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(54) **SYSTEM AND METHOD FOR THE ASSET MANAGEMENT OF RAILWAY TRAINS**

(57) A system for the asset management of railway trains is provided. It comprises a diagnosis system which includes a train surveillance system comprising sensors; at least one surveillance subsystem comprising sensors; a train autonomous agent, being a computer program; at least one subsystem autonomous agent, being a computer program; at least one communication network; wherein the train surveillance system, the at least one

surveillance subsystem, the train autonomous agent and the at least one subsystem autonomous agent are nodes of the at least one communication network and are communicatively connected over the at least one communication network. The diagnosis system is connected to a fleet surveillance system on the wayside. Further, a respective method is provided.

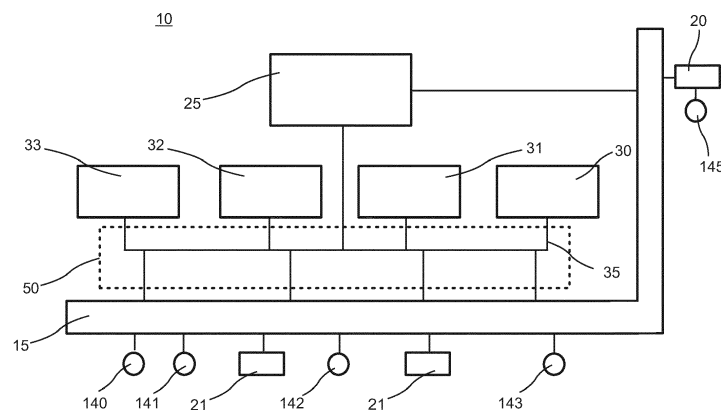


FIG. 1

Description

TECHNICAL FIELD

[0001] The present disclosure relates to an asset management system and method, more particularly for a diagnostic system and a method for monitoring a fleet of rail vehicles circulating on a rail infrastructure, for identifying particular faults relating to components of the rail vehicles, and for analyzing the health status of components of that fleet.

BACKGROUND OF THE INVENTION

[0002] Today, rail system operators are under increasing pressure to keep their trains running on time and for longer. Passenger expectations for comfort are greater than ever whilst increasingly sophisticated equipment creates both new challenges and opportunities for the rail system operator and its maintenance teams. The efficiency of any rail company hinges on the safety, reliability and availability of its trains. Yet with maintenance regimes typically being mileage or timescale related, as opposed to condition driven, trains can be out of operation for unnecessary servicing, or unforeseen repairs.

[0003] Thereby, conventional approaches for onboard diagnosis systems are usually based on an approach, where data from various sensors and steering devices of technical subsystems is collected in a central instance, not or only minimally processed, and sent via communication devices to a central analysis and diagnosis station on the wayside, i.e., at a fixed geographical location. Such prior approaches were sending huge amounts of raw sensor and status data, which has several disadvantages. Firstly, there is a considerable time delay in the transmission; secondly, the analysis is cumbersome due to the massive amount of data which is received with a time lag at the diagnosing instance, also lacking any contextual information about the train. Thus, a number of approaches have been made in order to reduce the amount of data sent.

[0004] For example, GB 2 392 983 A discloses a remote system condition monitoring, including a diagnostic apparatus and method for monitoring a system including a plurality of monitored components. GB 2 378 248 A discloses a fault detection and prediction system for vehicles, comprising sensors associated with individual components of a plurality of vehicles. EP 1 900 597 B1 describes a diagnostic system for monitoring a rail system, comprising a rail infrastructure and at least one fleet of vehicles circulating thereon.

[0005] However, the existing systems leave room for improvement. Hence, there is a need for an improved system and method for the asset management of railway systems.

SUMMARY OF THE INVENTION

[0006] The problems mentioned above are at least partly solved by a system for the asset management of railway trains according to claim 1 and a method for conducting prognostic and health monitoring assessment for trains according to claim 9.

[0007] In a first aspect, a system for the asset management of railway trains is provided. It comprises a diagnosis system which includes a train surveillance system comprising sensors; at least one surveillance subsystem comprising sensors; a train autonomous agent, being a computer program; at least one subsystem autonomous agent, being a computer program; at least one communication network; wherein the train surveillance system, the at least one surveillance subsystem, the train autonomous agent and the at least one subsystem autonomous agent are nodes of the at least one communication network and are communicatively connected over the at least one communication network, and wherein the at least one subsystem autonomous agent and the train autonomous agent are adapted to create abstracted information in the form of events, by:

filtering and aggregating sensor data and/or diagnosis data from the surveillance subsystem and train surveillance system, thereby creating abstracted information in the form of time-stamped events; - aggregating and reducing abstracted information in the form of events from at least one other subsystem autonomous agent by collaboration between the at least two subsystem autonomous agents; and wherein the at least one subsystem autonomous agent and the train autonomous agent, which may have the function of train or subsystem diagnostic autonomous agents, are adapted to communicate with each other over the at least one communication network in the form of events on the train event bus which originates in the train surveillance system.

[0008] In a second aspect, a method for conducting prognostic and health monitoring assessment for trains is provided, employing a system according to the first aspect, wherein the at least one subsystem autonomous agent collects and filters data from at least one subsystem diagnostic autonomous agent, and cooperates with at least one other subsystem autonomous agent for data comparison, and the train autonomous agent collects and filters data from the train diagnostic autonomous agent, cooperates with a subsystem autonomous agent by collecting and filtering data from the subsystem autonomous agent, and sends the collected and filtered data to a wayside system.

