the sensor data, automatically determining a time-slot for the sending the data and sending the sensor data at the time-slot that has been determined to the server.
- 10 M20. The method according to the preceding embodiment wherein the pre-storing of the sensor data is performed by the sensor component and/or the remote component, respectively.
- 15 M21. The method according to any of the preceding embodiments with the further step of pre-filtering the sensor data, automatically determining a time-slot for the sending the data and sending the pre-filtered sensor data at the time-slot that has been determined to the server.
- M22. The method according to the preceding embodiment wherein the pre-filtering is done according to the relevance-criteria according to embodiment 2.
- 20 M23. The method according to the preceding embodiment wherein the pre-filtering is either filtering the complete sensor data sampled by the sensor so that the sensor data won't get stored at all or by reducing volume of the sensor data by filtering out less relevant parts of the sensor data and/or compressing the sensor data.
- 25 M24. The method according to the preceding embodiment wherein the pre-filtering of the sensor data is performed by the sensor component and/or the remote component, respectively.
- M25. The method according to any of the preceding embodiments with the further step of increasing the sampling rate of the sensors after the filtering of the sensor data.
- 30 M26. The method according to any of the preceding embodiments with the further step of analyzing the sensor data by the server based on at least one analytical approach, each approach comprising at least one of signal filter processing, pattern recognition, probabilistic modeling, Bayesian schemes, machine learning, supervised learning, unsupervised learning and/or reinforcement learning.
- M27. The method according to any of the preceding embodiments wherein the sensors are associated with or arranged at least one of rolling stock, a sleeper, a frog, a

point machine, the frog on a rail, a blade on the rail and/or an interlocking for particularly measuring current at the interlocking.

- M28. The method according to any of the preceding embodiments wherein the sensor data comprises information of at least one of temperature, acceleration, vibration, ultra-sound, time, distance, current, pressure, movement, humidity, precipitation and/or acoustics.

Below, sample detection system embodiments will be discussed. The letter S followed by a number abbreviates these embodiments. Whenever reference is herein made to system embodiments, these embodiments are meant.

	System
S1.	A system for automatically transferring sensor data from or in railway, particularly railway infrastructure, comprising:
a.	a determining component for determining relevance-criteria for sensor data;
b.	at least one sensor (10, 11, 20, 30) for sampling sensor data;
c.	a categorization component (14, 21) for automatically categorizing the sensor data according to the relevance-criteria;
d.	a sending component (19, 25) for sending the sensor data according to their category; and
e.	a server (50, 60) for receiving the sensor data.
S2.	The system according to the preceding embodiment wherein the determining component (15, 40) comprises relevance criteria comprising at least one of
a.	a volume of the sensor data;
b.	a content of the sensor data;
c.	risk related information;
d.	a quality of a communication channel for the sending of the sensor data;
e.	traffic on the communication channel for the sending of the sensor data;
f.	costs for the sending of the sensor data;
g.	energy available for sending the sensor data; and
h.	energy consumption of the sending of the sensor data;
i.	a communication bandwidth and derived energy cost per data volume;
j.	a result of an analytic approach of measured data;
k.	specific expected data feature or combination of data features;
l.	specific expected data threshold passage;

- m. a detected anomaly in the data;
 - n. a detected trend in the data;
 - o. a difference of the result in comparison to historical results;
 - p. a difference of the result in comparison to last transmitted results;
 - 5 q. a trend analysis of result;
 - r. trace quality metrics for selection;
 - s. experience with communication quality from previous days; and
 - t. frequency of sending data.
- S3. The system according to any of the preceding embodiments wherein a plurality of
10 sensors (10, 11, 20, 30) of different kind are provided for sampling sensor data.
- S4. The system according to any of the preceding claims further comprising a remote component (15, 40) that is configured to collect sensor data from sensors (10, 11, 20, 30).
- 15 S5. The system according to any of the preceding embodiments wherein at least one of the sensor (10, 11, 20, 30) and the remote component (15, 40) comprises a rating component (16, 22) that provides a rating that will be used for determining the order of receiving the sensor data in the server (50, 60).
- 20 S6. The system according to any of the preceding embodiments wherein at least one of the sensor (10, 11, 20, 30) and the remote component (15, 40) comprises a rating component (16, 22) that provides a rating that will be used for determining the maximum numbers of attempts for the sending of data transmission in case the communication channel prevents the sending of the data.
- 25 S7. The system according to any of the preceding two embodiments the rating component (16, 22) further comprising accommodating command input signals from a range of server or cloud-based algorithmic decision modules, comprising:
- a. inspection signals for maintenance decision making;
 - b. inspection signals for component fault diagnostics;
 - c. client requests;
- 30 S8. The system according to the preceding embodiment wherein the input signals can modify a range of comprising:
- a. sampling frequency of the sensor data;
 - b. target rolling stock type;
 - c. target rolling stock speeds;
 - d. target acceleration features;
 - 35 e. target sampling campaign trace count;
 - f. specific data features characteristics;

- g. trend thresholds;
 - h. anomaly thresholds and distributions;
 - i. change the computation of the optimum strategy;
 - j. activate or deactivate specific sensors;
 - 5 k. change sensor payload; and
 - l. sensor data sending frequency.
- S9. The system according to any of the preceding embodiments further comprising a condition component (17, 23) for at least one of predicting, estimating and determining the condition(s) for sending the sensor data.
- 10 S10. The system according to the preceding embodiment wherein at least one of the sensor (10, 11, 20, 30) and the remote component (15, 40) comprise the condition component (17, 23).
- S11. The system according to any of the preceding embodiments further comprising an optimizing component (18, 24) for automatically optimizing the sending of the
15 sensor data.
- S12. The system according to the preceding embodiment wherein at least one of the sensor (10, 11, 20, 30) and the remote component (15, 40) comprise the optimizing component (18, 24).
- S13. The system according to any of the two preceding embodiments wherein the
20 optimizing component (18, 24) is connected with the categorizing component (14, 21) and the optimizing component is configured to automatically optimize the sending after the categorizing of the sensor data by the categorizing component (14, 21).
- S14. The system according to any of the preceding embodiments wherein the sending
25 component (19, 25) is configured to send the sensor data in real-time.
- S15. The system according to any of the two preceding claims wherein at least two of the categorizing component (14, 21), the optimizing component (15, 22), the rating component (16, 23), the condition component (18, 24) and the sending component (19, 25) are comprised by at least one of the servers (50, 60), the sensor (10, 11,
30 20, 30) and the remote component (15, 40).
- S16. The system according to the preceding claim, wherein the at least two of the categorizing component (14, 21), the optimizing component (15, 22), the rating component (16, 23), the condition component (18, 24) and the sending component (19, 25) integral with the server (50, 60), the sensor component (10, 11, 20, 30)
35 and the remote component (15, 40) and preferably contained in one housing with them, respectively.

- S17. The system according to any of the preceding embodiment wherein the optimizing component (15, 22) is configured to optimize at least one of factors
- a. reducing the volume of the sensor data;
 - b. compressing the sensor data;
 - 5 c. encrypting the sensor data;
 - d. timing the sending of the sensor data;
 - e. routing the sending of the sensor data over one out of a plurality of available sending routes.
- S18. The system according to the preceding embodiments further comprising a pre-storing component (13) for pre-storing the sensor data in or at the sensor (10, 11, 10 20, 30) and/or in or at the remote component (15, 40) that is remote to the sensor and preferably closer to the sensor than to the server (50, 60).
- S19. The system according to any of the preceding embodiments wherein the sending component (19, 25) comprises a communication network module and is configured 15 to send the data towards the server (50, 60).
- S20. The system according to the two preceding embodiments wherein the remote component (14) comprises a pre-storage (13) that is configured to pre-store data of a plurality of sensors (10, 11).
- S21. The system according to the three preceding embodiments wherein the remote component (14, 40) is at least in part hardwired with the server and/or connected 20 by a long range wireless component.
- S22. The system according to the preceding embodiment wherein the at least one of the sensors (10, 11, 20, 30) is configured to send the respective sensor data to the remote component (14, 40) wirelessly.
- 25 S23. The system according to the preceding embodiment wherein the sensors (10, 11, 20, 30) are connected to the remote component by a short range wireless component.
- S24. The system according to any of the preceding embodiments wherein the sending components (19, 25) are configured to automatically send the sensor data at the 30 time-slot that has been determined by the condition component (17, 23).
- S25. The system according to any of the preceding embodiments with the further step of pre-filtering the sensor data, automatically determining a time-slot for the sending the data and sending the pre-filtered sensor data at the time-slot that has been determined to the server.
- 35 S26. The system according to the preceding claim wherein the sensor and/or the remote component are configured to store and pre-filter the sensor data.