[0009] Further aspects, advantages and features of the present invention are apparent from the dependent claims, the description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] A full and enabling disclosure, including the best mode thereof, to one of ordinary skill in the art is set forth more particularly in the remainder of the specification, including reference to the accompanying figures wherein:

Fig. 1 schematically shows a diagnosis system according to embodiments;

Fig. 2 schematically shows an autonomous agent as of embodiments;

Fig. 3 schematically shows an overview of an asset management system according to embodiments;

Fig. 4 schematically shows a method for conducting prognostic and health monitoring according to embodiments.

DETAILED DESCRIPTION OF THE INVENTION

[0011] Reference will now be made in detail to various embodiments, one or more examples of which are illustrated in each figure. Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet further embodiments. It is intended that the present disclosure includes such modifications and variations.

[0012] Within the following description of the drawings, the same reference numbers refer to the same components. Generally, only the differences with respect to the individual embodiments are described. When several identical items or parts appear in a figure, not all of the parts have reference numerals in order to simplify the appearance.

[0013] The systems and methods described herein are not limited to the specific embodiments described, but rather, components of the systems and/or steps of the methods may be utilized independently and separately from other components and/or steps described herein. Rather, the exemplary embodiment can be implemented and used in connection with many other applications.

[0014] Although specific features of various embodiments of the invention may be shown in some drawings and not in others, this is for convenience only. In accordance with the principles of the invention, any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

[0015] As used herein, the terms "autonomous agent", "subsystem autonomous agent" "train autonomous agent", "fleet autonomous agent", and "maintenance autonomous agent", summed up under the terms "autonomous agents" or "agent", are each intended to be representative of a software instance run on a computer, which

work collaboratively together while connected over a communication network.

[0016] Embodiments of the invention pertain to a system for the asset management of railway trains, and for methods to operate such a system.

[0017] The provided methods are supported by the implementation of a hierarchical, multilevel and cooperative analysis system according to embodiments. Generally, embodiments make use of the concept of "active monitoring", which includes an embedded distributed cooperative diagnosis. This diagnosis is then sent to the wayside and is thereby used as information for maintenance action to mitigate failure impact during operation. This is achieved by avoiding failures due to the failure prediction of a predictive diagnosis. Hence, maintenance action can be carried out before a failure occurs. Further, failures are understood more thoroughly by providing an accurate diagnosis based on a failure context analysis. The maintenance action is done, for example, to solve the root cause of the failure, and to avoid a second failure, or even potentially costly immobilization of the train due to the need for stationary trouble shooting investigation.

[0018] The diagnosis system according to embodiments is organized in at least two levels, wherein one level is embedded in each train of a fleet, and the other level is on the ground (on the wayside), whereby a fleet server of the fleet diagnosis system collects outputs of each rolling stock of the fleet. Thus, analysis lead time is reduced. Robust diagnostics are performed close to the system and in live conditions, and are performed in a cooperative way. Regarding safety, the system is non-intrusive. The online-performed diagnosis allows to share live data with a complete fleet, and can thus be employed to create dynamic maintenance plans. Generally, the terms "system on the wayside", "wayside system", or just "wayside", etc., are used interchangeably herein to describe a part or parts of the system according to embodiments, which is/are located stationary and apart from the train(s) itself, thus on the wayside. The individual components of the system on the wayside may vary according to specific embodiments and are apparent from the following description.

[0019] The latter may be performed fully automatic by a central server based on the transmitted data from all rolling stock (all trains in the fleet). The data transmission from rolling stock to ground may be carried out cost effective by an intelligent processing of the raw data and uploading high level, robust and filtered information, including the context idea. The general availability of the fleet of rolling stock is improved, and the latter without any negative impact on safety of commercial operations. An achieved improvement of the reliability of the rolling stock typically leads to a reduction of liquidated damages during warranty phases. Out of warranty, it is a helpful tool for the maintenance service personnel to help for diagnosis, meaning a reduction in time, effort, and thus total cost of ownership.

[0020] Generally, in systems and methods according

to embodiments described herein, raw data or diagnostic data (diagnostic events) originating from various sources in the train surveillance system are treated as events. The events are supervised and combined on the level of raw data or (diagnostic) events at different levels in the train. These levels are represented by local systems (for example, one door), on a sub system level (e.g., all the doors of a train = passenger access function) and on a train level. Further levels pertain to the off board systems, which define a train level and a maintenance level. Depending on the level, the events are handled in a different manner, wherein the manner of handling becomes more sophisticated the higher the level is.

[0021] While data is collected from the various sources of raw data and diagnostic data on board of a train, an analysis is carried out on board, wherein the result of the analysis is the provision of events, which are dynamic. These dynamic events can reflect, for example, a short term behaviour drift of a supervised component, or a permanent failure, or a long term behaviour drift, or an unusual driver action, etc. That is, the collected amount of supervision data from all sensors, sub systems, etc. in the train is not only collected to be sent in raw form to a central computer on the wayside for further analysis, but the supervision data is computed and thereby analysed on the train. During this process, the data is evaluated and stripped of redundancy. Further, conclusions are drawn, such that a reduced amount of data is sent to a wayside computer in the form of events, wherein the events are chosen, in a rule-based manner, to represent only information determined to be significant. Thus, the mere amount of information to be sent to the wayside is reduced, while the quality and significance of the remaining extracted and condensed information is significantly increased.

[0022] For the above described purpose, connected systems in the train are employed, which are communicatively connected to a system on the wayside. Further, maintenance tools used to record maintenance activity may also be connected to the above system in embodiments, as described further below.

[0023] Thereby, the generation of events from surveillance data etc. is dynamic and is carried out according to configuration rules for event manipulation / event processing. Thereby, for example, threshold values employed in the rules are not fixed and can evolve, while also new rules can be added. This adaption of the rules, or the invention of new rules for the event handling, can be carried out by human operators according to their experience. In further embodiments, the adaption or generation of rules may at least partly be carried out by machine learning, or differently expressed, by an AI system.