- S27. The system according to the preceding embodiment wherein at least one of the sensor (10, 11, 20, 30) and the remote component (15, 40) comprise a pre-filtering component that is configured to pre-filter the sensor data and the pre-filtering is done according to the relevance-criteria according to embodiment S2.
- 5 S28. The system according to the preceding embodiment wherein the pre-filtering component is configured that the pre-filtering is either a filtering of the complete sensor data sampled by the sensor so that the sensor data won't get stored or by reducing volume of the sensor data by filtering out less relevant parts of the sensor data and/or compressing the sensor data.
- 10 S29. The system according to any of the preceding embodiments wherein the sensors are configured to increase the sampling rate of the sensors after the filtering of the sensor data.
- S30. The system according to any of the preceding wherein the server (50, 60) is configured compute the sensor data or filtered sensor data on at least one analytical
15 approach.
- S31. The system according to any of the preceding embodiments wherein at least one sensor is associated with or arranged at at least one of the railway infrastructure, in particular a sleeper, a frog, a point machine, rail frog, a rail blade and/or an interlocking.
- 20 S32. The system according to any of the preceding embodiments wherein the sensor (10, 11, 20, 30) is configured to measure at least one of temperature, acceleration, vibration, ultra-sound, time, distance, current, pressure, movement, humidity, precipitation and/or acoustics.
- 25 Below, sample detection use embodiments will be discussed. The letter U followed by a number abbreviates these embodiments. Whenever reference is herein made to use embodiments, these embodiments are meant.

Use

- 30 U1. Use of the method according to any of the preceding method embodiments and/or the system according to any of the preceding system embodiments for transferring sensor data in railway.

- U2. Use of the method according to any of the preceding method embodiments and/or the system according to any of the preceding system embodiments for transferring sensor data in railway infrastructure.

Whenever a relative term, such as "about", "substantially" or "approximately" is used in this specification, such a term should also be construed to also include the exact term. That is, e.g., "substantially straight" should be construed to also include "(exactly) straight".

Whenever steps were recited in the above or also in the appended claims, it should be noted that the order in which the steps are recited in this text may be the preferred order, but it may not be mandatory to carry out the steps in the recited order. That is, unless otherwise specified or unless clear to the skilled person, the orders in which steps are recited may not be mandatory. That is, when the present document states, e.g., that a method comprises steps (A) and (B), this does not necessarily mean that step (A) precedes step (B), but it is also possible that step (A) is performed (at least partly) simultaneously with step (B) or that step (B) precedes step (A). Furthermore, when a step (X) is said to precede another step (Z), this does not imply that there is no step between steps (X) and (Z). That is, step (X) preceding step (Z) encompasses the situation that step (X) is performed directly before step (Z), but also the situation that (X) is performed before one or more steps (Y1), ..., followed by step (Z). Corresponding considerations apply when terms like "after" or "before" are used.

Brief description of the drawings

Fig. 1 depicts an example of a set-up of several sensors to a railway infrastructure in accordance with the present invention;

Fig. 2 depicts an example of the set-up of the sensors according to Fig. 1 and associated infrastructure in accordance with the present invention;

Fig. 3 depicts an embodiment of a sensor according to a preferred embodiment of the present invention with a number of components either integrated therein or assembled to it; and

Fig. 4 depicts an embodiment of a remote component according to a preferred embodiment of the present invention with a number of components either integrated therein or assembled to it.

Detailed description of the figures

Fig. 1 provides a schematic description of a system configured for railway or a railway infrastructure. There is shown an example of a railway section with the railway 1 itself, comprising rails 2 and sleepers 3. Instead of the sleepers 3 also a solid bed for the rails 2 can be provided.