[0024] Thereby, the general manner of handling events in the system is based on at least two basic main mechanisms: One is filtering, which means that if an event occurs, and in the same time another event occurs, the second event may erase the first event, if certain conditions are met. An example is the occurrence of a fault,

while the second event is that the train is in maintenance, therefore the fault is not propagated as the train is in a maintenance environment anyway. The second mechanism is fusioning (also called aggregation): For example, if all doors in the train would generate the same fault, only one event will be propagated as a synthesis of the situation. The described handling mechanisms for events are carried out by a plurality of cooperating, but independent software instances, henceforth called autonomous agents.

[0025] Generally, but with exceptions, the event handling is not carried out by describing or propagating alarm states or signals - rather, events are generated for diagnosis analysis and for monitoring, or for maintenance action. Alarms are generally only employed if absolutely required from the events, that is, if the meaning of the event is analysed as critical, for example a major failure in the HVAC system leading to a strong temperature deviation in the train.

[0026] Generally speaking, the systems and methods according to embodiments disclosed herein are suitable to control the ever growing amount of raw data delivered by surveillance systems with increasing numbers of items which produce raw data. Thus, the amount of data having to be transferred to a wayside is reduced and made more valuable and usable by generating contextualized, and thus context dependent, high level, robust knowledge from the raw data. This is achieved by a hierarchical, cooperative monitoring architecture. Thereby, from low level monitoring and surveillance components to the train itself, for each level basically the same monitoring principles and functions apply, whereby with a growing level in the hierarchy, more intelligent data is generated in the form of events, while the overall amount of data is increasingly reduced.

[0027] By an intra-level communication among autonomous agents, false alarms may be identified and reduced, while the reliability of the remaining real alarms and drifts is enhanced by confirming them through analysis. Thus, an integrated reactive and proactive monitoring process is provided.

[0028] The disclosed generic monitoring method is applicable on different complex systems to be monitored, such as railway trains, but also other complex systems, and has the built-in ability to address a higher hierarchic fleet level and the interaction with maintenance centers, which are remote from the monitored system(s), such as typically a maintenance facility on the wayside.

[0029] As should have become evident from the above general description of the working principle of systems and methods according to embodiments, the hardware infrastructure does not play a crucial role and may be implemented in various differing manners. Thus, the concrete systems described in the following should be regarded as non-limiting, and as examples only. At the same time, the implementation of the described method may be carried out in different manners, for example implementing various degrees of analysis by software hav-

ing differing complexity levels.

[0030] Fig. 1 shows a system for the asset management of railway trains according to embodiments, comprising a diagnosis system 10 which is located in a railway train. The diagnosis system 10 includes a train surveillance system 15 comprising sensors 140, 141, 142, 143 and at least one surveillance subsystem 20, 21 comprising at least one sensor 145. Further, the diagnosis system 10 comprises a train autonomous agent 25 and at least one subsystem autonomous agent 30 realized as computer programs. The train surveillance system 15 and the at least one surveillance subsystem 20, 21 are connected on a network 35 with the train autonomous agent 25 and the at least one subsystem autonomous agent 30 (in Fig. 1, four subsystem autonomous agents 30, 31, 32, 33 are exemplarily shown, which is non-limiting). Hence, the surveillance system and the surveillance subsystem are nodes of the communication network 35, such as are the train autonomous agent 25 and the subsystem autonomous agent 30.

[0031] To sum up the basic working principle of the above diagnosis system 10 in the train, the at least one subsystem autonomous agent 30 and the train autonomous agent 25 are adapted to create abstracted information in the form of events, which are time-stamped, as an output. This is carried out by processing input data provided in the form of sensor data and/or diagnosis data. The input data is generally delivered to the agents by the surveillance subsystem(s) 20, 21 and train surveillance system 15 over the communication network 35. The agents process the input data by firstly adding a time stamp to it. Further, the agents are configured to process the input data in a number of manners, which may be carried out by and on each agent independently, or in collaboration between at least two agents. Thereby, input data can be aggregated and/or reduced to achieve information in the form of events. For example, if two agents each receive input data from different sensors, it may be decided by collaboration of the two agents that the two pieces of information are redundant to each other, and that only one event shall be further processed, while the other is omitted. Hence, one of the two pieces of information is filtered, and the overall amount of information is reduced, while not losing valuable information, as the cause for the reduction is redundancy. The resulting presence and flow of events on the network 35 is henceforth called event bus 50. The event bus originates in the train surveillance system 15, as nearly all events (provided some exceptions) in the system are originating from the train surveillance system 15.

[0032] Thereby, a local context is defined in the architecture for each device to be monitored. This context comprises known possible fault conditions, and a list of possible operating stati provided by the door operating units, for example. These operating stati may for example include a fault condition of the electric motor of the door operating unit, an overload of the electric motor of the respective door control unit due to a blocking of the door

by a foreign object, etc. These operating stati are implemented in at least one of the autonomous agents 30, 31, 32, 33. The sum of the operating stati and fault conditions are employed in a model for various operational states for each monitored device.

[0033] Further, in embodiments, a train level is defined including a specific context. This context may, for example, comprise speed of the train, driving status, outside temperature, drive motor temperature, status if the train is coupled to another train or not, etc. A train autonomous agent 25 makes use of the previous elements, that is, the context in which the train is operating, in order to process the input from the subsystem autonomous agents. As a consequence, the train autonomous agent provides an embedded cooperative multi-agent-diagnosis summarizing the input from all subsystem autonomous agents. The train autonomous agent 25 may also receive data from other sources than the subsystem autonomous agents 30, 31, 32, 33. It may for example receive events from a surveillance subsystem 20, which is adapted to monitor elements of the train which are not supervised by the subsystem autonomous agents via the train surveillance system 15.

[0034] The train autonomous agent 25 and the subsystem autonomous agents 30, 31, 32, 33 are adapted to execute rules, which are part of the integrated model, based on a trigger event. This involves, for example, checking other simultaneous or quasi-simultaneous events (in a time window prior and after a trigger event) by checking the presence of the other events within a temporal window around this trigger event. In this manner, the train autonomous agent may, for example, come to the conclusion that a blocking of all doors on one side of the train is due to passengers which still enter the train despite a command for closing the doors was provided. When the train autonomous agent receives a first event from a subsystem autonomous agent, that the respective door does not close properly, it will thus, based on an internal rule as part of the model, check if there are other events from other subsystem autonomous agents which indicate the same fault condition.

[0035] Generally, each of the autonomous agents 30, 31, 32, 33 in the train have at least one configuration file. With an exchange of the configuration file, typically remotely via the fleet surveillance system 100 on the wayside by an operator, the components of the diagnosis system 10 may be individually updated from the wayside 110. Further and deeper analysis of the status of parts of the train 127 can further be carried out by using log files, which are typically routinely produced during operation, for selected ones or for each of the agents of the diagnosis system 10.

[0036] As should have become clear, the agents have a central and crucial role in the systems and methods described herein. Thereby, the singular train autonomous agent collects events from the plurality of subsystem autonomous agents. Thereby, the subsystem autonomous agents are dedicated to watching a specific sub-

system, sensor or sensor group each. To this end, a subsystem autonomous agent 30 subscribes to a list of events coming from the train surveillance system 15 or another subsystem autonomous agent 31, 32, 33. The subsystem autonomous agent constantly listens, on the communication network 35, for the occurrence of events which he is subscribed to via the list. This list is configurable and may be configured by an operator, for example. Thus, the subsystem autonomous agent 30 collects input data in the form of events from the train surveillance system 15. The agent also receives events which are sent to it by another subsystem autonomous agent 31, 32, 33, to which it is connected over the communication network 35, for cooperation with the aim of, for example, fusing different events or filtering events in a collaborative manner between the agents.

[0037] The autonomous agents of the system according to embodiments, including the train autonomous agent and subsystem autonomous agents, are typically configured to carry out a number of different tasks or processes for processing the input data (events), collaborate with other connected autonomous agents, or to output data for further processing. Agents may temporarily store a time stamped event for further triggering and processing. Also, an agent can trigger a process under the condition of a specified event, wherein the parameters of the trigger are also configurable.

[0038] Thereby, the autonomous agents are typically adapted to perform at least one of the following processes, wherein the output of each process is typically in the form of a time stamped event. Autonomous agents can "black box" events. Agents may filter raw data and/or diagnosis data coming from a train surveillance system 15 or from another subsystem autonomous agent 31, 32, 33. They may receive and aggregate information from at least two other autonomous agents 31, 32, 33, and aggregate information by collaboration, via the train event bus 50, with at least one other autonomous agent 31, 32, 33.

[0039] An agent may perform a diagnosis of, for example, a subsystem, when the subsystem autonomous agent is configured to be a diagnostic autonomous agent. Information resulting as output from any of the above described processes carried out by an agent is typically time stamped and sent as an event onto the train event bus 50. From there, it may be received by another subsystem autonomous agent, or by the train autonomous agent 25, or it may be used to create an output on a human interface terminal (user display 77) such as a screen, for example.

[0040] As was already laid out, a subsystem autonomous agent 30, 31, 32, 33 or train autonomous agent 25 is generally configured to aggregate information in the form of events over the event bus 50. This comprises the collection of data from distinct events, wherein two or more events are defined as distinct - and thus treated as distinct by an agent - when one or more of the following criteria are met: a) The two events are timely distinct and

originate from the same subsystem or source. b) The two events are stemming from different subsystems, but are collected at (nearly or exactly) the same time by an agent. c) Two events represent or comprise diagnosis data stemming from different subsystem autonomous agents 30, 31, 32, 33. d) The two events belong to a consecutive number of diagnosis events stemming from the same single subsystem diagnostic autonomous agent.

[0041] For the treatment of events, the subsystem autonomous agents 30, 31, 32, 33 and train autonomous agent each comprise a rule-based context process. The process includes reducing a number of collected distinct events based on predefined rules. The rules may comprise filtering of single events, as well as collecting several events according to rules, followed by a rule-based deduction that certain of the collected distinct events belong to a single technical cause in a subsystem or system - and thus may be aggregated or some may be filtered.

[0042] The train autonomous agent 25 and the subsystem autonomous agent 30, 31, 32, 33 may comprise at least one diagnostic process. This diagnostic process can be adapted to check for and determine clear defects, which is also called curative diagnosis. A further diagnostic process can be adapted to check for and determine hidden defects, also called predictive diagnosis. The respective agents having a diagnostic function are called train diagnostic autonomous agent and subsystem diagnostic autonomous agent 30, 31, 32, 33.

[0043] A case of predictive diagnosis might be as follows: If a subsystem delivers data via the train surveillance system as an event, which contains a parameter indicating that the heating power of an HVAC has declined by, e.g. 7% from its nominal value stored in the rules, this may be regarded by the agent as a case of predictive diagnosis. This means, an event is generated as an output for the train autonomous agent 25, which indicates that there is a maintenance need for the HVAC subsystem. The thresholds for this predictive diagnosis are also configurable as lists from the wayside 110.

[0044] Subsystems 60 which can be subject of such supervision by agents comprise, as non-limiting examples, a single door, a set of doors, an HVAC, electrical and hydraulic systems of the washrooms, a pantograph 68, a bogie 70, or any other subsystem of the rail vehicle.