Moreover, a mast 4 is shown that is just one further example of constructional elements that are usually arranged at or in the vicinity of railways. Also a tunnel 5 is shown. It is needless to say that other constructions, buildings etc. can be present and also used for the present invention as described before and below.

A first sensor 10 can be arranged on one or more of the sleepers. The sensor 10 can be an acceleration sensor and/or any other kind of railway specific sensor. Examples have been mentioned before.

A second sensor 11 is also arranged on another sleeper distant from the first sensor 10. Although it seems just a small distance in the present example, those distances can range from the distance to the neighboring sleeper to one or many more kilometers. Other sensors can be used for attachment to the sleepers as well.

Another or the same kind of sensor 20 can be attached to the mast 4 or any other structure. This could be another sensor, such as an optical, temperature, even acceleration sensor etc. A further kind of sensor 30 can be arranged above the railway as at the beginning or within the tunnel 5. This could be height sensor for determining the height of a train, an optical sensor, a doppler sensor etc. All those sensors mentioned here and before are just non-limiting examples.

The sensors can be configured to submit the sensor data via a communication network, such as a wireless communication network. As the communication network bears several advantages and disadvantages regarding availability, transmittal distance, costs etc. the transmittal of sensor data is optimized as described herein before and below.

Fig. 2 is intended to provide an example for a hardware/software infrastructure that can vary for different needs. Sensors 10 and 11 can be connected to a common component or remote component 15, such as a server 15, with the functions mentioned before (pre-storing, pre-filtering, transmitting and/or processing etc.). All sensors 10, 11, 20, 30 could additionally or alternatively be connected to another server or storage or remote component 40 that is collecting the data, storing and transmitting it in the manner described before. The data being received from remote component 15 can be treated differently than the data received directly from the sensors 20 and 30. Thus, any remote

component can be arranged in series or in parallel or in a combination thereof with sensors and other remote components.

In the example shown, the data is further submitted (pushed and/or pulled) to a remote server, a plurality of servers, cloud computing, cloud storages etc. regularly or irregularly upon need. These components may be used for more sophisticated computing, as for example used for training a neural network.

Any transmission between the sensors, other components, such as servers etc., can be hard-wired and/or wireless, depending on the needs and the further infrastructure. In some cases when remote components are rather close to a plurality of sensors, short range wireless sending or transmittal can take place, such as Bluetooth or perhaps also GSM. Longer distances can make use of long distance wireless transmittance systems, such as GSM or any derivate thereof, as mentioned before. Therefore, the system can be made more efficient regarding costs, failure, etc.

The sensors 10, 11, 20, 30 can be any kind of sensor, such as acceleration sensors. Such sensors measure acceleration and from the values or patterns thereof and a number of variables can be directly or indirectly determined, such as wear of the railway infrastructure and/or of rolling stock.

In order to calculate the vertical movement correctly, the recorded acceleration data is fitted to patterns via machine learning algorithms. The remote system also combines the data with one or more different data sources or even previous records from the sensor. In the example according to Fig. 5, the data is combined with a list of train types that provides the train type properties like number of axels and distance between axles to identify the train type.

The identification is solved via use of any analytical approach, such as machine learning methods like an artificial neural network that can be trained locally and/or remotely. As one result of the train type classification and the prior list of train types the invention calculates the speed and accumulated the vibration energy of the recorded data from a train passage. Such information was not available continuously in the state of the art and therefore could not be used for condition monitoring and prediction. The invention also uses data from multiple sensors at one asset to separate different origins of recorded signals via different signal processing methods or analytical approaches. In this example a train runs over three succeeding sensor systems at one asset and an independent component analysis is used to separate noise from train borne signals and from asset borne signals.

The information derived in previous steps is used to a) detect anomalies, b) provide a health condition conclusion, c) diagnose the failing component, and/or d) predict a condition development trend, ballast and geometrical condition of the railway infrastructure that, if reliable, ensures an optimal transition of train borne forces into the ground to ensure safety and asset life time. Train type, calculated speed and vibration power to build a model for a normal behavior of an asset can be used as well. A model makes use of statistical distribution of train type and speed related values for the vertical displacement and the vibration power since different train types and speeds induce different vibration.

The boundaries for normal behavior are pre-set, automatically set and/or set via machine learning methods (like by support vector machines). The anomaly lies outside the boundary but it does not resemble known failure. Compared to the state of the art in which such derived models are not possible the invention can reduce uncertainty and enable automated anomaly detection with higher accuracy. The invention can use the information to identify patterns related to failure modes of the ballast or the geometry, here the unsupported sleepers or surface failures of rails. Such pattern is formed by single values that directly reveal a failure or intolerable condition like the certain vertical movement at a certain speed and train type. Alternatively or additionally, such patterns are present in the frequency and time domain of measured and combined data and transformed via signal processing methods such as Fourier Transformation or Wavelet Transformation. Machine learning classification methods like artificial neural networks are used to identify the class of the defect (here a crack) and/or the component (here the frog) and/or the location (here the tip of the frog). Compared to the state of the art in which dedicated temporal measurement devices are used to execute a certain measurement the invention derives multiple condition assessments from one or multiple sources using one or more ranges of the signals (e.g. for estimating the track displacement only signals < 100Hz are relevant, thus the signal is low pass filtered; however for crack detection signals are analysed in the kHz region). The invention further uses the combined data to predict the future health status. It propagates the past recorded data or such data that was previously transformed via methods of signal processing and/or artificial intelligence. The propagation is done by a regression function and/or by a complex model (here a probabilistic inference model such as Hidden Markov Model).

Fig. 3 shows an embodiment of a sensor 20 in accordance with the present invention. The sensor 20 is the kind of sensor described before. Anyhow it can comprise a number of other components or can be assembled to them. They can be all arranged in one housing or a number of adjacent housings.

The sensor 20 in the example shown comprises a sensor for measuring or determining parameters as described before. It can also house or be assembled to other components, either hardware and/or software components.

5 In the example a categorizing component 21 can be affiliated to the sensor 20. The categorization component 21 and its function has been described before. It will categorize the sensor data in many aspects, particularly according to the relevance-criteria mentioned before. Then the data can be labeled according to its content or even pre-processed, pre-filtered, compressed, etc.

10 A still further component can be the rating component 22 that provides a rating that can be used for determining the order of receiving the sensor data in the server and/or for determining the maximum numbers of attempts for the sending of data transmission in case the communication channel prevents the sending of the data.

15 Another component that can be comprised can be the optimizing component 23 that can be provided at or near to the sensor 20 for optimizing the sensor data, particularly according to the label or criteria detected. The optimizing can also be a pre-optimizing step so that the data will be further processed or computed downstream. However, the data
20 can be shortened or interpreted or both in order to simplify the handling of the data at the sensor or close to the sensor.

A still further component can be the condition component 24 that determines the condition for the transmittal or sending of the data. The condition can be detected in real-time, can
25 be predicted on the basis of data from the past or estimated or any combination thereof. According to the condition the time, kind, volume etc. of the data to be sent can be optimized.

A sending component 25 is responsible for the sending or submission or transferal of the
30 data and comprises the components for wireless and/or hardwired transmission.

Fig. 4 shows a similar kind of structure for a remote component 15 with equivalent sub-components. It can also comprise a categorizing component 14, a rating component 16, an optimizing component 17, a condition component 18 and a sending component 19.

35 Further a pre-storing component 13 can be provided for pre-storing data from at least one, preferably a plurality of sensors (not shown) before their pre-processing and sending.

Two or more of the categorizing components 14, 21, the rating component 16, 22, the optimizing component 17, 23, the condition component 18, 24 and the sending component 19, 25 can be also realized integrally regarding hardware and/or software. In case of the

presence of any antenna belonging to the sending component 19, 25, it can be arranged or embedded in the outer housing or casing.