[0045] The various agents described herein are typically software instances, such as executable files, which run on a computer. A basic exemplary structure of such an autonomous agent 30, as employed in embodiments, is described in the following with reference to Fig. 2. The autonomous agent 30 has a configurable list of listened signals 72 with events to which it listens on the communication network 35 to which it is connected. The events are input to the communication network 35 typically by the train surveillance system 15. The agent further listens to events addressed to itself, which have been sent by other autonomous agents on the communication network 35. It has a generic processing unit 73, which processes events on the basis of configurable rules 74 for inhibition

(I), fusion (F) and cooperation (C). Further, it comprises a specific processing unit 79 which processes events according to configurable models 78. The output of the autonomous agent is sent to the communication network 35 in the form of events. The events may be addressed to other subsystem autonomous agents on the communication network 35, to the train autonomous agent 25, or to a human interface or user display 77 to be noted by an operator. The autonomous agent further comprises a start/stop processing condition 80, and means 81 for changes memorization. It goes without saying that the skilled person will be able to modify the exemplary structure of an autonomous agent, as described herein, wherein such modifications are regarded to fall under the scope of this disclosure.

[0046] A method for conducting prognostic and health monitoring assessment for trains employs the above described diagnosis system 10 in a railway train. Thereby, the subsystem autonomous agents 30, 31, 32, 33 collect and filter data from at least one subsystem diagnostic autonomous agent, and cooperate with at least one other subsystem autonomous agent for data comparison. The train autonomous agent 25, as a central instance in the train, collects and filters data from the train diagnostic autonomous agent, cooperates with a subsystem autonomous agent by collecting and filtering data from the subsystem autonomous agent, and sends the collected and filtered data to a wayside system. This system is a fleet surveillance system 100 as part of a wayside system 110 and comprises an interface for receiving data from each train autonomous agent of each train of a fleet, in real time or near real time. Each train autonomous agent 25 and the subsystem autonomous agents 30, 31, 32, 33 receive data from the respective train surveillance system 15. Thereby, the fleet surveillance system 100 on the wayside creates a dedicated fleet event bus 120 per train. A fleet autonomous agent 115 executes processes based on, or using, events on the fleet event bus 120. Thereby, the fleet autonomous agent 115 has basically the same structure and working principle as the subsystem autonomous agents and the train autonomous agent 25 of the train - wherein models, rules and the list of listened signals is configured for the role of the fleet autonomous agent 115, differing from the former.

[0047] In embodiments, the wayside system 110 further comprises a maintenance surveillance system 105. It transforms human maintenance activities, which are collected in an aided maintenance tool management (database based), into time stamped events. Thus, in a similar manner to the event buses 50 on the trains and the fleet event buses 120, a single maintenance event bus 130 is created. In embodiments, the maintenance surveillance system 105 is connected to the fleet event buses 120 of the trains. The fleet event buses 120 originate in the train autonomous agent 25 of each train and span over the typically wireless connection to the maintenance surveillance system 105 on the wayside.

[0048] In the maintenance surveillance system 105,

maintenance autonomous agents 125, 126 are connected via the maintenance event bus 130. They realize processes from the event subscription to fleet event buses 120 and the maintenance event bus 130. Decisions on maintenance activities, their planning and optimization are derived by combining maintenance events from the train autonomous agents 25 via the fleet surveillance system and with data from human maintenance activities via maintenance surveillance system 105 and maintenance autonomous agents 125, 126. Thereby, fleet availability and maintenance quality are enhanced while rationalizing and reducing overall maintenance activities and thus also cost.

[0049] On each level of the maintenance surveillance system 105, log files are provided by the respective autonomous agents, which allow an operator to understand with accuracy the nature and cause(s) of complex failures. Simultaneously, the maintainer may define corrective action to avoid that a failure might cause further, or more significant, damage.

[0050] In Fig. 4, a method 200 for conducting prognostic and health monitoring according to some embodiments is schematically shown, wherein only the basic method steps are depicted. In a block 210, data is collected and filtered on a subsystem level in the train. In a block 220, the autonomous agents cooperate with each other, as was described further above. In a block 230, data in the form of events is collected and filtered on a train level by the train autonomous agent. In a block 240, the resulting data is sent in the form of events to a wayside system 110. In a block 250, the data is processed on the fleet event bus. In a block 260, maintenance activities are scheduled.

[0051] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. While various specific embodiments have been disclosed in the foregoing, those skilled in the art will recognize that the spirit and scope of the claims allows for equally effective modifications. Especially, mutually non-exclusive features of the embodiments described above may be combined with each other. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

Claims

1. System for the asset management of railway trains, comprising a diagnosis system (10) which includes:

a train surveillance system (15) comprising sensors (140, 141, 142, 143),
 at least one surveillance subsystem (20) comprising at least one sensor (145),
 a train autonomous agent (25), being a computer program;
 at least one subsystem autonomous agent (30), being a computer program;
 at least one communication network (35);
 wherein the train surveillance system (15), the at least one surveillance subsystem (20), the train autonomous agent (25) and the at least one subsystem autonomous agent (30) are nodes of the at least one communication network (35) and are communicatively connected over the at least one communication network, and wherein the at least one subsystem autonomous agent (30) and the train autonomous agent (25) are adapted to create abstracted information in the form of events, by:

- filtering and aggregating sensor data and/or diagnosis data from the surveillance subsystem (20) and train surveillance system (15), thereby creating abstracted information in the form of time-stamped events;
- aggregating and reducing abstracted information in the form of events from at least one other subsystem autonomous agent (31, 32, 33) by collaboration between the at least two subsystem autonomous agents (30, 31, 32, 33);

and wherein the at least one subsystem autonomous agent (30) and the train autonomous agent (25), which may have the function of train or subsystem diagnostic autonomous agents, are adapted to communicate with each other over the at least one communication network (35) in the form of events on a train event bus (50) which originates in the train surveillance system (15).