Claims

1. A method for an automatized transferring sensor data from railway infrastructure comprising the steps of
 - a. determining relevance-criteria for sensor data;
 - 5 b. sampling sensor data by sensors;
 - c. automatized categorizing the sensor data according to the relevance-
 - d. criteria;
 - e. sending the sensor data according to their category; and
 - f. receiving the sensor data at least in one server.
- 10 2. The method according to the preceding claim wherein the relevance criteria is at least one of
 - a. a volume of the sensor data;
 - b. a content of the sensor data;
 - c. risk related information;
 - 15 d. a quality of a communication channel for the sending of the sensor data;
 - e. traffic on the communication channel for the sending of the sensor data;
 - f. costs for the sending of the sensor data;
 - g. energy available for sending the sensor data; and
 - h. energy consumption of the sending of the sensor data;
 - 20 i. a communication bandwidth and derived energy cost per data volume;
 - j. result of an analytic approach of measured data;
 - k. a specific expected data feature or combination of data features;
 - l. a specific expected data threshold passage;
 - m. a detected anomaly in the data;
 - 25 n. a detected trend in the data;
 - o. a difference of the result in comparison to historical results;
 - p. difference of the result in comparison to last transmitted results;
 - q. a trend analysis of result;
 - r. a trace quality metrics for selection;
 - 30 s. experience with communication quality from previous days; and
 - t. frequency of sending data.
3. The method according to any of the preceding claims wherein the step of automated categorizing comprises a rating that will be used for determining the order of receiving the sensor data in the server.
- 35 4. The method according to any of the preceding claims wherein the step of automated categorizing comprises a rating that will be used for determining the maximum

numbers of attempts for the sending of data transmission in case the communication channel prevents the sending of the data.

5. The method according to any of the preceding two claims the step of rating further comprising accommodating command input signals from a range of server or cloud-based algorithmic decision modules, comprising:

- a. inspection signals for maintenance decision making;
- b. inspection signals for component fault diagnostics;
- c. client requests;

6. The method according to the preceding claim wherein the input signals can modify a range of comprising:

- a. sampling frequency of the sensor data;
- b. target rolling stock type;
- c. target rolling stock speeds;
- d. target acceleration features;
- e. target sampling campaign trace count;
- f. specific data features characteristics;
- g. trend thresholds;
- h. anomaly thresholds and distributions;
- i. change the computation of the optimum strategy;
- j. activate or deactivate specific sensors;
- k. change sensor payload; and
- l. sensor data sending frequency.

7. The method according to any of the preceding claims further comprising the step of automated optimizing the sending of the sensor data.

8. The method according to any of the preceding claim wherein the optimizing can comprise at least one of

- a. reducing the volume of the sensor data;
- b. compressing the sensor data;
- c. encrypting the sensor data;
- d. timing the sending of the sensor data;
- e. routing the sending of the sensor data over one out of a plurality of available sending routes.

9. The method according to the preceding claims with the further step of pre-storing the sensor data at a further sensor component being housed together with or adjacent to the sensor and/or a remote component that is remote to the sensor and preferably closer to the sensor than to the server.

10. The method according to the preceding claim wherein the sensor component comprises a GSM module and is configured to send the data by GSM towards the server.

11. The method according to any of the preceding claims with the further step of pre-filtering the sensor data at the sensor or the remote component, automatically determining a time-slot for the sending the data and sending the pre-filtered sensor data at the time-slot that has been determined to the server wherein the pre-filtering is preferably performed according to the relevance-criteria according claim 2.

12. The method according to the three preceding claims wherein the remote component is configured to pre-store data of a plurality of sensors and wherein preferably the remote component is at least in part hardwired with the server and/or connected by a long range wireless component, such as GSM.

13. The method according to the preceding claim wherein the sensors are connected to the remote component by a short range wireless component.

14. The method according to any of the preceding claims with the further step of pre-storing the sensor data, automatically determining a time-slot for the sending the data and sending the sensor data at the time-slot that has been determined to the server.

15. A system for automatically transferring sensor data from railway infrastructure, particularly for carrying out a method according to the preceding claims, comprising:

- a. a determining component for determining relevance-criteria for sensor data;
- b. at least one sensor (10, 11, 20, 30) for sampling sensor data;
- c. a categorization component (14, 21) for automatically categorizing the sensor data according to the relevance-criteria;
- d. a sending component (19, 25) for sending the sensor data according to their category; and
- e. a server (50, 60) for receiving the sensor data.

Fig 1

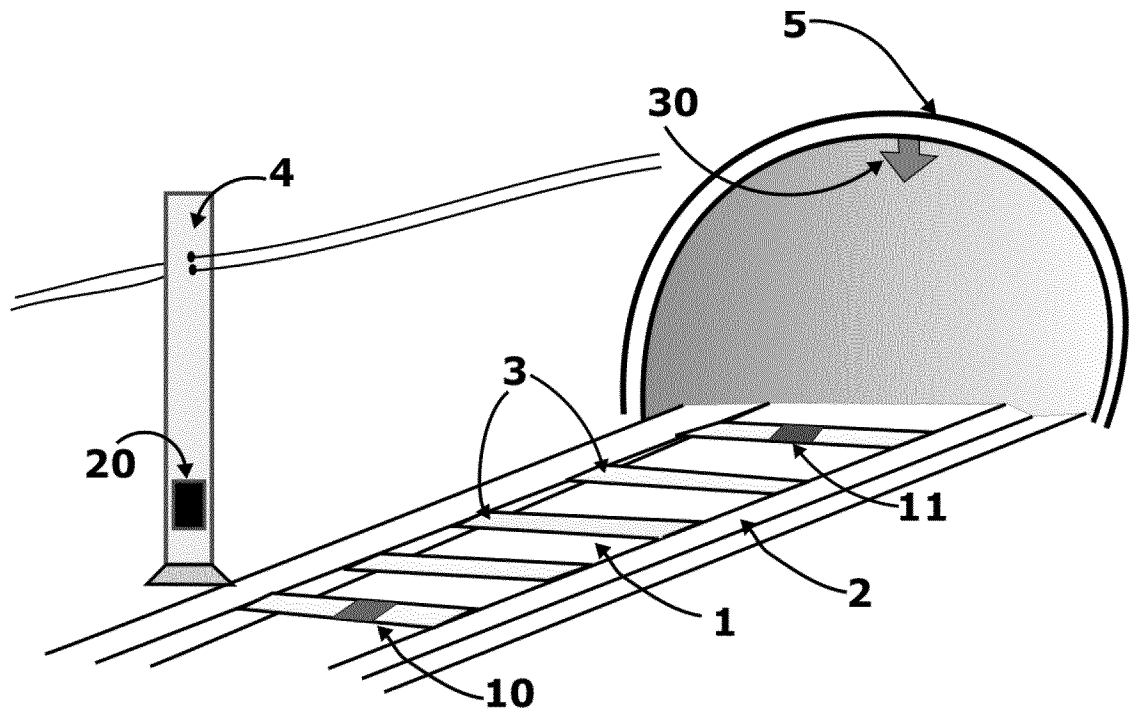
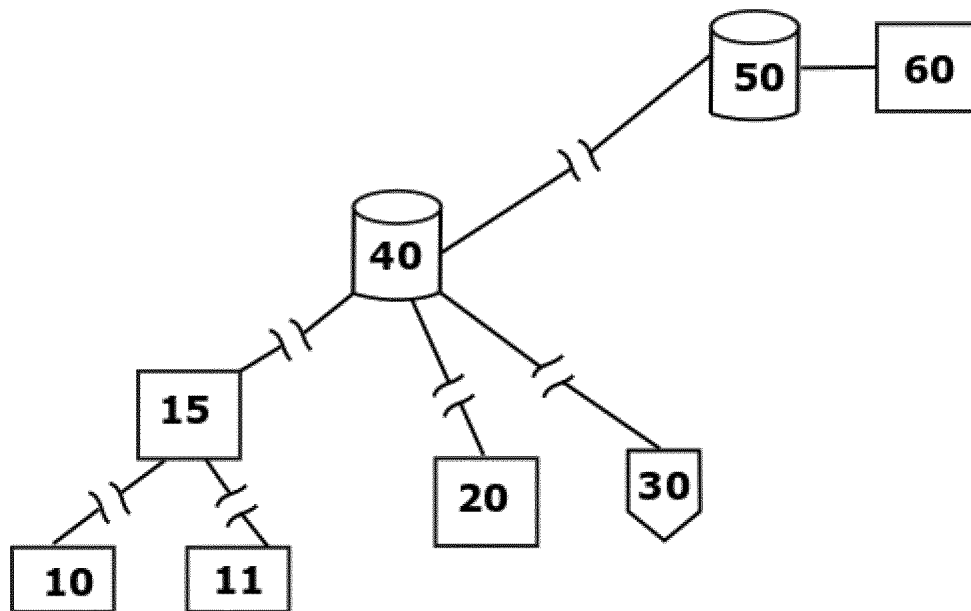