2. The system of claim 1, wherein the at least one subsystem autonomous agent (30) is adapted to:

- a. subscribe to a list of events coming from the train surveillance system (15) or another subsystem autonomous agent (31, 32, 33), wherein the list is configurable;
- b. collect time stamped events from the train surveillance system (15) or another subsystem autonomous agent (31, 32, 33);
- c. temporarily store the time stamped events for further triggering and processing;
- d. trigger a process under the condition of an event, wherein the trigger is configurable;

and wherein the subsystem autonomous agent (30) is further adapted to perform at least one of the following processes, each with an output in the form of a time stamped event:

- e. black boxing of events;
- f. filtering raw data and/or diagnosis data coming from a train surveillance system (15) or a subsystem autonomous agent (31, 32, 33);
- g. aggregating information from at least two other autonomous agents (31, 32, 33);
- h. aggregating information by collaboration with at least one other autonomous agent (31, 32, 33) via the train event bus (50);
- i. performing a diagnosis, when the autonomous agent is a diagnostic autonomous agent;
- j. sending time stamped events coming out of any of these processes onto the train event bus (50).

3. The system of claims 1 or 2, wherein a subsystem autonomous agent (30, 31, 32, 33) or train autonomous agent (25) is adapted to aggregate information, comprising the collection of data from distinct events, wherein two or more events are defined as distinct by at least one of the following criteria:

- the events are timely distinct while stemming from the same subsystem or source;
- the events are stemming from different subsystems;
- the underlying diagnosis data is stemming from different subsystem autonomous agents (30, 31, 32, 33);
- the events belong to a consecutive number of diagnosis events stemming from a single subsystem diagnostic autonomous agent.

4. The system of claim 3, wherein the subsystem autonomous agent (30, 31, 32, 33) comprises a rule-based context process, and is adapted to reduce a number of collected distinct events based on predefined rules of the subsystem autonomous agent, wherein the rules may comprise filtering of single events, or collecting several events followed by a rule-based deduction that certain distinct events belong to a single technical cause in a subsystem or system.

5. The system of claim 4, wherein the subsystem autonomous agent (30, 31, 32, 33) is further adapted to transmit a diagnosis based on a plurality of aggregated distinct events to a train autonomous agent (25).

6. The system of any preceding claim, wherein the train diagnostic autonomous agent (25) and/or the subsystem diagnostic autonomous agent (30, 31, 32,

- 33) comprises at least one diagnostic process for clear defects, named curative diagnosis, and/or at least one diagnostic process for hidden defects, named predictive diagnosis.
7. The system of any preceding claim, wherein the subsystem (60) comprises at least one of: a door (62), a set of doors (64), an HVAC (66), a pantograph (68), a bogie (70), a further subsystem of the rail vehicle.
8. The system of any preceding claim, further comprising a fleet diagnostic agent (115) as part of a fleet surveillance system (100) of a wayside system (110).
9. Method for conducting prognostic and health monitoring assessment for trains, employing a system according to any one of claims 1 to 8, wherein:
- the at least one subsystem autonomous agent (30, 31, 32, 33) collects and filters data from at least one subsystem diagnostic autonomous agent, and cooperates with at least one other subsystem autonomous agent for data comparison, and
- the train autonomous agent (25) collects and filters data from the train diagnostic autonomous agent, cooperates with a subsystem autonomous agent (30, 31, 32, 33) by collecting and filtering data from the subsystem autonomous agent, and sends the collected and filtered data to a wayside system (110).
10. The method of claim 9, wherein the train diagnostic autonomous agent and/or the subsystem diagnostic autonomous agent determines the occurrence of clear defects, named curative diagnosis, and/or hidden defects, named predictive diagnosis.
11. The method of any of claims 9 or 10, wherein a fleet surveillance system (100) of the wayside system (110) comprises an interface, receiving data from each train autonomous agent (25) of each train in real time.
12. The method of any of claims 9 to 11, wherein a fleet surveillance system (100) of the wayside system (110) receives data from each train autonomous agent (25), while the train autonomous agent (25) and the subsystem autonomous agent (30, 31, 32, 33) receive data from the train surveillance system (15), preferably in real time.
13. The method of any of claims 9 to 12, wherein the fleet surveillance system (100) creates one fleet event bus (120) per train, and wherein a fleet autonomous agent (115) executes processes from events on the fleet event bus (120).
14. The method of any of claims 9 to 13, wherein a maintenance surveillance system (105) transforms human maintenance activities collected in an aided maintenance tool management into time stamped events, creating a maintenance event bus (130), and wherein the maintenance surveillance system (105) is connected to the fleet event buses (120) of the trains, and wherein preferably, at least two maintenance autonomous agents (125, 126) are connected via the maintenance event bus (130), and realize processes from the event subscription to fleet event buses (120) and the maintenance event bus (130).
15. The method of claim 14, wherein decisions on maintenance optimization and increasing fleet availability on the wayside are derived by combining maintenance events from the train autonomous agents (25) via the fleet surveillance system (100) and with data from human maintenance activities via maintenance surveillance system (105) and maintenance autonomous agents (125, 126).