Fig. 2



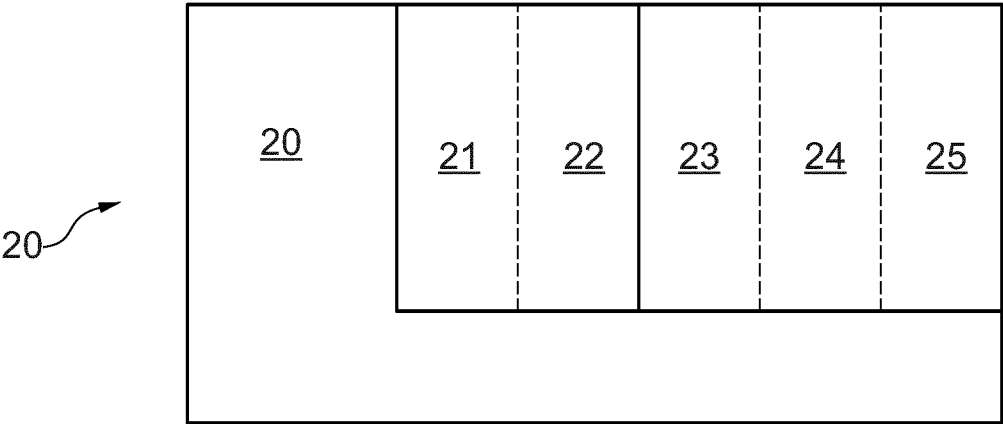


Fig. 3

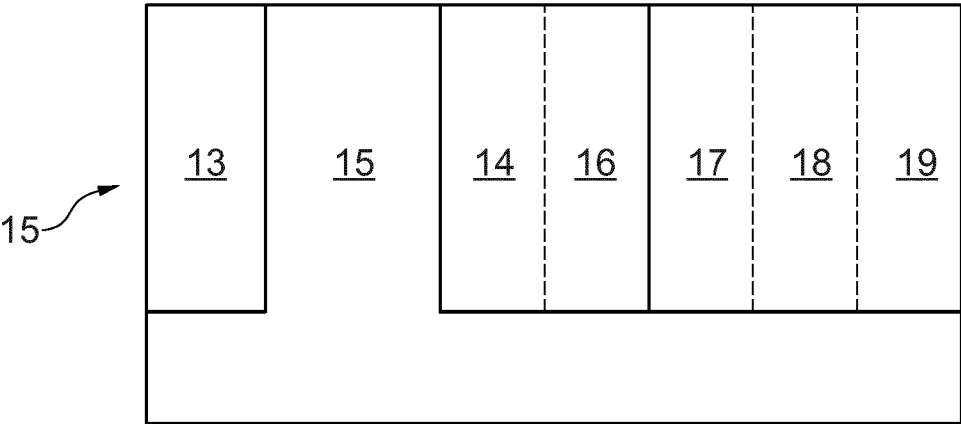


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/065836

A. CLASSIFICATION OF SUBJECT MATTER
INV. B61L15/00 B61L27/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B61L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2012/047529 A1 (SIEMENS CORP [US]; SIEMENS AG [DE] ET AL.) 12 April 2012 (2012-04-12)	1-3,5,6, 15
Y	paragraph [0014] - paragraph [0015] paragraph [0018] - paragraph [0035] -----	4,7-14
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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search

19 November 2019

Date of mailing of the international search report

29/11/2019

Name and mailing address of the ISA/

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Authorized officer

Janssen, Axel

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2019/065836

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 2 862 778 A1 (BAYERN ENGINEERING GMBH & CO KG [DE]) 22 April 2015 (2015-04-22) paragraph [0048] -----	9,11,12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2019/065836

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-3, 5, 6, 15

Relevance-based railway asset monitoring

2. claims: 4, 7-14

Data transmission optimisation in railway applications

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/065836

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