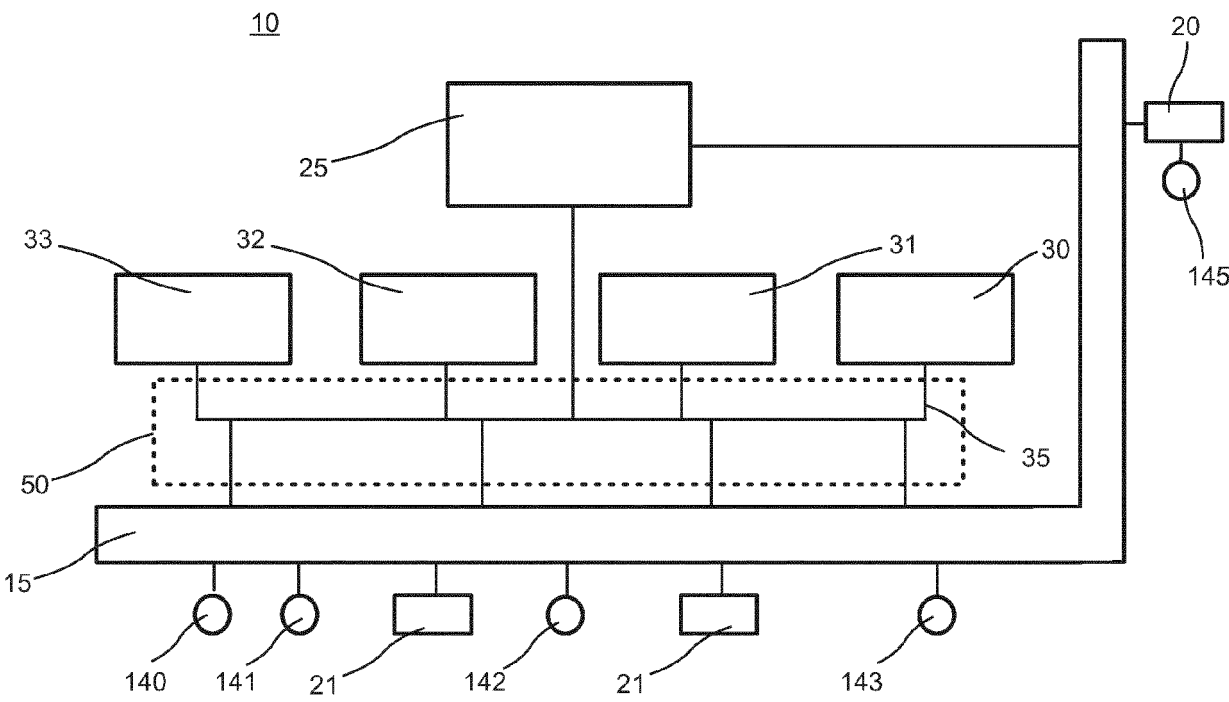


FIG. 1

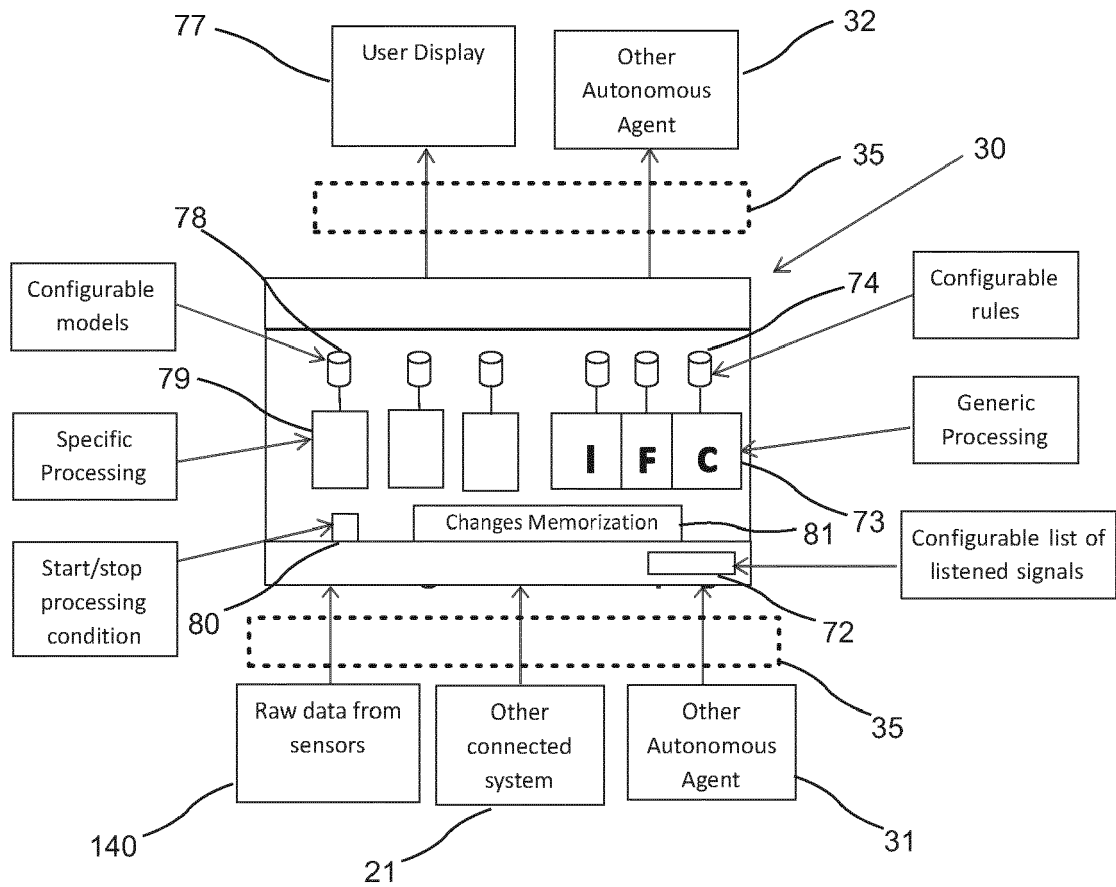


FIG. 2

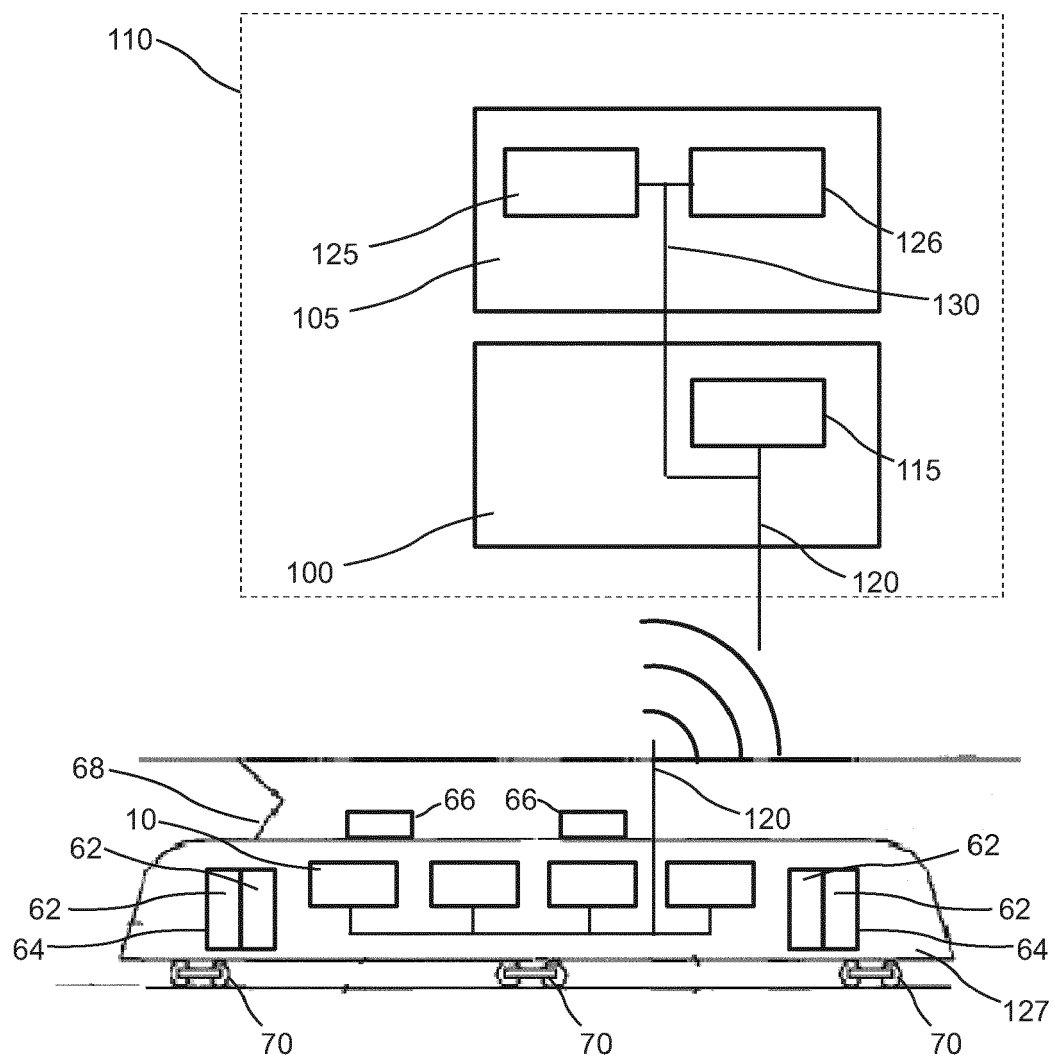


FIG. 3

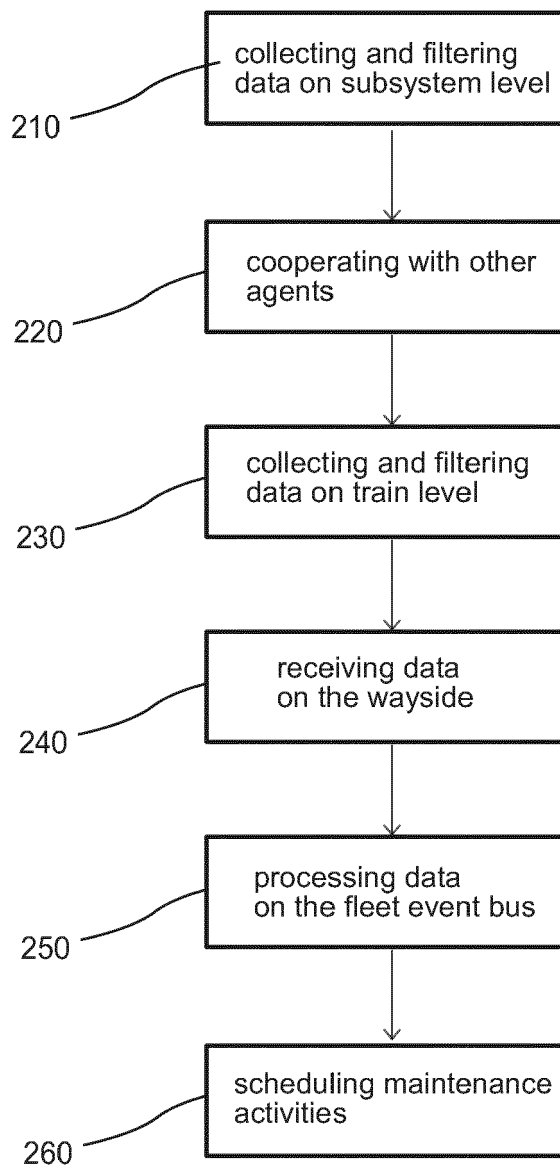
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FIG. 4



EUROPEAN SEARCH REPORT

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Place of search Munich		Date of completion of the search 29 November 2016	Examiner Robinson, Victoria
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